Comparison of graded compression ultrasonography and unenhanced spiral computed tomography in the diagnosis of acute appendicitis

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ABSTRACT

Introduction: To compare the accuracy of graded compression ultrasonography (US) and unenhanced spiral computed tomography (CT) in the diagnosis of acute appendicitis.

Methods: This prospective study comprised 58 consecutive patients with high clinical suspicion of acute appendicitis. After careful clinical assessment and laboratory investigations, all the patients were independently evaluated by graded compression US followed by unenhanced spiral CT, in order to establish the diagnosis. CT was performed from the level of the third lumbar vertebral body to the pubic symphysis, and no patient was given oral, rectal or intravenous contrast agents. The results were compared with operative findings and clinical follow-up.

Results: Out of the 58 patients evaluated, surgical confirmation was obtained in 52 patients and the remaining six patients were managed conservatively. Statistical analysis was based on the 52 patients who were surgically confirmed. 48 of the operated patients had evidence of appendicitis and four patients had negative findings. In our study, 90 percent of patients were adults and the following results were more applicable to the adult age group. Analysis of the data for US and CT, respectively, revealed a sensitivity of 67.3 percent versus 95.8 percent, specificity of 100 percent versus 75 percent, accuracy of 71.2 percent versus 90.3 percent, positive predictive value of 100 percent versus 97.8 percent, and negative predictive value of 15.8 percent versus 60 percent. Out of the operated patients, four patients did not have acute appendicitis and alternative diagnosis was suggested by US and CT in one patient. Of the six patients managed conservatively, an alternative diagnosis was reached both by US and CT in two patients.

Conclusion: We conclude that unenhanced spiral CT is more sensitive than US in detecting appendicitis, especially in adult patients.

Keywords: acute appendicitis, appendicitis, computed tomography, ultrasonography

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INTRODUCTION

Acute appendicitis is the most common abdominal surgical emergency that can affect individuals of all ages. An accurate diagnosis of acute appendicitis can be established with great confidence in the majority of patients, on the basis of history and physical examination. Sometimes, patients present with atypical clinical features and non-specific physical findings, and evaluation of these patients becomes challenging. The aim of investigations in patients with atypical clinical features and non-specific physical findings is to diagnose the condition as early as possible, in order to operate before appendiceal perforation and peritonitis develop.

Many imaging modalities have been used to improve the diagnostic accuracy in patients with acute appendicitis. In the past, radiographs of abdomen and barium studies were done but they had a limited role in the diagnosis of acute appendicitis[1,2]. The newer techniques of ultrasonography (US) and computed tomography (CT) have shown great promise in evaluation of patients with suspected acute appendicitis[3–17]. US is a simple, rapid,

non-invasive and inexpensive modality which is not associated with ionising radiation. It can be used as a screening modality for initial evaluation of such patients. But US is highly operator-dependent, and excessive bowel gas hinders proper evaluation of the appendix. Graded compression US, in particular, performs much better in experienced hands, requiring a high level of skill and expertise.

In comparison, CT is readily available, is supposed to be operator-independent, is relatively easy to perform, and has results that are easy to interpret. Unenhanced spiral CT provides global cross-sectional evaluation and important information regarding the appendix, mesentery and retroperitoneum. A distinct advantage of unenhanced spiral CT is the short examination time because it does not require patient preparation or contrast administration. However, compared to US, CT is associated with the disadvantage of exposure to ionising radiation.

Both modalities are not only helpful in confirming the diagnosis of acute appendicitis but also in excluding other conditions that mimic acute appendicitis. Bearing in mind the advantages and limitations inherent in both US and CT, in experienced hands, these modalities have been effective in evaluating patients with suspected acute appendicitis. The purpose of the present study was to evaluate the role of both graded compression US and unenhanced spiral CT in patients with suspected acute appendicitis and to assess the utility of these investigations in patient management.

METHODS

This prospective study was carried out over a period of two years between November 1999 and October 2001. The study comprised 58 consecutive patients who presented to the casualty department with acute abdominal pain and were evaluated by a senior surgical medical officer or staff surgeon. If the history, physical examination findings and laboratory test results raised the suspicion of acute appendicitis, patients were asked to participate in this study. The patients were admitted to the hospital either for observation or for surgery. There were 40 male and 18 female patients, with age range from 12 to 74 years (mean, 25 years); among these, ten percent were paediatric patients. The radiological procedures and logistics of the study were explained to the patients, and informed consent was obtained from each patient or from a parent of each paediatric patient. The hospitalised patients underwent CT and US before undergoing surgery or during the first 24 hours of observation. Pregnant women were excluded from the study.

All patients were evaluated initially by using graded compression US followed by unenhanced spiral CT within 30 minutes of US, and the scans were initially interpreted by the attending resident radiologists. Later, the hard copies of both US and CT images were presented to two consultant radiologists, who were unaware of the clinical setting and the operative details. These results were compared with operative findings in 52 patients and clinical follow-up in the remaining six patients. The interpretation and the diagnosis given by the consultant radiologists in operated patients were used for statistical analysis.

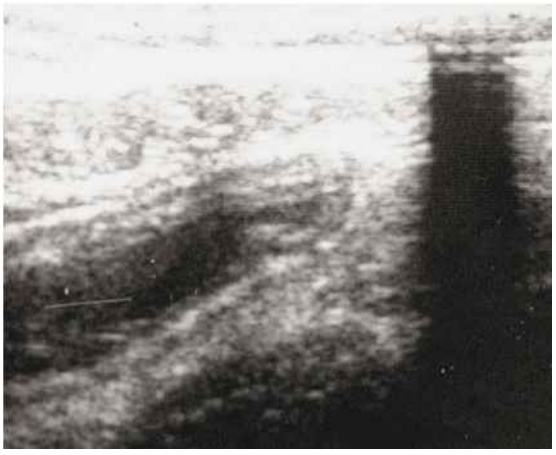

Fig. 1 Longitudinal US image shows a thickened appendix with indistinctness of wall layers and presence of ascites, consistent with impending perforation.

Graded compression US was performed on ATL APOGEE 800 plus US machine (Philips Medical System, Bothell, WA, USA) using high frequency (5–7.5 MHz) linear array and 3MHz curved array transducers. Curved array transducers were used in obese patients to allow deeper penetration. US was performed using the graded compression technique described by Puylaert[18]. The study was focused in the region of maximum pain/tenderness, which helped in locating even an aberrantly positioned appendix. Scanning was started from right upper quadrant with graded compression, and the transducer was gradually moved across the ascending colon towards the caecal tip and the region of appendix. Graded compression was used to displace gas containing bowel loops to facilitate the visualisation of the inflamed appendix. Once the appendix was localised, images were taken both in transverse and longitudinal planes.

The inflamed appendix is seen as a tubular, aperistaltic and noncompressible structure. Total diameter was measured on transverse section. On US, the primary criterion to establish the diagnosis of acute appendicitis was direct visualisation of the inflamed appendix. The classic appearance is an incompressible appendix with a diameter of 6 mm or larger and echogenic incompressible periappendiceal inflamed fat with or without an appendicolith (Fig. 1) (Table I). Subsequently screening of the whole abdomen was performed to look for other

Table I. US features of appendicitis[3–6, 18,19].

Abnormal appendix	Periappendiceal inflammatory changes and associated findings
Non-compressible, tubular aperistaltic structure	Localised periappendiceal fluid collection
Total diameter of appendix > 6mm	Prominent hyperechoic meso-appendix or pericaecal fat
Mural wall thickness >2mm	Interloop fluid pockets
Diffuse hypoechogenicity of the wall	Aperistaltic bowel loops
Lumen distended with anechoic or hyperechoic material	Enlarged lymph nodes
Visualisation of appendicolith	Presence of free fluid
Loss of wall layers	
Anechoic lumen, echogenic mucosa, hypoechoic thickened wall	
Increased mucosal vascularity	

NB: Criteria for perforation: Asymmetry in wall thickness with indistinctness of wall layer or the presence of air or fluid collection around the appendix.

associated findings. Whenever an appendix was not localised or was found to be normal, a search was made to find out an alternative cause responsible for the presenting complaint. Non-visualisation of appendix was classified as a normal examination. The US examinations were performed by resident radiologists, who have received formal training in the technique, under the supervision of consultant radiologists.

Unenhanced spiral CT was performed with a single-detector spiral CT scanner (Siemens Somatom Plus 4 or AR-STAR, Erlangen, Germany) with single breath hold helical acquisition from top of third lumbar vertebra to pubic symphysis using 5-mm beam collimation and 5-mm/sec table speed (pitch of 1). Images were reconstructed at 5mm intervals and photographed on hard copy using standard soft tissue windows (width 300 HU; level 40 HU). No oral, rectal or intravenous contrast agent was given except in one patient. In patients younger than 15 years old, the tube current was 63 mA and a kV of 120 was used. In patients 15 years or older, the tube current was 220-230 mA and a kV of 120 was used.

Interpretation of the unenhanced spiral CT images was done by locating the caecum, ileocaecal valve and the adjacent terminal ileum. Once the caecum/terminal ileum complex was located, the appendix could be easily identified. The total diameter of appendix was then measured. CT findings were interpreted as positive for acute appendicitis when an enlarged appendix (6 mm in outer diameter) was identified. Ancillary signs of appendicitis including right lower quadrant inflammation, appendicoliths (Fig. 2), and lymphadenopathy were recorded (Table II). CT findings were interpreted as negative if the appendix was visualised with intraluminal air. An appendix less than 6 mm in outer diameter was also diagnosed as being normal (Fig. 3). Subsequently, other associated findings that help in making the diagnosis of acute appendicitis were assessed. The CT examinations were performed by the same resident radiologist who did the US. No effort was made to re-examine those patients with repeat US, in whom initial US examination was normal but subsequent CT revealed an abnormal appendix.

The CT and US findings were grouped as follows:
a. Appendicitis
b. No appendicitis
c. An alternative diagnosis

The surgeon was informed of the radiological diagnosis. If findings other than appendicitis that had possible clinical consequences were diagnosed on CT or US, these were also made known to the operating surgeon. The decision on whether to operate was based on the clinical parameters and laboratory findings by the attending surgeon and it was not based on imaging findings. The diagnosis of acute appendicitis at surgery was established on the basis of macroscopic findings.

RESULTS

Out of the 58 patients evaluated, surgical confirmation could be obtained in 52 patients and the remaining six patients were managed conservatively. Of the 52 operated patients, a diagnosis of appendicitis was made in 32 patients based on the criteria discussed vide supra and appendicular abscess in one patient (in whom appendix was not seen separately) on US. Of the remaining 19 patients in whom appendix was not visualised on US, 16 patients had acute appendicitis at surgery (false negative results) and three patients were true negative for acute appendicitis. Out of these three patients, one patient had right tubo-ovarian abscess detected by US and later confirmed at surgery, and in the other two patients, the appendix was normal at surgery. There was only one false positive result by US (Tables III and IV). This was a case in which appendix was abnormal on US with a total

Table II. CT features of appendicitis[1, 4, 23–28].

Abnormal appendix	Periappendiceal inflammatory changes and associated findings
Appendix diameter >6mm	Periappendiceal oedema and fluid collection
Appendicolith	Fat stranding or phlegmon
Extensive intra luminal, intra mural or extra luminal appendiceal air with inflammatory changes	Subtle asymmetric obliteration of the fat immediately anterior to the right psoas muscle (compared to the normal left side psoas)
	Enlarged lymph nodes
	Focal distal ileal wall thickening
	Extra luminal gas bubbles
	Thickening of right lateroconal fascia resulting in double comet tail sign
	Focal caecal apical thickening

Fig. 2 Axial CT image shows a thickened appendix with intraluminal hyperdense focus consistent with an appendicolith.

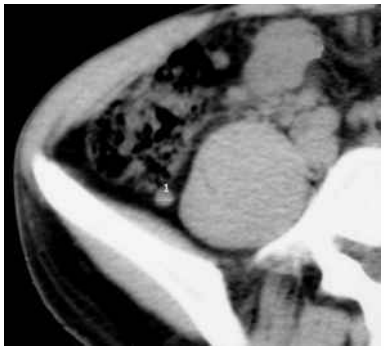

Fig. 3a Axial CT image shows a normal appendix measuring 5mm, located posterior to the caecum.

Fig. 3b Transverse US image of the same patient shows a tubular structure measuring about 9mm (arrow), which was considered diagnostic of appendicitis (false positive).

diameter >6mm; later CT of this patient showed a normal appendix which was confirmed at surgery (Figs. 3a–b). This patient was however operated on, due to a strong clinical suspicion of appendicitis.

In patients with acute appendicitis, all the abnormal appendices were seen as tubular, aperistaltic, blind-ending structures measuring more than 6mm on US (Fig. 1). The most common abnormality observed on US was total diameter of appendix of more than 6mm and localised periappendiceal fluid collection. Appendicoliths were seen in three patients on US. Indistinctness of the wall layers, highly suggestive of impending perforation, was seen in two patients on US but only one of these patients had appendiceal perforation at surgery. In these two patients, apart from indistinctness of wall layers, the appendix was thickened and also there was presence of periappendiceal fluid collection. Normal appendix could not be documented on US in any patient. The inflamed appendix showed increased mucosal vascularity on Doppler ultrasound.

On the basis of the CT findings, 47 out of 52 patients were diagnosed to have acute appendicitis. Of these, acute appendicitis was confirmed in 46 patients at surgery. In all these patients, the appendices measured more than 6mm on CT. Appendicular inflammatory mass/abscess was seen in three patients (Fig. 4). In only one of these patients, the appendix could be seen separately from the abscess/inflammatory mass, which was also abnormal. Appendicular perforation was seen in one patient on CT and this was confirmed at surgery. The most common location of appendix on CT was pelvic (27 patients). The next common location was retrocaecal (22 patients). In one patient the appendix was post-ileal in location. Appendicoliths were seen in four patients (Fig 2). The most common abnormality apart from the thickened appendix was fat stranding around the appendix (31 patients). Another common sign of appendicitis was obliteration of fat plane anterior to right psoas muscle,

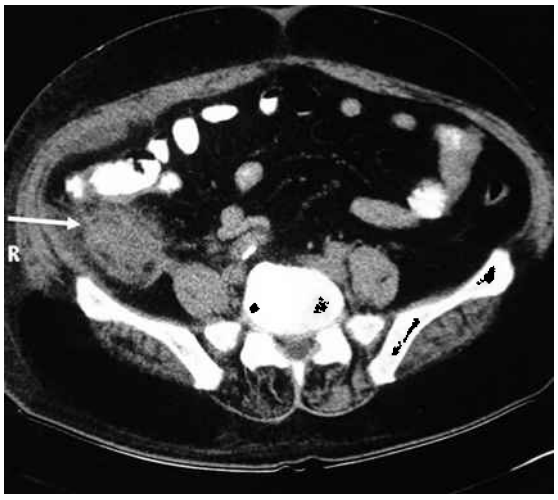

Fig. 4 Axial CT image shows an ill-defined soft tissue density mass with streakiness of the surrounding fat. The appendix is not separate from the mass consistent with inflammatory appendicular mass (arrow).

Table III. List of ultrasonographical findings.

Findings	Number
Appendix localised	32
Appendix not localised	19
Visualised appendix abnormal	32
Visualised appendix normal	Nil
Features of appendicitis (n=52)	
Total diameter of appendix > 6mm	32
Appendicoliths	3
Indistinctness of wall layers	2
Diffuse hypoechogenicity of wall	6
Periappendiceal fluid collection	18
Hyperechoic mesoappendix	2
Enlarged lymph nodes	2
Ileus	3
Free fluid	3
Appendicular abscess	1
Other findings	
Right tubo-ovarian abscess	1
Right hydroureteronephrosis	1

seen in 26 patients. The comet tail sign caused by thickening of lateral conal fascia was seen in six patients on CT. CT showed a normal appendix in two patients who were both managed conservatively. Enlarged lymph nodes (three patients) (Figs. 5a–b), caecal wall thickening (seven patients) and ileal wall thickening (three patients) were the other findings detected on CT, as a part of the inflammatory process (Table V).

Out of 47 patients diagnosed to have acute appendicitis on CT, one patient had an abnormal appendix on CT (Fig. 6) but at surgery, an inflammed right ovary was found and the normal appendix was seen separately (false positive result). Of the remaining five patients with either a non-visualised appendix (two patients) or normal appendix (three patients) on CT, two patients had appendicitis at surgery (false negative results) and three patients were true negative for acute appendicitis. Of these, one patient had right tubo-ovarian abscess (Fig. 7) which was detected by CT and later confirmed at surgery (Table VI).

Out of 58 patients, six patients were treated conservatively; these cases were not included in statistical analysis. Four of these patients later underwent interval appendicectomy. One of the remaining two patients managed conservatively had right ureteric calculus and the other had non-specific mesenteric adenopathy. Most of the statistical parameters, viz, sensitivity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of CT, were found to be higher than those of US in the diagnosis of acute appendicitis (Tables VII–VIII). Specificity of US and CT was found to be 100% and 75%, respectively. US had advantage over CT in the detection of periappendiceal fluid collection and impending perforation of appendix. However, CT was found more sensitive in the localisation of appendix, evaluation of periappendiceal inflammation, detection of appendicoliths, enlarged nodes, and detection of complications of appendicitis. CT offered definite advantage over US in detection of ileal wall and caecal wall thickening, and localisation of the position of appendix. The sensitivity of US and CT was 67.34%

Table IV. US correlation with operative findings.

US findings	Operative findings		Total
	Acute appendicitis	Normal appendix	
Visualisation of abnormal appendix or appendicular abscess	33	0	33
Non-visualised or normal appendix on US	16	3	19
Total	49	3	52

Table V. CT findings.

Findings	Number
Appendix localised	50
Appendix not localised	2
Visualised appendix abnormal	47
Visualised appendix normal	3
Location of appendix	
Pelvic	27
Retrocaecal	22
Post ileal	1
Features of appendicitis (n=52)	
Total diameter of appendix > 6mm	45
Appendicolith	4
Periappendiceal fluid	13
Fat stranding	31
Enlarged lymph nodes	3
Caecal wall thickening	7
Ileal wall thickening	3
Obliteration of fat anterior to right psoas	27
Thickened lateral conal fascia (Double comet tail sign)	6
Ascites	1
Inflammatory mass, abscess	3
Appendicular perforation	1
Other findings	
Right tubo-ovarian mass	1
Right ureteric calculus	1
Mesenteric adenopathy	1

and 95.8%, and the specificity was 100% and 75%, respectively. The PPV was 100% and 97.8%, and the NPV was 15.78% and 60%. The accuracy of US and CT was 71.15% and 90.3%, respectively. On the basis of the statistical values, CT was superior to US in the diagnosis of acute appendicitis (Table VII).

DISCUSSION

To the best of our knowledge, our paper appears to be the second prospective study of patients suspected of acute appendicitis and which comprised graded compression US and limited unenhanced spiral CT[29]. In the previous series, abnormal appendix was visualised on US in 37%–93.3%[3, 6, 18–20, 29] of patients with acute appendicitis. The normal appendix was not visualised in any of the patients without acute appendicitis. In these studies, an appendix that was not visualised was considered to be normal and no surgical confirmation was available but only clinical follow-up was done. Thus, it is difficult to agree that none of these patients had appendicitis at the time of presentation, based on clinical follow-up only

Fig. 5a Axial CT image shows multiple mesenteric nodes (arrow) with fluid- filled bowel loops.

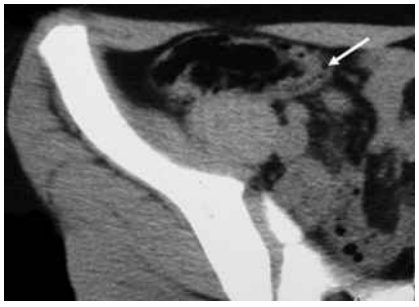

Fig. 5b Axial CT image of the same patient shows a thickened appendix with intraluminal air inside (arrow) and no evidence of periappendiceal streakiness.

Fig. 6 Axial CT image shows a fluid-filled terminal ileum (arrow) which was mistaken for a thickened appendix.

Fig. 7 Axial CT image shows a well-defined right lower quadrant soft tissue mass lesion (arrow) anterior to the right iliac vessels. The normal appendix is not seen. Diagnosis at surgery was right tubo-ovarian abscess.

Table VI. CT correlation with operative findings.

CT features	Operative finding		Total
	Acute appendicitis	Normal appendix	
Visualisation of abnormal appendix or appendicular abscess	46	01	47
Non-visualised or normal appendix on CT	02	03	05
Total	48	04	52

Table VII. Statistical analysis of US and CT findings.

	US	CT
Sensitivity (%)	67.34	95.8
Specificity (%)	100	75
Accuracy (%)	71.15	90.3
PPV (%)	100	97.8
NPV (%)	15.78	60

and without any surgical confirmation, as only 6.3% of these patients are likely to develop recurrent attacks after an average follow-up of 30 weeks[21]. In a recent article, Poortman et al did not mention the visualisation of normal appendix[29].

In our study, the appendix was not visualised on US in 16 patients with acute appendicitis proven at surgery. Nonvisualised appendices in all these patients were abnormal at surgery, thus nonvisualisation of the appendix on US does not exclude appendicitis. In our study, the false negative rate of 31% was very high compared to the previous series in which the false negative rate was 4.5–5%[3, 6, 18,19]. The false negative rate in the study of Poortman et al was 21%[29]. US is highly operator-dependent and excessive bowel gas hinders proper evaluation of the appendix. US performs much better in experienced hands and requires a high level of skill and expertise. The high false negative results in our study could be due to the unfavourable location of appendix (retrocaecal or high location), obese patients and excessive bowel gas. In our study, 90% of patients were adults. As it is well known that US is more sensitive and accurate in the paediatric age group for the detection of acute appendicitis compared to the adult population, the statistical analysis data is unfavourable towards US in our study. There was one patient who at surgery was found to have a normal appendix which on US appeared abnormal (false positive).

In most of the studies, visualisation of tubular, aperistaltic and noncompressible structures was taken as the primary criterion for the diagnosis of acute appendicitis[1,3,19]. No size criterion was used. Subsequent studies revealed that a normal appendix could be seen on US in < 5% of patients without acute appendicitis[6, 20]. Thus, some authors used the size criterion of total diameter of appendix > 6mm as one of the criteria[5,6,18]. Likewise, we also used total diameter of appendix > 6mm as one of the criteria for labelling an appendix to be abnormal. In our study, US detected appendicoliths in three out of four patients with appendicoliths at surgery. All these patients had a thickened appendix and periappendiceal fluid collection,in addition to appendicoliths. All the three patients with appendicoliths on US had appendicitis at surgery. However, demonstration of appendicolith alone does not suggest acute appendicitis[22]. In our study, the alternative diagnosis of tubo-ovarian abscess was established in one patient, in whom normal appendix was not visualised, and in another patient, a tiny ureteric calculus was detected.

Statistical analysis of US results in our study are nearly comparable to previous results[3–6,18,19] except for its NPV. The NPV was found to be very low because of a high false negative rate and low true negative rate. In the initial CT study by Balthazar et al, an abnormal appendix was identified as a ring-like structure having a symmetrical and circumferential thickened wall without any size criteria[1]. Since the normal appendix is identified in 44%–51% of routine abdominal CT studies in asymptomatic adults[23], mere visualisation of an appendix at CT cannot be used as a criterion for acute appendicitis. In subsequent studies, an appendix was considered abnormal if it was identified as a ring-like

Table VIII. Comparison between US and CT in the evaluation of acute appendicitis.

Features	US	CT
Appendix localised	32	47
Appendix		
Normal	0	2
Abnormal	32	45
Appendicoliths	3	4
Periappendiceal inflammation	18	31
Periappendiceal fluid collection	18	13
Enlarged nodes	2	3
Impending perforation	2	1
Inflammatory mass / abscess	1	3
Alternative diagnosis	2	3

structure having an asymmetrical and circumferential thickened wall with total diameter of >6mm[24–28]. Some of the studies reported non-visualisation of appendix in 6.3%–33% of patients, and the authors considered these to be normal appendices[27,28,30]. All these patients were confirmed only on clinical follow-up and did not have surgical confirmation. But it is difficult to accept that these patients had no appendicitis at the time of presentation, as this assessment was based only on clinical follow-up without surgical confirmation.

In our study, of the two patients in whom the appendix was considered normal on CT, one patient had an appendix measuring <6mm with no associated surrounding inflammation and in the other patient, the appendix was not visualised. In both these patients, their appendices were abnormal at surgery. Thus the false negative rate was 3.8%, as compared to previous series in which false negative rate varied from 1% to 10%[1, 4, 24, 26–28]. There was one false positive case (2%) in our study. In this patient, the appendix was found abnormal on CT but at surgery was found to be normal; however, the right ovary was found inflammed. In the previous series, false positive rates varied from 0% to 5%[1, 24, 26–28]. In the present series, appendicoliths were seen in four patients (7.6%), and all these appendices also showed periappendiceal fat stranding apart from the appendicoliths. All these patients had appendicitis at surgery. It should be noted that presence of an isolated appendicolith is not sufficiently specific to be the basis for the diagnosis of acute appendicitis[22].

The modalities, US and CT, are not only helpful in confirming the diagnosis of acute appendicitis, but also in excluding other conditions that mimic acute appendicitis, such as caecal diverticulitis, typhilitis, mesenteric adenitis, acute terminal ileitis, small bowel diverticulitis, epiploic appendagitis, segmental infarction of the bowel, acute ureteric obstruction, pelvic inflammatory disease, ovarian torsion, and ectopic pregnancy. In our study, an alternative diagnosis of right tubo-ovarian mass was made in one out of three patients in whom CT was a true negative for acute appendicitis. Among the six patients managed conservatively, two patients were offered an alternative diagnosis, right ureteric calculus in one and non-specific mesenteric adenopathy in the other. In conclusion, from our data analysis, we conclude that unenhanced spiral CT is more sensitive in picking up appendicitis than US, especially in adult patients.

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