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Diagnostic efficacy of ultrasound and computed tomography imaging in acute appendicitis & its histopathological correlation

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Abstract

Background: Many patients who come to the emergency have an inconclusive clinical history & physical examination, especially children & pregnant women. An imaging study allows an objective confirmation of the diagnosis before an invasive procedure is performed.

Objectives: To evaluate the diagnostic efficacy of CT & USG imaging in diagnosing appendicitis and its comparisons with histopathological correlation.

Methods: This was a prospective study conducted over the duration of one year. All patients clinically suspected of acute appendicitis referred to the department of radiology were included in the study. 100 patients were referred for USG, CT and histopathological examination. Findings were noted and analysed.

Results: 78 patients had appendicitis on 2.187 mm respectively. CT reported peri- appendicular fat standing in 74%, peri- appendiceal adenopathy in 78%, appendicoliths in 15% and peri-appendicular abscess in 31% of patients. Statistically significant association was observed between USG and histopathology in observation of luminal diameter >6mm, increased pericaecal echogenicity and appendicular perforation. On comparison of CT with histopathology findings such as pericaecal fat standing, appendicular perforation and

presence of tubular structure were found to be significantly associated.

Conclusion: CT is more accurate than USG in diagnosis of appendicitis.

Keywords: Diagnostic Efficacy, Appendicitis, Sensitivity, Specificity and Positive Predictive Value.

Introduction

The vermiform appendix is considered a part of the digestive tract, present in the Right Lower Quadrant of the abdomen. It is a worm-like structure & arises during embryological life from the posteromedial wall of the caecum, about2 cm below the ileocecal valve.[1] However, it can be located in any region of the abdomen, depending on if there are any abnormal developmental issues, including midgut malrotation, or if there are any other special conditions such as pregnancy or prior abdominal surgeries.[2]

Acute appendicitis is the leading cause of surgical emergencies in the abdomen with a lifetime risk of 7-8%.[3] It occurs mostly in young adults, with a peak incidence in the second & third decades of life. Typically, the patients describe pain around the peri-umbilical region, which increases during the first 24 hours, becoming constant & sharp & migrates typically to right iliac fossa region.[4,5] Progressive loss of appetite isoften considered as a predominant feature, & constipation & nausea are often present. Copious vomiting may indicate the development of generalized peritonitis after perforation but is rarelya major feature in simple appendicitis.[5]

The diagnosis of acute appendicitis islargely thought to be a clinical one, a meaningful number of patients are foundto have normal appendices at the surgery. The erroneous diagnosis of this acute condition led to a high rate (8- 30%) of inappropriate removal of the normal appendix. This high rate needs to be balanced with the problem of being over-restrictive regarding the diagnosis of acute appendicitis, which may allow uncomplicated appendices to progress to perforation & peritonitis.[6]

An imaging study allows an objective confirmation of the diagnosis before an invasive procedure is performed. The two most common modalities in use are computed tomography (CT) and abdominal ultrasound (US).[7] Both are considered to have acceptable sensitivities, specificities, and positive and negative predictive values, though CT has been shown to be superior in numerous studies.[7] The sensitivity &specificity of USG is 55% & 95% respectively for diagnosing acute appendicitis. However, it is very much operator-dependent& therefore an equivocal or negative study cannot rule out appendicitis. CT remains to be the immensely used radiological study, given its speed, sensitivity, & specificity. In a recent study conducted by Iamwat J et al in 2021, it was observed that the overall CT sensitivity, specificity & accuracy for differentiation of complicated & uncomplicated appendicitis were 87.2%, 75.7%, & 81.1% respectively.8Many patients who come to the emergency have an inconclusive clinical history & physical examination, especially children & pregnant women therefore, diagnostic imaging is often necessary.[9,10] With this background, the current study is undertaken with the goal to evaluate the diagnostic efficacy of CT & USG imaging in diagnosing acute appendicitis & its comparisons with histopathological correlation.

Materials & Methods

Study design: Prospective cross- sectional study.

Study area: Department of Radiodiagnosis, Gandhi Medical College, & associated Hospitals (Hamidia Hospital) Bhopal.

Study duration: August 2021 to September 2022

Sample population: 100 participants

Inclusion criteria

- All patients clinically suspected of acute appendicitis referred to our department for imaging and planned for operative and intra- operative care.
- Cases of all age groups irrespective of gender.

Exclusion criteria

- Patients with previous history of contrast sensitivity
- Patient not giving consent.

Study tool

USG Abdomen

Plain and contrast-enhanced computer tomography (CECT) abdomen.

Histopathological Reports Methodology: Permission to conduct the study was obtained from the ethical committee (Letter no.27075/MC/IEC/2021) of Gandhi Medical College, Bhopal, Madhya Pradesh. The study was conducted on patients referred to the radio-diagnosis department, Gandhi Medical College, & associated Hospitals (Hamidia Hospital) Bhopal with clinically suspected appendicitis. After obtaining informed consent and explaining the purpose of study to the participants, data collection was done and information was recorded on a patient proforma and entered in MS-excel sheet. The proforma included information on baseline characteristics of study participants, USG findings, CECTfindings and histopathological findings.

Consent: Informed consent was obtained from the participants afterexplaining them the nature and purpose of the study. They were assured that confidentiality would be strictly maintained. The option to withdrawfrom the study was always open forthem.

Statistical analysis: Data was entered into MS excel 2007, and analysis was done with the help of Epi info Version 7.2.2.2. Frequency and percentages were calculated. Quantitative variables were expressed as the mean and standard deviation. Categorical data were expressed as percentage. Microsoft office was used to prepare the graphs. Diagnostic accuracy was calculated. $P<0.05$ was considered to be statistically significant. Kappa statistics was applied,wherever required.

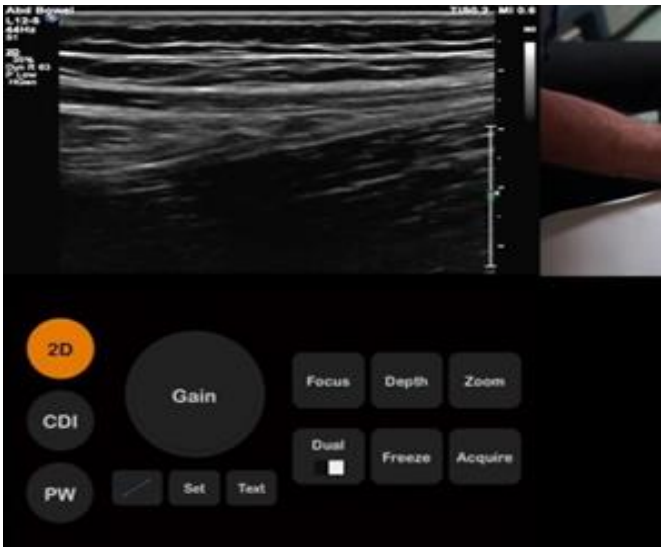
Ultrasound examination: Color doppler sonography of right lower quadrant was performed, giving attention to the site of maximal tenderness, using a 7-15–MHz linear transducer. In case of difficult visualization of appendix the graded compression technique is used using the linear probe over site of maximal tenderness, with gradual increasing pressure exerted to displace gaseous distended bowel loops. Findings were entered in patient proforma. (figure 1)

MDCT examination: It was performed using a multi-slice CT scanner. Physical (local) examination was performed for local & rebound tenderness, guarding, rigidity in RIF region and for evaluation of different signs including Rovsing's sign, Dunphy's sign and obturator sign. Patients were initially prepped for “Full Oral Preparation” which usually requiresa low-residue diet. About 100 mL of 20% mannitol (70 patients) in 1000ml of water or 5ml of non-ionic iodinated contrast iohexol 647mg/ml (30 patients) in 1000ml water was given to the patient to drink intermittently in next 40-60 minutes for adequate bowel distension. MDCT was performed using a 128-slice scanner at 120 kVp and 100 mAs. CT of abdomen and pelvis, from the xiphoid to the pubic symphysis was done. Plain scan was done then iv non-ionic contrast material, Iohexol 647mg/ml (according to 1.5-2ml per kg body weight) was given, and portal venous phase was scanned 50-70 seconds after the contrast injection. The material was injected through an 18-gauge cannula placed in the volar aspect of the cubital vein at a flow rate of 4 ml/s. Axial reconstructions

from the raw data of 5 mm thickness. The second data set was reformatted at a thickness of 1.5mm.

Histopathological examination: Afterthe diagnosis, the patients underwent surgery, and samples were sent for histopathological examination and observations were recorded.

Figure 1: Schematic diagram of USG scanning in patient of acute appendicitis.



Results: Majority (63%) of the participants were males while 37% of were females. Mean age of study participants was observed to be about 31.11±15.10 years. Out of 100 patients in our study, the maximum number of patients belonged to age group 21-30 years (33 patients).

Figure 2: Distribution of study participants based on the USG findings

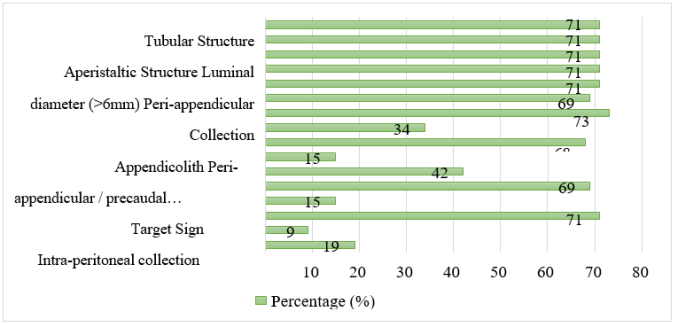


Figure 2 depicts the distribution of USG findings among participants. 71% of USG findings showing blind-ended, tubular structure, non-compressible, with no peristalsis and probe tenderness each, 69% of cases showed dilated appendix(>6mm), and 73% cases showed increased wall thickness (>3mm) of appendix. 34% had a peri-appendicular collection. 68% of findings were found to have peri-appendiceal/per caecal echogenicity. Appendicolith was present in 15% of the findings. Raised vascularity was observed in 42%, peri-appendicular lymph nodes in 69%, appendicular perforation in 15% of and 9% of the findings had appendicular lump in USG. Out of 100 patients, 19% of observed intra-peritoneal collection and 71% cases showed target signs on USG. On USG, the mean luminal diameter of the appendix was observed to be about 7.48 ± 4.641 mm.

Table 1: Distribution of study participants based on the CT findings

Variable	n (%)
Mucosal/wall Enhancement	97 (97)
Luminal diameter (>6mm/ ≤6mm)	77 (77)/ 23 (23)
Wall thickness (>3mm/ ≤3 mm)	76 (76)/ 24 (24)
Peri -appendicular abscess/collection	31 (31)
Peri -appendiceal/ Peri caecal Fat Standing	74 (74)
Peri -appendiceal/ Peri-caecal Lymph Nodes	78 (78)
Appendicolith	15 (15)
Appendicular Perforation	17 (17)

Appendicular lump	11 (11)
Ileo-caecal Thickening	23 (23)
Intra peritoneal collection	18 (18)
Caecal bar sign	27 (27)
Arrowhead sign	25 (25)
Apical Caecal thickening	22 (22)
Tubular structure	97 (97)
Luminal diameter of Appendix (mm)	9.92 ± 2.187
Position of appendix	
Sub-caecal	43 (43)
Retro-ceacal	40 (40)
Pelvic	7 (7)
Pre-ileal	1 (1)
Post ileal	2 (2)
Promontory	0 (0)
Para-caecal	7 (7)

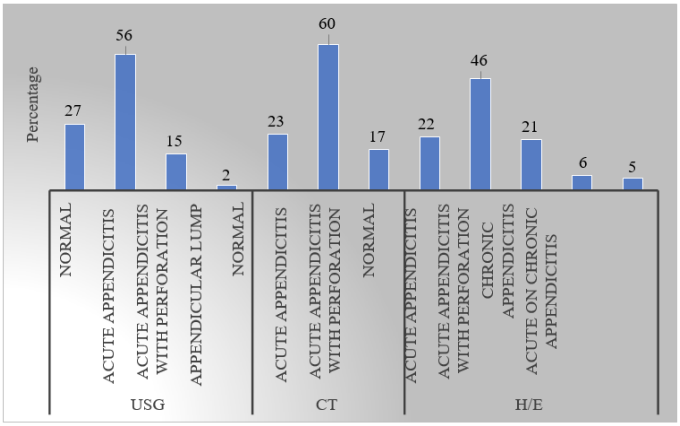
Table 1 displays distribution of study participants based on the CT findings. The mean luminal diameter of the appendix was found to be about 9.92 ±2.187 mm. Mucosal/wall enhancement was observed in 97% of patients and 77% of cases showed dilated lumen &76% cases showed thickened appendicular wall. Peri-appendicular abscess/ collection was seen in 31%, peri appendiceal/ peri caecal fat strands were observed in 74% of and peri appendiceal/ peri caecal lymph nodes were found in 78% of CT findings. 15% of patients reported appendicolith, 17% of reported appendicular perforation,11% of found appendicular lump, and 23% of had ileocecal thickening on CT. Free fluid was also observed in 18% of patients. Caecal bar sign was found in 27%, Arrow head sign in 25% and apical caecal thickening in 22% patients. Aforementioned table displays position of appendix on the basis of CT findings. Sub-caecal appendix was observed in 43% of patients and retro-caecal appendix in 40% of patients. Pelvic appendix was observed in 7% patients, pre-ileal in 1%, post-ileal in 2% and para-caecal in 7% patients. Promontory.

Table 2: Distribution of study participants based on the H&E findings

Variable	n (%)
All layers of appendix	99 (99)
Tubular structure	99 (99)
Luminal Content (Air/ Feces)	9 (9)/ 91 (91)
Peri -appendiceal Inflammation (Peri-appendicitis)	76 (76)
Appendicular Perforation	21 (21)

H&E observed tubular structure and all layers of appendix each in 99% of patients (table 2). In lumen, faeces were found in majority (91%) of the samples.

Figure 3: Distribution of study participants based on their diagnosis by various modalities



Distribution of study participants based on their diagnosis by various modalities have been displayed in figure 3. USG, CT and H/E reported normal abdominal findings in 76% of samples had peri-appendiceal inflammation (Peri-appendicitis) and 21% of samples found appendicular perforation on H&E

27%, 23% and 22% of the participants respectively. On USG, acute appendicitis was observed in 71% of cases, acute appendicitis with perforation in 15% of findings and 2% were appendicular lump/mass on USG examination. On CT, 77% of patients were observed to have acute appendicitis with 17% found perforation as well. On H/E, acute appendicitis was observed in 67% of patients with perforation in 21% of patients. Chronic appendicitis was observed in only 6% of participants followed by acute on chronic appendicitis (5%).

Table 3: Comparison of USG with histopathological findings

Variables	USG Findings	H/E	P-value
Luminal diameter (dilated appendix>6mm)	71 (71)	99 (99)	0.05
Increased peri-appendiceal/ pericaecal echogenicity	68 (68)	76 (76)	0.046
Appendicular perforation	15 (15)	21 (21)	0.035

Table 3 displays comparison between USG and histopathological findings of appendicitis. P value < 0.05 indicates that significant association exists between the two modalities in identification of luminal diameter (>6mm), Increased peri-appendiceal/ pericaecalechogenicity and Appendicular perforation.

Similarly, table 4 depicts comparison between CT and histopathological findings of appendicitis. P value < 0.05 indicates that significant association exists between them in identification of Peri -appendiceal/ Peri caecal Fat Standing, Appendicular Perforation and Tubular structure.

Table 4: Comparison of CT with histopathological findings

Variables	CT Findings	H/E	P value
Peri -appendiceal/ Peri caecal Fat Standing	74 (74)	76 (76)	0.03
Appendicular Perforation	17 (17)	21 (21)	0.042
Tubular structure	97 (97)	99 (99)	0.039

Table 5: Contingency Table (2×2) to Determine Diagnostic Performance of USG andCT in diagnosing appendicitis

Appendicitis		H&E		Total
		Yes	No	
USG	Yes	72 (TP)	1 (FP)	73
	No	6 (FN)	21 (TN)	27
CT	Yes	76 (TP)	1 (FP)	77
	No	2 (FN)	21 (TN)	23
Total		78	22	100

*TP- True Positive, FP- False Positive, FN- False Negative, TN- True NegativeTable 5 documents comparison of USG and CT diagnosis with H&E for diagnosis of appendicitis. A total of 72 were truly found by USG as appendicitis positive. While out of 22, 21 were found as true negative both in USG and H&E. Out of 100 participants, only 1 were false positive by USG while 6 were false negatives with sensitivity, specificity, PPV and NPV92.3%, 95.5%, 98.6, 77.8% respectively for diagnosing appendicitis. Similarly, a total of 76/78 participants were truly reported by CT as appendicitis positive. While out of 22 participants, 21 were reported as true negatives by CT. Out of100 participants, only 1 were false positives by CT while 2 were false negatives with sensitivity, specificity, PPV and NPV 97.4%, 95.5%, 98.7, 91.3% respectively for diagnosing appendicitis.

Table 6: Summary on comparison of USG and CT findings with H&E diagnosis

Invest.	Sensitivity	Specificity	PPV	NPV	Kappa value
USG	92.30%	95.50%	98.60%	77.80%	0.811
CT	97.40%	95.50%	98.70%	91.30%	0.916

Table 6 shows that Sensitivity, Specificity, PPV&NPV in differentiating appendicitis on USG from histopathological findings was found to be 92.3%, 95.5%, 98.6% & 77.8%respectively. Kappa value of 0.811 implies that there is almost perfect agreement between USG and H&E findings. Sensitivity, Specificity, PPV&NPV in differentiating appendicitis on CT from histopathological findings was found mentioned 97.4%, 95.5%,98.7% & 91.3% respectively. Kappa value of 0.916 implies that there is almost perfect agreement between CT and H&E findings. 11% of the patients who were diagnose as acute appendicitis on CT /USG were diagnosed as either chronic (6%) or acute on chronic (5%) on HPE, therefore sensitivity of diagnosing chronic appendicitis in CT/USG is poor and it is falsely diagnosing chronic appendicitis as acute.

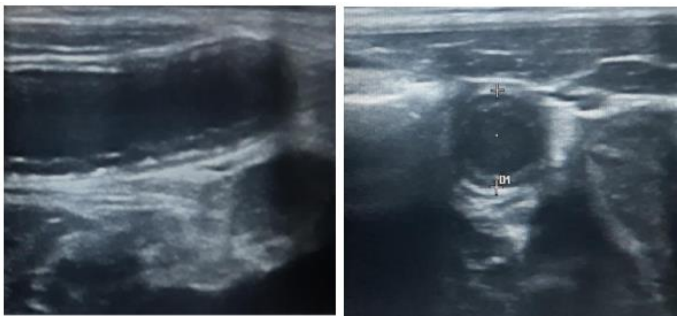


Figure 4: A 15years- old male patient presenting with complaints of RIF pain, High-frequency sonogram (A-longitudinal & B-transverse axis) shows a blind-ended tubular structure with thickened wall and maximal luminal diameter measuring approx. 8mm without any

obvious peri-appendiceal collection/lymph nodes- Likely acute appendicitis.

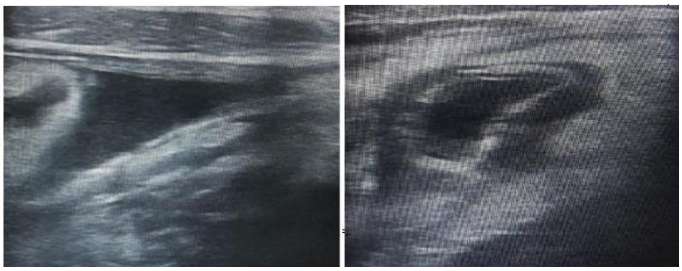


Figure 5: High-frequency ultrasound in 50 years old patient with acute abdomen shows thickened and dilated non-compressive blind-ended tubular structure showing few focal hypoechoic defects in its wall associated with mild hypoechoic fluid in RIF region and adjacent echogenic inflamed mesentery suggestive of acute appendicitis with perforation.

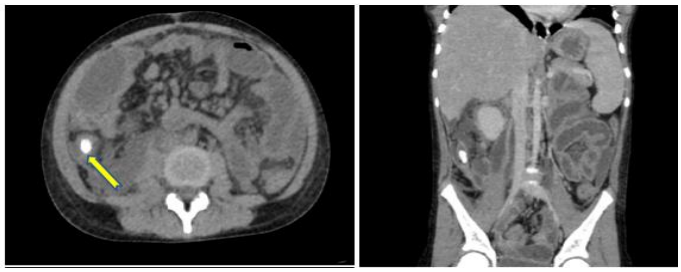


Figure 6: Axial (A) &reconstructed coronal (B) CT images, in 43years old female patient showing enlarged and enhancing thickened wall of appendix measuring approx. 7.8mm in diameter with a hyperdense solitary intraluminal content of calcific attenuation (mean HU+250), representing appendicolith associated with hypodense collection in RIF region.

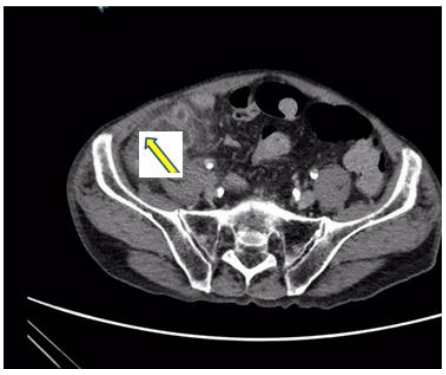


Figure 7: 58 years male patient complaining of acute abdominal pain, fever and vomiting, CECT abdomen axial image shows a well-defined peripherally enhancing hypodense collection noted in RIF region in peri-appendiceal location with dilated appendix suggestive of sealed appendicular perforation with abscess formation.

Discussion

In our study, male predominance was observed among study participants which is concurrent with the study findings of Macklin AA et al11 and Ramarajan et al12. In the present study, the mean age of study participants was found to be about 31.11±15.10 years and the maximum number of patients belonged to age group 21-30 years which is consistent with the findings of study conducted by Puylaert JB13 in which mean age of participants was 30 years. In the study conducted by Reich B et al85 mean age of CT cohorts and USG cohorts were between 30.2 years and 40.2 years. On USG, the mean luminal diameter of the appendix in our study was found to be about 7.48 ± 4.641 mm. Approximately 69% of cases had dilated appendix (>6mm) and 73% of cases showed increased wall thickness (=/>3mm) of appendix diagnosed asacute appendicitis. This is similar to the findings of study by Kessler N et al14 andHussain S et al15 where luminal diameter>6mm was accurately observed by USG. On CT our study found peri-appendicular fat standing in 74% of patients, enlarged appendix in 77% of patients, peri- appendiceal adenopathy in 78% of patients, appendicoliths in 15% of patients, peri-appendicular abscess/ collection in 31% of patients and wall enhancement in 97% of patients. Caecal bar sign and arrow head sign was found in 27% and 25% of patients. Karakas SP et al16 found peri-appendiceal fat stranding in 100% of patients, enlarged appendix (>6mm) in 97% of patients, peri-appendiceal adenopathy in 57%, appendicoliths in 43% and abscess in 10% which was similar to present study.

Similar findings were observed in study of Iamwat J et al8 who observed breach in continuity of appendicular wall in 83.2%,moderate-to-severe peri-appendiceal fat stranding in 96.8% of cases. Balthazar EJ et al17 observed appendicoliths in 20% and abscesses in 28% of patients. In the present study, CT found that sub- caecal appendix was observed in 43% of patients followed by retro-caecal appendix in 40% of patients. This is in accordance with the findings by Lee et al17 where sub-caecal position was most frequently encountered in 42.8% of patients. On gross examination, our study showed tubular structure in 99% of patients and on microscopic examination all layers of appendix were found in 99% of patients. In the lumen, faces were found in majority (91%) of the samples. 76% of samples had peri-appendicular inflammation and 21% of samples found focal necrosis in wall of appendix representing appendicular perforation on H&E. Acute appendicitis was observed in 67% of patients with perforation in 21% of patients. Chronic appendicitis was observed in only 6% of participants followed by 5% showing acute on chronic appendicitis as well, which is similar to the findings observed by Prabhu R et al, acute appendicitis was observed in 65%, normal appendix in 19% chronic appendicitis in 12% and unusual findings in 4%.18

Also, Šutakimle K et al observed in histopathological examination that 9% of appendix was with no signs of inflammation, 80% with inflammatory changes,10% with chronic appendicitis and 2% had other histological findings.19 As per current study Sensitivity, Specificity, Positive predictive value and Negative predictive value in diagnosing appendicitis on USG was found to be about 92.3%, 95.5%, 98.6% of and 77.8% of respectively. Kappa value of 0.811 implies that there is almost perfect agreement between USG and H&E findings. Studies have shown that the sensitivity of ultrasound to detect acute appendicitis was 55-96% and the specificity is 85-98%. The sensitivity of ultrasound to detect acute appendicitis was also reported to be 95% and reported to be 97% in another study. Studies also show that in the hands of experienced people, ultrasound has a sensitivity of 75-95% with a diagnostic accuracy of 87-96%.20-22In our study Sensitivity, Specificity, PPV and NPV in differentiating appendicitis on CT from histopathological findings was found to be about 97.4%, 95.5%, 98.6% and 91.3% respectively. Kappa's value of 0.916 implies that there is almost perfect agreement between CT and H&E findings. Crocker C et al23 reported sensitivity and specificity in CT examination to be 98.9% and 97.2%, respectively. Arruzza et al24 found pooled sensitivity and specificity for CT to be 97.2%. in meta-analysis by Eng KA et al25, the pooled sensitivities and specificities of second-line CT for diagnosis of appendicitis in 11 studies of adults were 89.9% (95% CI: 85.4%,93.2%) and 93.6% (95% CI: 91.2%,95.3%), respectively.

Conclusion

The sensitivity and specificity of USG and CT findings for the diagnosis of appendicitis were compared with histopathology. CT was found to have higher diagnostic accuracy than USG. CT has higher sensitivity, specificity, PPV and NPV as 97.4%, 95.5%, 98.7% and91.3% respectively as compared to USG with sensitivity, specificity, PPV and NPV of 92.3%, 95.5%, 98.6%, and 77.8%respectively which gives CT higher diagnostic importance for diagnosing appendicitis. However, when compared with CT, USG has certain advantages as it is of relatively low cost, non-invasive, and without radiation exposure which makes it a primary imaging modality, especially in children, non-obese patients, and in primary health care settings. Hence, as

per our study, CT is considered more specific than USG to diagnose appendicitis.

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