DOI: 10.7860/IJARS/2017/32360:2330

Original Article

Radiology Section

Utility of Ultrafast MRI for Suspected Acute Appendicitis with Inconclusive Ultrasound

SATISH PRASAD, DEEPTI H VIJAYAKUMAR

ABSTRACT

Introduction: Acute appendicitis is the commonest cause of Right Lower Quadrant (RLQ) pain requiring immediate surgery. The lack of confirmatory imaging diagnosis may lead to unnecessary surgery or prolonged hospital stay for monitoring. MRI appendix protocol provides a fast and accurate way to diagnose the cause of RLQ pain when the ultrasound is inconclusive. MRI can ascertain the various features of acute appendicitis and its complications as well as other differential diagnosis for RLQ pain.

Aim: The purpose of this study was to evaluate the utility of ultrafast MRI appendix protocol in evaluation of RLQ pain in paediatric and reproductive age group patients with inconclusive ultrasound.

Materials and Methods: This prospective study comprised of 71 patients who underwent MRI appendicitis protocol (T2 SSH TSE, T2 SPAIR, T1 TSE and DWI) within 4 hours after an inconclusive ultrasound between May 2016 and May 2017. MRI images were reviewed independently by 2 radiologists and the diagnosis was graded as positive, negative and equivocal. The final diagnosis was established after review of operative, pathological findings and clinical follow-up for cases with no evidence of acute appendicitis on MRI.

Results: Twenty one out of 71 patients had acute appendicitis. Both radiologists graded the same 22 patients as positive, and the same 34 patients as negative. The sensitivity and specificity of MRI appendix protocol in patients with inconclusive ultrasound were 100% and 97.14% respectively. The positive predictive value was 95.45% and negative predictive value was 100% and overall test accuracy was 98.21%. The Fisher's exact test showed a p-value of <0.001 showing the correlation between MRI and clinical/pathological test for acute appendicitis is extremely statistically significant. MRI diagnosed an alternate cause of RLQ pain in about 21% of patients.

Conclusion: MRI appendix protocol yields excellent results in paediatric and reproductive age patients with RLQ pain with an inconclusive ultrasound. Restriction on DWI helps in identifying acutely inflamed appendix with confidence. It helps us in ruling out acute appendicitis thus reduces negative appendectomy rate. It is a safe, reliable and potentially cost effective technique.

Keywords: MRI abdomen, Perforation, Reproductive age group, RLQ pain

INTRODUCTION

Acute appendicitis is the most common abdominal emergency [1], requiring immediate diagnosis and surgical intervention to prevent perforation [2]. Most common clinical presentation is pain in RLQ of abdomen [3]. Lack of confirmatory imaging diagnosis can lead to unnecessary surgery and prolonged hospital stay for observation.

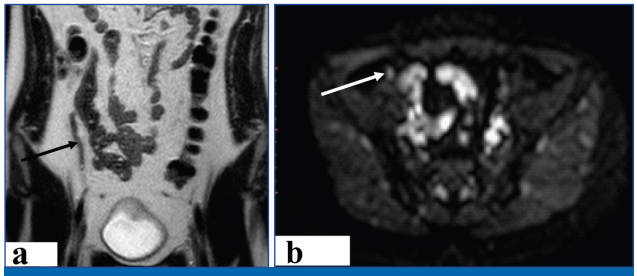
Conventional modes of diagnosis like ultrasound and Computed Tomography (CT) have proven to be dependable in diagnosing acute appendicitis. Sensitivity of ultrasound to detect acute appendicitis ranges from 60%- 69% [3,4]. Some pitfalls preventing accurate ultrasound diagnosis include retrocaecal appendix, perforated appendix, excess bowel gas and un-cooperative patient [5]. Ultrasonogram also depends on many factors like patient's body habitus, equipment, operator dependency [6].

The sensitivity and specificity of CT in diagnosing acute appendicitis was found to be 90% and 94% respectively [7]. Although, CT is very good in assessing the cause of RLQ pain, it has the disadvantage of requiring IV contrast and radiation exposure. The mean whole body effective dose in a limited CT protocol for appendicitis is found to be 9.1 mSv [8].

Therefore, CT can be avoided in benign diseases like acute appendicitis, especially in paediatric and reproductive age groups.

MRI is increasingly available now and the newer ultrafast sequences can be used to complete the study in shorter duration with lesser artefacts. MRI is an effective modality to visualise the normal appendix [9]. It appears as isointense cord like structure without intraluminal hyperintense fluid [Table/Fig-1]. Studies have shown that MRI has a high accuracy for the diagnosis of acute appendicitis for a wide range of patients, including high BMI patients, paediatric and pregnant patients [10]. Excess intra-abdominal or subcutaneous fat does not hinder in identification of appendix [Table/Fig-2].

MRI offers excellent contrast resolution which helps in identifying the inflammatory process with confidence. Addition of Diffusion Weighted Imaging (DWI) increases the conspicuity of acute appendicitis [11]. Inflamed wall of appendix and abscess show restricted diffusion. Other advantages of MRI are non-requirement of intravenous or oral contrast and lack of ionising radiation. Ascites, appendix mural thickening and periappendiceal high signal intensity correlate well with severity [12]. Even in the small number of patients with non-identification of appendix due to paucity of RLQ fat, if there are no RLQ inflammatory changes, acute appendicitis can be excluded [13].



[Table/Fig-1]: a) Coronal T2 SSH-TSE showing the appendix as a thin long cord like structure in the RLQ; b) Axial diffusion weighted imaging showing no restricted diffusion in the normal appendix.

[Table/Fig-2]: Axial T2 SSH-TSE showing acute appendicitis in a patient with high BMI.

MATERIALS AND METHODS

This prospective study was conducted between the period of May 2016 and May 2017 in a tertiary care Central Government Hospital Karnataka, India, with round the clock emergency facilities. Sample size was calculated based on the previously established diagnostic accuracy of MRI in detecting appendicitis and the prevalence of the acute appendicitis. Medical ethics committee clearance was obtained and informed consent from patients/guardians were obtained.

During the study period, there were 174 patients between the age groups 5-45 years who were referred to the Department of Radiodiagnosis with complaints of RLQ pain, nausea, low grade fever, leucocytosis.

All the 174 consecutive patients were suspected to have acute appendicitis clinically underwent ultrasound examination initially.

After the ultrasound examination, 78 patients were diagnosed to have acute appendicitis.

There were 17 patients who had alternate diagnosis based on ultrasound examination, commonest being obstructive right renal calculus followed by pelvic inflammatory disease.

Ultrasound was considered as inconclusive, if appendix was not visualised, presence of phlegmon, lack of peri appendiceal inflammatory changes and if no alternate diagnosis for RLQ pain was found.

The 79 patients who had inconclusive ultrasonogram were referred to MRI for diagnosis. Out of these 79 patients, 8 did not undergo MRI due to claustrophobia and other general MRI contraindications. Thus, 71 patients formed the study cohort, who underwent MRI appendix protocol after an inconclusive ultrasonography. The MRI images were interpreted by two radiologists, one with 14 years and other with four years cross-sectional experience.

In majority of the cases MRI was done within 4 hours of the initial ultrasound.

Inclusion criteria: All patients between the age group of 5-45 years. Clinical and lab criteria suggestive of acute appendicitis. Ultrasound examination is inconclusive.

Exclusion criteria: Features of acute appendicitis on ultrasound itself. Alternate cause of RLQ pain on ultrasound. General MRI contraindications.

MRI Technique

MRI was performed on 1.5 T Philips Achieva. All the 71 patients underwent MRI appendix protocol. The MRI sequences were acquired from mid/lower pole of kidneys to pubic symphysis.

The following sequences were acquired - T2 weighted Single SHot Turbo Spin Echo (T2- SSH-TSE) in coronal and axial planes, T2 Spectral Attenuated Inversion Recovery (T2-

[Table/Fig-3a-e]: Features of acute appendicitis- a) shows dilated appendix (> 6mm in calibre); b) shows restricted diffusion in the same patient; c) shows periappendiceal fat stranding and increased wall thickness of appendix; d) shows RLQ free fluid; e) showing restricted diffusion in appendicular abscess.

SPAIR) in axial and sagittal planes, T1 weighted sequence in axial plane for assessment of lymph nodes and DWI with b=0, 400, 800 s/mm^2 using body phased array coil. No sedation or IV contrast was used. Multislice imaging technique was used Slice thickness 3 mm, slice gap was 0 mm, matrix size was 256x256. The FOV was chosen based on the body habitus ranging from 26-40 cm. The scan time ranged from 7-9 minutes as limited sequences were used.

MRI Criteria for Diagnosis of Acute Appendicitis

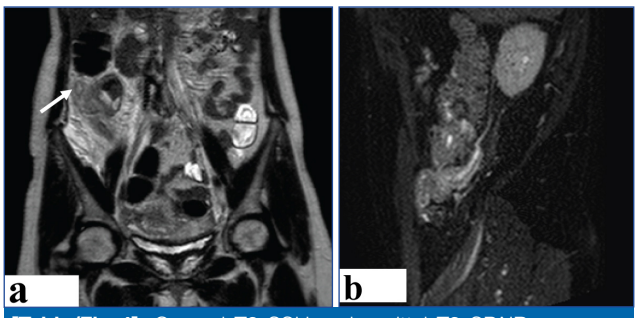
1. Enlarged appendix with a diameter of more than 6 mm, appendix mural oedema (increased mural signal hyperintensity and wall thickness > 3 mm).

2. Presence of intraluminal appendiceal fluid (increased intraluminal signal intensity).

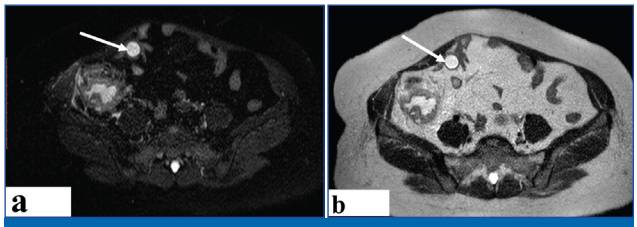
3. Signs of periappendiceal inflammatory changes, like fat stranding (increased peri-appendiceal signal intensity on T2 weighted images).

4. Presence of RLQ inflammation (increased signal intensity on fat suppressed sequence, phlegmon or abscess) [Table/Fig-3a-e].

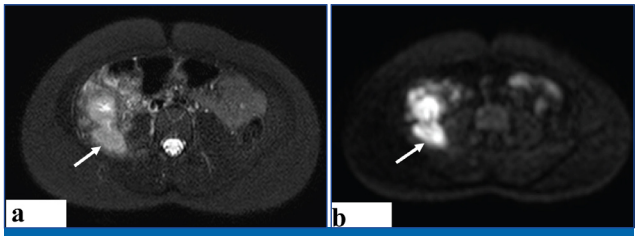
MRI was able to identify appendix in various positions like retrocaecal, paracaecal and sub-hepatic [Table/Fig-4]. Presence and location of perforation, Mucocele [Table/Fig-5], abscess [Table/Fig-6] and mass formation can be ascertained.The MRI criteria that excluded appendicitis were a normal appendix of less than 6 mm or an appendix with a diameter of more than 6 mm with no evidence of peri appendicitis.



[Table/Fig-4]: Coronal T2 SSH and sagittal T2 SPAIR sequence showing acute appendicitis in patients with paracaecal and retrocaecal appendix.



[Table/Fig-5]: Axial T2 SPAIR and; b) Axial T2 SSH TSE showing hyperintense contents distending the appendix- Mucocele of the appendix.



[Table/Fig-6]: Axial T2 SPAIR and; b) DWI showing dilated appendix with focal perforation and collection posteriorly-Appendicular abscess.

The MRI result were tabulated into three possible categories [14]-

1. Positive for acute appendicitis: if abnormal appendix was identified with other secondary inflammatory changes in RLQ

2. Negative for acute appendicitis: with no alternate diagnosis- if normal appendix was identified with no RLQ inflammatory changes.

3. Equivocal: if appendix was not identified, however RLQ inflammatory changes were present.

All patients with radiological signs of appendicitis, or with high clinical suspicion of appendicitis, were operated within a few hours after the MRI studies. Acute appendicitis was diagnosed pathologically based on the presence of polymorphic granulocytes throughout the appendiceal wall. Patients who did not undergo surgery and had no other alternate diagnosis on MRI were followed up clinically for the period of two months.

Proof of Diagnosis

Patients who underwent appendicectomy and had signs of appendicitis intraoperatively and pathologically were considered as true positives. Patients who had a normal

appendix intraoperatively or pathologically and patients who were followed-up clinically for two months without any signs of acute appendicitis were considered as true negatives.

STATISTICAL ANALYSIS

The sensitivity, specificity, positive predictive value, negative predictive value, and accuracy of appendix MRI for acute appendicitis in patients after an inconclusive ultrasound were calculated using GraphPad. The Kappa value for strength of agreement between MRI and operative/pathological diagnosis was also calculated. A Kappa value greater than 0.8 is defined as very good agreement beyond chance, a value between 0.40 and 0.8 indicates moderate to good agreement beyond chance, and a value of less than 0.40 indicates fair to poor agreement.

RESULTS

The mean age of the study population was 23.4 years. Appendix was identified in 70 of the 71 patients. Twenty two patients with MR imaging features of acute appendicitis were graded as positive by both radiologists. These patients underwent surgery, 21 of these patients had documented appendicitis intraoperatively and pathologically. This group was considered as true positives. One patient who was considered as having acute appendicitis on MRI, had high signal intensity fluid in the lumen of appendix with the diameter of the appendix measuring 6.5 mm. However, there was no inflammatory changes in the appendix intraoperatively or pathologically. Thus, one patient was falsely positive.

In 33 patients, both radiologists identified the normal appendix and MRI was reported as negative for acute appendicitis with no other definite cause of RLQ pain identified. In one patient, normal appendix was not identified and no definite cause of RLQ pain was also identified, hence considered as negative for acute appendicitis. These patients were documented as having non specific abdominal pain and were clinically followed up for two months. None of the patients who had a normal appendix and absence of RLQ inflammatory changes on MRI appendix protocol were operated for acute appendicitis in the follow-up period of two months. Thus, 34 patients were considered as truly negative. There was no false negative MRI examination [Table/Fig-7].

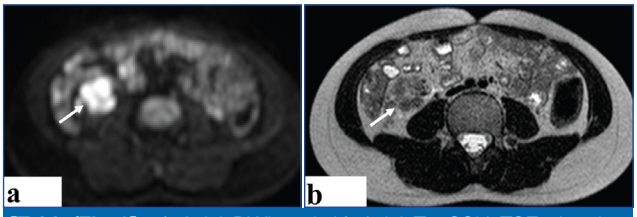
The sensitivity and specificity of MRI appendix protocol in patients with inconclusive ultrasound were 100% and 97.14% with the CI of 83.89 to 100% and 85.08 to 99.93% respectively.

The positive predictive value was 95.45% with CI of 75.26% to 99.31%, negative predictive value was 100% and overall test accuracy was 98.21%. The Fisher's exact test showed a p-value of <0.001 showing the correlation between MRI and clinical/pathological test for acute appendicitis is extremely statistically significant. Kappa value is 0.962 with 95% CI 0.889 to 1.000 showing that the strength of agreement is very good.There was no interobserver variability in identifying positive and negative appendicitis patients.

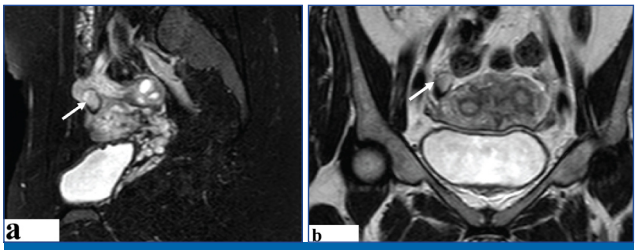
None of the MRI examination was interpreted as equivocal regarding the presence or absence of appendicitis by either reader.

Observations	No. of Patients
Patients who underwent MRI after an inconclusive ultrasound	71
Patients graded 'positive' for Acute appendicitis on MRI	22
Patients diagnosed as acute appendicitis intraoperatively and pathologically	21
Patients graded 'negative' for appendicitis on MRI	34
Patients graded 'negative' for appendicitis on MRI, but diagnosed as acute appendicitis intra operatively or on follow-up	Nil
Patients with alternative diagnosis on MRI for RLQ pain	15

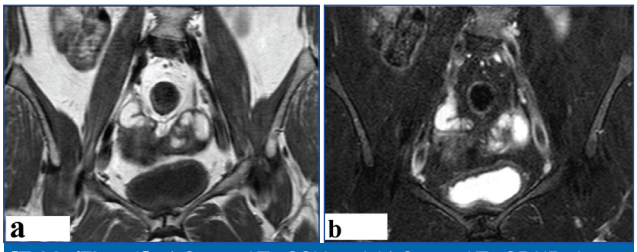
[Table/Fig-7]: Distribution of patients who underwent MRI appendix protocol after an inconclusive ultrasound.



[Table/Fig-8]: a) Axial DWI and; b) Axial T2 SSH TSE showing conglomerate necrotic lymph nodal mass in RLQ with restricted diffusion.



[Table/Fig-9]: a) Sagittal T2 SPAIR and; b) Coronal T2 SSH TSE showing a cystic structure in the right adnexa-right ectopic gestational sac. Uterus shows subseptate configuration.



[Table/Fig-10]: a) Coronal T2 SSH and; b) Coronal T2 SPAIR shows dilated tortuous fluid filled tubes: Bilateral mild hydrosalpinx.

MRI diagnosed an alternate cause in 15 patients including right adnexal ectopic gestational sac, hydrosalpinx, inflammatory caecal wall thickening and RLQ lymph nodal mass [Table/Fig-8-10].

DISCUSSION

This study shows, that MRI yields excellent results in patients suspected of acute appendicitis with inconclusive ultrasound. It markedly reduces negative appendicectomy rate without increase in the perforation rates. MRI appendix protocol has 100% sensitivity implying that acute appendicitis if present, MRI appendix protocol will help us in diagnosing it accurately. There was one false positive implying that MRI may over diagnose normal appendix with increased calibre or subacutely inflamed appendix. There was no false negative implying that in a patient with RLQ pain if a normal appendix is visualised on MRI and there are no RLQ inflammatory change then acute appendicitis can be ruled out. This helps in faster discharge of the patient from the hospital and significantly reduces negative appendectomy rate.

There were no MRI equivocal cases in the study cohort. DWI increases the conspicuity of inflamed appendix and shows restriction in appendicular abscess. It is a valuable addition in qualitative assessment of acute appendicitis.

There is no radiation exposure or iodinated contrast risks as compared to CT and hence must be used as an alternate to CT in patients with inconclusive ultrasound.

In a study done on pediatric age group patients, MRI was found to be a good imaging modality for the diagnosis of acute appendicitis with 100% sensitivity and specificity [15]. In another study performed on adult patients with suspected appendicitis, MRI changed the course of management in 40% of the patients with savings in the hospital resources [16]. MRI was found to be efficacious method of diagnosing lower abdominal pain in acute setting [17]. It not only accurately detects acute appendicitis, but diagnoses other lower abdominal or pelvic pathology which may present with RLQ pain. In a multicentric study to estimate the diagnostic accuracy of MRI in general population, it was concluded that MRI is an effective replacement of CT for diagnosing acute appendicitis in cases with suboptimal ultrasound [18]. Our study assesses the feasibility of implementing MRI appendix protocol in a tertiary care institution where there is easy access of MRI immediately after an inconclusive ultrasound for RLQ pain. Addition of DWI to the MRI appendix protocol helps in accurate identification of inflamed appendix based on restricted diffusion. As per our knowledge, this study is the first of its kind in India to assess a diverse group of paediatric and reproductive age group patients with ultrafast MRI appendix protocol after an inconclusive ultrasound and show that MRI is the best line of investigation to identify or rule out acute appendicitis with accuracy.

LIMITATION

MRI appendix protocol offers excellent diagnostic information in a patient with RLQ pain with the ultrasound being inconclusive. However, few of the limitations we identified in our study were as follows-Image degradation by motion artefacts, especially in paediatric age group as no sedation was given. Susceptibility artefacts may be seen due to interface between gas filled bowel and soft tissue causing difficulty in identification of the normal appendix. Paucity of RLQ fat resulted in non visualisation of appendix in one paediatric age group patient.

CONCLUSION

Based on this study, an ultrafast MRI appendix protocol in the evaluation of patients suspected of acute appendicitis with an inconclusive ultrasound is a safe, reliable and potentially cost effective technique, especially when used in paediatric and reproductive age group patients. Addition of DWI provides valuable additional information. This protocol can be implemented where the facilities are available to perform MRI without delay after an inconclusive ultrasound.

REFERENCES

[1] Humes DJ, Simpson J. Acute appendicitis. BMJ. 2006;333(7567):530-34.
[2] Bickell NA, Aufses AH, Rojas M, Bodian C. How time affects the risk of rupture in appendicitis. J Am Coll Surg. 2006;202(3):401-06.
[3] Nshuti R, Kruger D, Luvhengo TE. Clinical presentation of acute appendicitis in adults at the Chris Hani Baragwanath Academic Hospital. Int J Emerg Med. 2014;7(1):12.
[4] Ehrman RR, Favot MJ. Can abdominal ultrasonography be used to accurately diagnose acute appendicitis? Ann Emerg Med. 2017. pii: S0196-0644(17)30188-89.
[5] Ang A, Chong NK, Daneman A. Pediatric appendicitis in "real-time": The value of sonography in diagnosis and treatment. Pediatr Emerg Care. 2001;17(5):334-40.
[6] Abo A, Shannon M, Taylor G, Bachur R. The influence of body mass index on the accuracy of ultrasound and computed tomography in diagnosing appendicitis in children. Pediatr Emerg Care. 2011;27(8):731-36.
[7] Xiong B, Zhong B, Li Z, Zhou F, Hu R, Feng Z, et al. Diagnostic accuracy of noncontrast CT in detecting acute appendicitis: A meta-analysis of prospective studies. Am Surg. 2015;81(6):626-29.
[8] Corwin MT, Chang M, Fananapazir G, Seibert A, Lamba R. Accuracy and radiation dose reduction of a limited abdominopelvic CT in the diagnosis of acute appendicitis. Abdom Imaging. 2015;40(5):1177-82.
[9] Nikolaidis P, Hammond N, Marko J, Miller FH, Papanicolaou N, Yaghmai V. Incidence of visualization of the normal appendix on different MRI sequences. Emerg Radiol. 2006;12:223.
[10] Duke E, Kalb B, Arif-Tiwari H, Daye ZJ, Gilbertson-Dahdal D, Keim SM, et al. A systematic review and meta-Analysis of diagnostic performance of MRI for evaluation of acute appendicitis. Am J Roentgenol. 2016;206(3):508-17.
[11] Inci E, Kilickesmez O, Hocaoglu E, Aydin S, Bayramoglu S, Cimilli T. Utility of diffusion-weighted imaging in the diagnosis of acute appendicitis. Eur Radiol. 2011;21(4):768-75.

[12] Nitta N, Takahashi M, Furukawa A, Murata K, Mori M, Fukushima M. MR imaging of the normal appendix and acute appendicitis. J Magn Reson Imaging. 2005;21(2):156-65.
[13] Nikolaidis P, Hwang CM, Miller FH, Papanicolaou N. The nonvisualized appendix: incidence of acute appendicitis when secondary inflammatory changes are absent. AJR Am J Roentgenol. 2004;183(4):889-92.
[14] Herliczek TW, Swenson DW, Mayo-Smith WW. Utility of MRI after inconclusive ultrasound in pediatric patients with suspected appendicitis: retrospective review of 60 consecutive patients. Am J Roentgenol. 2013;200(5):969-73.
[15] Johnson AK, Filippi CG, Andrews T, Higgins T, Tam J, Keating D, et al. Ultrafast 3-T MRI in the evaluation of children with acute lower abdominal pain for the detection of appendicitis. Am J Roentgenol. 2012;198(6):1424-30.
[16] Heverhagen JT, Pfestroff K, Heverhagen AE, Klose KJ, Kessler K, Sitter H. Diagnostic accuracy of magnetic resonance imaging: A prospective evaluation of patients with suspected appendicitis (Diamond). J Magn Reson Imaging. 2012;35(3):617-23.
[17] Singh AK, Desai H, Novelline RA. Emergency MRI of acute pelvic pain: MR protocol with no oral contrast. Emerg Radiol. 2009;16(2):133-41.
[18] Leeuwenburgh MMN, Wiezer MJ, Wiarda BM, Bouma WH, Phoa SSKS, Stockmann HBAC, et al. Accuracy of MRI compared with ultrasound imaging and selective use of CT to discriminate simple from perforated appendicitis. Br J Surg. 2014;101(1):147-55.

AUTHOR(S):
1. Dr. Satish Prasad
2. Dr. Deepti H Vijayakumar

PARTICULARS OF CONTRIBUTORS:
1. Head and Associate Professor, Department of Radiodiagnosis, ESIC Medical College and PGIMSR, Bengaluru, Karnataka, India.
2. Senior Resident, Department of Radiodiagnosis, ESIC Medical College and PGIMSR, Bengaluru, Karnataka, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Deepti H Vijayakumar,
Senior Resident, Department of Radiodiagnosis,
ESIC Medical college and PGIMSR, Rajajinagar 3rd Block,
Bengaluru-560010, Karnataka, India.
E-mail: deeptihv@gmail.com

FINANCIAL OR OTHER COMPETING INTERESTS: None.

Date of Publishing: **Oct 01, 2017**