Original Article

DOI: 10.7860/IJARS/2022/57121.2848

Radiology Section

Diagnostic Performance of MRI in Acute Appendicitis in Adult Population: A Cross-sectional Study

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ABSTRACT

Introduction: Acute appendicitis is the most common cause of acute abdomen requiring surgical intervention. The diagnosis of acute appendicitis is primarily clinical which is based upon various signs and symptoms and blood tests. Although the sensitivity of clinical evaluation is high but specificity is very low and requires further evaluation by imaging prior to surgery to avoid unnecessary negative appendectomy. In view of these, current practices involves use of imaging to diagnose acute appendicitis. Magnetic Resonance Imaging (MRI) is an imaging test that can be used to diagnose appendicitis but still not the modality of choice. Computed Tomography (CT) is the modality of choice but causes radiation hazards. MRI is an alternative cross-sectional modality with no radiation issues.

Aim: To evaluate the diagnostic performance of MRI in clinically suspected cases of acute appendicitis.

Materials and Methods: This cross-sectional study was conducted on 84 clinically suspected cases of appendicitis from September 2020 to November 2021 in a Central Government Hospital Jammu, India. Patients diagnosed as suspected acute appendicitis by surgical specialist underwent MRI abdomen as first line of investigation. Positive cases underwent laparoscopic evaluation followed by laparoscopic appendectomy and histopathological evaluation. The final diagnosis of histopathology report taken as gold standard for evaluation of diagnostic performance of MRI in which sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, Positive Predictive Value (PPV) and Negative Predictive Value (NPV) of MRI for appendicitis was calculated by using STATA Texas (Version 16) statistical analysis software.

Results: Out of 84 patients, 70 were males with mean age of 26.66±6.9 years while 14 were females with mean age of 31.2±6.34 years. The sensitivity, specificity, positive likelihood ratio, negative likelihood ratio, PPV and NPV of MRI for appendicitis is 96.9%, 90%, 9.69, 0.03, 96.9% and 90% respectively at 95% confidence interval. There is a strong agreement between MRI and histopathological findings with kappa value of 0.87 (p-value<0.0001).

Conclusion: MRI has high sensitivity and specificity for acute appendicitis and has potential to become modality of choice to diagnose acute appendicitis.

Keywords: Diagnosis of appendicitis, Evaluation of appendix, Magnetic resonance imaging

INTRODUCTION

Acute appendicitis as a clinical entity has often been described as the “Bread and Butter” case for surgeons across the globe [1]. It is the most common cause of acute abdomen requiring surgical intervention [2]. The lifetime risk for appendicitis is 8.6% in males and 6.7% in females [3]. Since long time, the diagnosis of acute appendicitis is primarily clinical, with the role of radiological analysis merely supportive. Appendicitis is diagnosed clinically in patients with features of right iliac fossa pain, pyrexia and leukocytosis and various clinical tests. To improve the clinical accuracy, various scores have been developed like much acclaimed MANTRELS or the Alvardo Score, the Raja Isteri Pengiran Anak Saleha Appendicitis (RIPASA) score and the recent Appendicitis Inflammatory Response (AIR) criteria [4]. But the clinical presentations are often atypical and due to overlapping of symptoms, the diagnosis of appendicitis becomes difficult. Although the sensitivity of clinical evaluation is high but specificity is very low and requires further evaluation by imaging prior to surgery.The efficiency and accuracy of imaging of acute appendicitis is of paramount importance in guiding treatment decisions and surgical planning [5]. Ultrasonography (USG), CT scan and MRI are the available modalities of imaging appendicitis and rule out its mimics.

Although ultrasound is a safe, cheap, easily available modality but its use is limited as it is highly operator dependent. The reported sensitivity and specificity of USG is 83.7% and 95.9% respectively while its overall test yield is only 15.8% and accuracy is just 13.7% [5,6]. Many times, the ultrasound is either negative or non diagnostic for appendicitis leaving clinicians in dilemma. CT has sensitivity of 98.5% and a specificity of 98% and diagnostic accuracy of 95.6% and is being used as primary modality in many countries but has issues related to its ionising radiation [5,6,7].

MRI is an alternative cross-sectional modality with no radiation issues. Very limited study available in use of MRI in diagnosis of appendicitis in general population [8]. Hence, the present study was conducted with an aim to evaluate the diagnostic performance of MRI in clinically suspected cases of acute appendicitis.

MATERIALS AND METHODS

This was a cross-sectional study carried out at a secondary care Central Government Hospital in Jammu, India from September 2020 to November 2021. This study was approved by the Ethics Committee of the hospital and informed consents were obtained.

Inclusion criteria: All patients diagnosed as suspected acute appendicitis on clinical and laboratory evaluation by surgical specialist in emergency department.

Exclusion criteria: Patients with contraindications to MRI like any metallic implants, ferromagnetic aneurysmal clips, implanted pacemaker, cochlear implants were excluded from the study.

Procedure

The study used case-referent approach where consecutive patients presenting to emergency department of the hospital with features of acute appendicitis like pain in right lower abdomen,

nausea, decreased appetite was evaluated clinically and when surgeons diagnosed the case after thorough clinical examination and laboratory testing, patient was referred for MRI abdomen as first line of investigation for confirmation of acute appendicitis after taking informed consent. All these patients (n=84) underwent MRI abdomen using 1.5 T Philips Achieva scanner. MRI Sequences were acquired from mid-liver to pubic symphysis. The sequences as described in [Table/Fig-1] were acquired:

Sequences features	Coronal T2 TSE	Axial T2 TSE	Sagittal T2 TSE	Axial T2 SPAIR
Repetition time (msec)	423	1500	1500	1500
Echo Time (msec)	80	80	80	80
2D/3D	2D	2D	2D	2D
Slice thickness	5 mm	5 mm	3 mm	3 mm
Interval gap	1 mm	1 mm	1 mm	1 mm
Field of View (FOV)	450	430	375	430
Fat suppression	No	No	No	Yes

[Table/Fig-1]: MR Protocols for patients with suspected appendicitis.
2-Dimensional; 3-Dimensional

The key imaging features used for diagnosis of appendicitis on MRI were as follows: [9]

1. Enlarged appendix with total diameter of >6 mm
2. Fluid filled lumen
3. Thickening of appendiceal wall (>3 mm) with increased mural hyperintensity.
4. Periappendicular fat stranding.
5. Periappendicular fluid collection/abscess/phlegmon.

The MRI criteria that excluded appendicitis on MRI were a normal appendix with diameter <6 mm or appendix with diameter >6 mm without periappendicular fat stranding/fluid collection which were reported as no evidence of appendicitis on MRI and alternative diagnosis for pain abdomen was searched on MRI in clinically suspected case of acute appendicitis [9].

The location of appendix like retrocaecal, postileal, preileal, subcaecal and pelvic was identified on MRI along with the size and location of appendicolith. The presence of mucocele, abscess or phlegmon formation were also noted.

Patients with MRI findings suggestive of appendicitis, were subjected to laparoscopic evaluation where laparoscopic findings like visualisation of signs of inflammation viz swollen, oedematous and/or erythematous appendix was looked for. Appendix was also looked for focal or segmental congestion/necrosis/perforation, any abscess or phlegmon formation or pus-flaking or any fluid in right iliac fossa. Laproscopic evaluation confirming appendicitis was followed by laparoscopic appendectomy within 2-4 hours of MRI by surgical team and appendicular specimens were sent for histopathological evaluation by pathologist of the hospital where transmural neutrophil infiltration was evaluated apart of other features of appendicitis.

STATISTICAL ANALYSIS

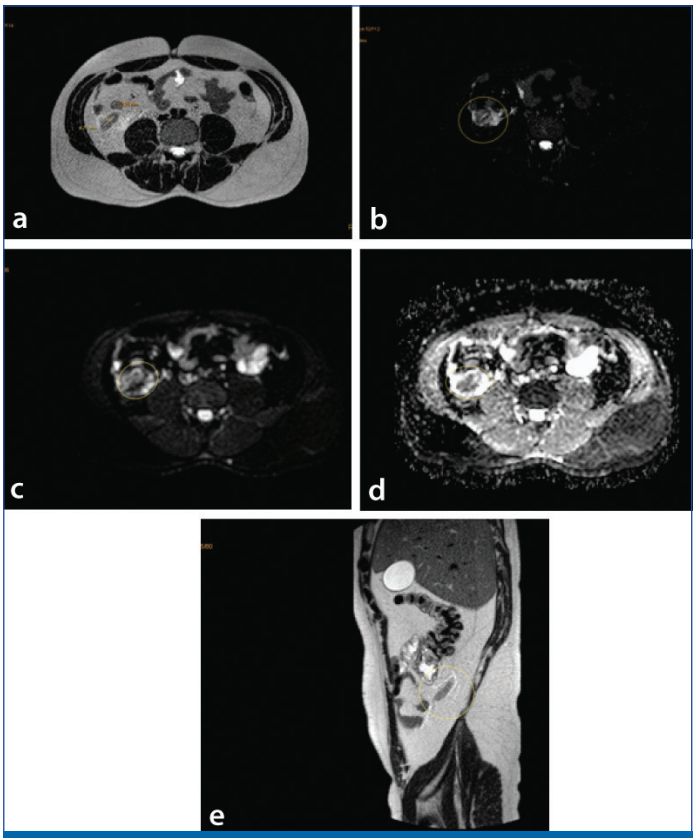
The sensitivity, specificity, PPV, NPV of MRI for acute appendicitis were calculated by taking histopathological results as gold standard using STATA Texas (Version 16) statistical analysis software.

RESULTS

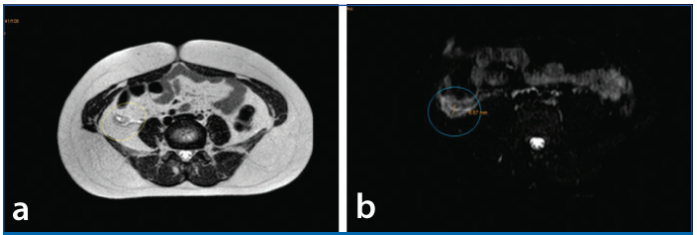
During the study period, 84 patients suspected of having appendicitis on clinical evaluation were subjected to MRI Scanning. Out of these, 70 were males with mean age of 26.66±6.9 years while 14 were females with mean age of 31.2±6.34 years.

Total of 64 cases were diagnosed as acute appendicitis on MRI while 20 cases were diagnosed as either normal or had other findings. In 2 cases, it was difficult to comment on appendix on MRI hence were subjected to Non Contrast Computed Tomography (NCCT) abdomen which later confirmed appendicitis; 3 cases were diagnosed as normal scan and followed up without undergoing appendectomy and eventually became asymptomatic; 2 cases were diagnosed as mucocele of appendix, whereas 1 case was diagnosed as a case of acute pancreatitis. Among them, 12 cases ended up being diagnosed as right ureteric calculus which was confirmed on USG/Radiographs KUB (Kidney, Ureter and Bladder region) and underwent respective management.

All the 64 cases of appendicitis on MRI had luminal diameter >6 mm with luminal diameter ranging from 6.41 mm to 16 mm with average luminal diameter of 8.95 mm. All these patients had periappendicular fat stranding [Table/Fig-2a-e,3a,b]. Only 2 cases had perforated appendix and 14 cases had mild fluid in periappendicular region and 14 cases had appendicolith. The various location of appendix on MRI is as per [Table/Fig-4].



[Table/Fig-2]: (a) T2 TSE axial(Turbo spin echo (TSE) imaging on T2-weighted images), (b) SPAIR (Spectral Attenuated Inversion Recovery) showing dilated fluid filled appendix with thick walls and periappendicular fat stranding. T2 TSE has excellent soft tissue resolution and can show most of features of appendicitis. Mural hyperintensity and fat stranding is better appreciated on T2 SPAIR images but T2 SPAIR has poor resolution. Diffusion weighted imaging (DWI) (c image) and corresponding ADC (d image) showing restriction of diffusion but images have poor resolution. Sagittal T2 TSE (e) showing retrocaecal position of appendix.

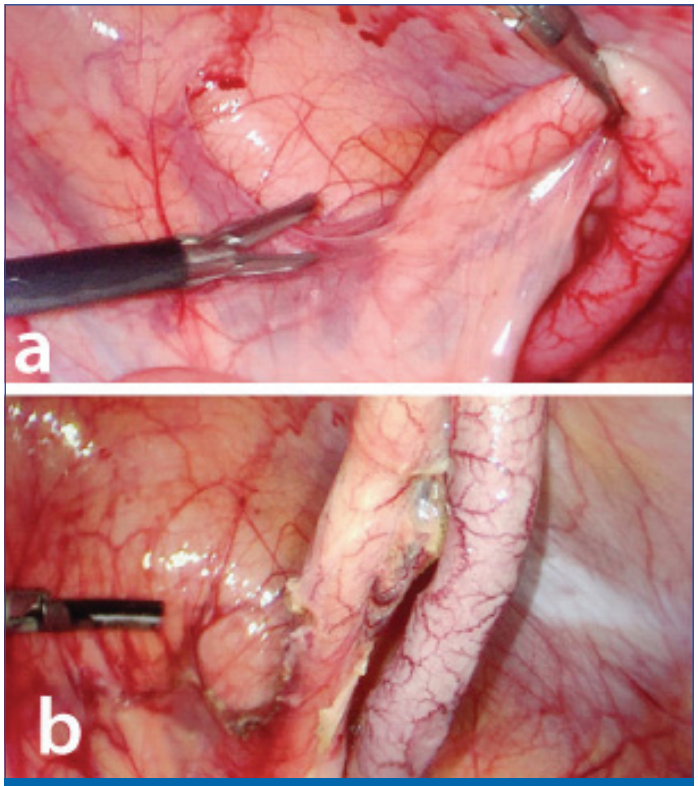


[Table/Fig-3]: (a- T2 TSE axial and b- T2 SPAIR axial) in another patient showing dilated fluid filled appendix with periappendicular fat stranding and mural hyperintensity.

All the findings of MRI were confirmed on laparoscopy [Table/Fig-5a,b] and patients underwent laparoscopic appendectomy. Among them, 2 cases were diagnosed as suspected early acute appendicitis and right hemorrhagic cysts on MRI. These appendix appeared normal on laparoscopic evaluation. Rest all cases were diagnosed as appendicitis on laparoscopy and were further confirmed by histopathological evaluation.

Position	Numbers	Percentage
Preilieal	1	1.56
Postileal	1	1.56
Pelvic	22	34.4
Subcaecal	2	3.1
Retrocaecal	38	59.4

[Table/Fig-4]: Various position of appendix on MRI for appendicitis (N=64).



[Table/Fig-5]: (a) Showing acutely inflamed long appendix on laproscopic view; (b) Showing acutely inflamed appendix after dissection of mesoappendix upto base of appendix.

The MRI findings had strong agreement with laparoscopic and histopathological findings with kappa value of 0.87 (p-value<0.0001). The diagnostic performance of MRI in cases of suspected appendicitis has been summarised in [Table/Fig-6].

Author, year and place of the study	N	Sensitivity (95% CI)	Specificity (95% CI)	TP	FP	FN	TN
Inci E et al., 2011, Turkey [10]	119	0.99 (0.93, 1.00)	1.00 (0.91, 1.00)	78	0	1	40
Chabanova E et al., 2011, Denmark [11]	48	0.87 (0.69, 0.96)	0.61 (0.36, 0.83)	26	7	4	11
Inci E et al., 2011, Turkey [12]	85	0.96 (0.88, 1.00)	0.89 (0.72, 0.98)	55	3	2	25
Heverghagen JT et al., 2012, Germany [13]	52	0.85 (0.61, 0.93)	0.97 (0.91, 1.00)	11	1	2	38
Zhu B et al., 2012, China [9]	41	0.92 (0.78, 0.98)	1.00 (0.48, 1.00)	33	0	3	5
Avcu S et al., 2013, Turkey [14]	44	0.97 (0.87, 1.00)	1.00 (0.78, 1.00)	39	0	1	15
Leeuwenburgh MMN et al., 2013, Netherland [15]	223	0.97 (0.91, 0.99)	0.93 (0.87, 0.97)	113	7	4	99
Present study, 2022	84	0.97(0.89, 1.00)	0.9 (0.68, 0.99)	62	2	2	18

[Table/Fig-7]: Sensitivity and specificity at 95% CI, True positives (TP), False positives (FP), False negatives (FN) and True negatives (TN) in various previous studies and present study.

97%) respectively [17]. This study also recommended to consider MRI as first line of investigation in suspected case of appendicitis which will avoid the potential risk of exposure to ionising radiations and iodinated contrast medium.

In the present study, very limited sequences were included which takes only 20 min to complete entire study. Previous studies have used T1, T2, Short Tau Inversion Recovery (STIR), Diffusion-weighted Imaging (DWI) and Gradient Echo (GRE) sequences for evaluation of appendicitis but we used only T2 and T2 SPAIR sequences and found that these are adequate to diagnose appendicitis [8]. T2 sequences has high resolution and helps in morphological evaluation of appendix, periappendicular fat stranding, intraluminal fluid, phlegmon and periappendicular fluid collection. In few cases, it was difficult to decipher periappendicular fat stranding in early appendicitis where T2 SPAIR was helpful. T2 SPAIR has poor resolution but has high sensitivity for mural hyperintensity and periappendicular fat stranding. Initially, author did DWI sequences in fewer cases but due to its poor resolution and not much benefit

Imaging	Sensitivity	Specificity	Likelihood ratio positive	Likelihood ratio negative	Positive predictive value	Negative predictive value	Receiver operating characteristic area	Positivity prevalence of MR findings
MRI	96.9% (89.2%-99.6%)	90% (68.3%-98.8%)	9.69 (2.6-36.1)	0.03 (0.01-0.14)	96.9% (89.2%-99.6%)	90% (68.3%-98.8%)	93.4% (86.4%-100%)	76% (66%-84.8%)
Laparoscopy	100% (94.4%-100%)	100% (83.2%-100%)	-	0	100% (94.4%-100%)	100% (83.2%-100%)	100%	

[Table/Fig-6]: Diagnostic performance of MRI and Laparoscopy with respect to histopathological evaluation with 95% Confidence interval.

DISCUSSION

In this study, MRI has high accuracy for diagnosing acute appendicitis in adult population. Present study also shows strong agreement between MRI positivity and histopathological findings with kappa value of 0.87 (p-value<0.0001).

Several studies have cited high sensitivity and specificity of MRI in diagnosing acute appendicitis as shown in [Table/Fig-7] [8-15]. In a meta-analysis by Repplinger MD et al., the sensitivity for MRI in appendicitis was 96.6% (95% confidence interval [CI]: 92.3%-98.5%) and specificity was 95.9% (95% CI: 89.4%-98.4%) [8]. Although the American College of Radiology has consistently rated the appropriateness of MRI as being lower than that of CT scan in their most recent guidelines, citing a relative lack of evidence of diagnostic accuracy of MRI in general population [16] but in another meta-analysis by Eugene Duke in 2016 involving 30 studies found that sensitivity and specificity of MRI for the diagnosis of acute appendicitis was 96% (95% CI, 95-97%) and 96% (95% CI, 95-

on T2 and T2 SPAIR, we stopped doing DWI sequences and used MR criteria for diagnosis of appendicitis on these images only. Our limited sequences has significantly reduced the time required for scan which is a major drawback of MRI.

Present study also found that common mimic of appendicitis is right ureteric calculus which was found to be masquerading in 12 cases of total clinically suspected appendicitis. Two cases in our study had appendix with diameter >6 mm with periappendiceal fat stranding along with right ovarian hemorrhagic cyst. These patients were diagnosed as acute appendicitis on MRI which was found to have normal appendix on laparoscopy associated with findings of ovarian pathology. The diameter of appendix >6 mm is a normal variant and reactive fluid around appendix due to right ovarian hemorrhagic cyst could mimic as periappendicular fluid/fat stranding on MRI and can be mistaken as acute appendicitis on MRI as found in our study.

The most common position of appendix is retrocaecal followed by pelvic which was also observed in our study [18]. The diagnosis of

retrocaecal appendicitis is very difficult on USG especially in obese patients and in patients where appendix is obscured by excessive bowel gas shadows and MRI will be helpful in diagnosing these cases [19]. Apart from diagnosing appendicitis, MRI can elucidate the position of appendix which can help in the planning of surgical procedures, will rule out various mimics of appendicitis like acute cholecystitis, pyelonephritis, urolithiasis, tubo-ovarian abscess, pelvic inflammatory diseases, ovarian torsion and can diagnose various complications of appendicitis like perforations, abscess or bowel obstruction [20].

We recommend MRI to be used as a first line of investigation in cases of suspected acute appendicitis and NCCT be considered only in case of diagnostic dilemma on MRI scanning, in order to protect patients from radiation hazard. Being a safe and effective investigation, a cafeteria approach should be offered to patient to undergo MRI for diagnosing acute appendicitis if patient can afford. The field of teleradiology and artificial intelligence is growing and further research in these fields can help in remote diagnosis of acute appendicitis by a safer modality like MRI which can be deployed at any remote location where trained radiologist are not available for effectively diagnosing appendicitis.

Limitation(s)

Firstly, the entire MRI images in the study has been evaluated by single radiologist and possibility of observer bias cannot be ruled out and inter-observer variations has not been identified. Secondly, most of the cases in the study are in second or third decade age group. In older age group, there are may be inconclusive MRI due to motion artifacts. Thirdly, this was a single center-experience and application of our protocol and results has to be validated in other medical centers and in different make of MRI machines before labelling MRI as modality of choice for imaging of acute appendicitis.

CONCLUSION(S)

MRI has high sensitivity and specificity for acute appendicitis. It is a safe, reliable and has potential to become modality of choice for evaluation of acute appendicitis. Further studies on larger cohorts of patients are warranted before labelling it as modality of choice.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Apr 18, 2022
- Manual Googling: Jul 23, 2022
- iThenticate Software: Sep 15, 2022 (11%)

ETYMOLOGY: Author Origin

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval Obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? Yes
- For any images presented appropriate consent has been obtained from the subjects. Yes

Date of Submission: **Apr 15, 2022**
Date of Peer Review: **Jun 14, 2022**
Date of Acceptance: **Jul 24, 2022**
Date of Publishing: **Oct 01, 2022**