Ultrasonography and Computed Tomography in a Clinical Algorithm for the Evaluation of Suspected Acute Appendicitis in Children

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ABSTRACT

Aim: To evaluate the roles and effectiveness of US and CT in a clinical algorithm for the evaluation of children with suspected appendicitis.

Methods: Patients with suspected appendicitis were prospectively evaluated with ultrasound (US), and in some cases with CT, after they were graded to have high, intermediate or low clinical likelihood for appendicitis. Imaging findings were made known to clinicians who then decided on a line of management. Patho-histological examination and clinical follow-up established the final diagnoses, which were correlated with the imaging findings. The effect of imaging on the management of patients was examined.

Results: Overall, the sensitivity of US was 92.9%, specificity 96.9%, accuracy 96.0%, positive predictive value 89.7% and negative predictive value 97.9%. Imaging did not affect the decision to operate in 13/14 (92.9%) patients in the high likelihood subgroup. Imaging guided the clinicians to the right management pathway in 26/30 (86.7%) patients in the intermediate group. 77/82 (93.9%) of US was truly negative in the low likelihood group. CT was performed in 12 patients because of unsatisfactory US scans or incompatibility between the US and the clinical findings. CT correctly diagnosed the presence or absence of appendicitis in all 12 patients.

Conclusion: US and CT are accurate modalities in the diagnosis of acute appendicitis in children. US is most useful in patients with equivocal clinical findings. US should be the first modality used to evaluate children with suspected appendicitis. CT should be reserved for cases where US is sub-optimal or where the findings are inconsistent with the clinical findings.

Keywords: acute appendicitis, ultrasound, computed tomography, children

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INTRODUCTION

Acute appendicitis is the most common emergency condition requiring abdominal surgery in children[1]. The early diagnosis of acute appendicitis is critical but may at times be difficult. This is because of the variable presentation of the disease, the lack of definitive laboratory tests, and in young children, their inability to effectively communicate their complaints. Failure to diagnose acute appendicitis early may lead to perforation, abscess formation and peritonitis. Ultrasonography (US) has been shown to be an accurate modality in the diagnosis of acute appendicitis in children[2-5]. However, US is an operator-dependant modality and the evaluation of patients with large body habitus, markedly tender right iliac fossas or who are uncooperative, may be difficult. It can also be difficult to diagnose retrocaecal appendicitis on US[3]. Thus, in recent years, Computed Tomography (CT) has been playing an increasing role in the diagnosis of acute appendicitis, especially in adults[6]. CT has been shown to be more accurate than US in the diagnosis of acute appendicitis[7]. The role of CT in the evaluation of acute appendicitis in children has not been assessed. The objectives of this prospective study were to evaluate the roles and to determine the effectiveness of US and CT in a clinical algorithm for the evaluation of suspected appendicitis in children in our local population.

METHODS

From February 1998 to March 1999, 129 children with suspected acute appendicitis were prospectively evaluated with US. 13 cases had additional CT scans. Prior to the US examination, the paediatric surgical team graded the likelihood that the patient was suffering from acute appendicitis. The patients were graded as having high, intermediate or low probability of having acute appendicitis. The clinical grading was performed using findings in the clinical history, physical examination and laboratory tests when available. During the period of the study, US was available on a 24-hour basis. The US examination was performed by 4 radiologists, 2 of who were trained paediatric radiologists. US of the

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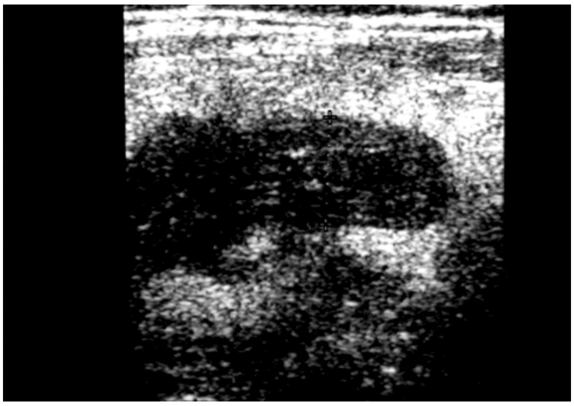

Fig. 1 Acute appendicitis. Longitudinal section of an inflamed appendix with a wall-to-wall measurement of 8 mm.

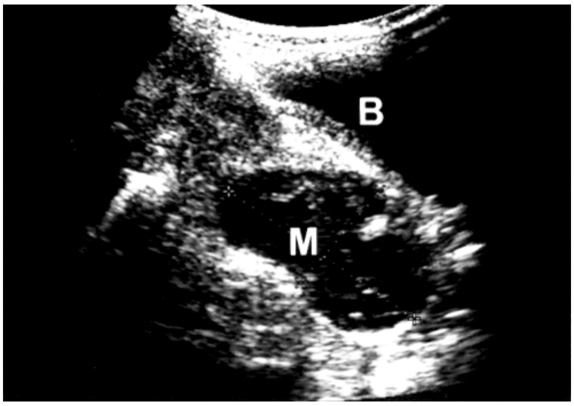

Fig. 2 Appendiceal abscess. Longitudinal sonogram of the pelvis demonstrating a complex mass (M), posterior to the bladder (B), secondary to a ruptured appendix.

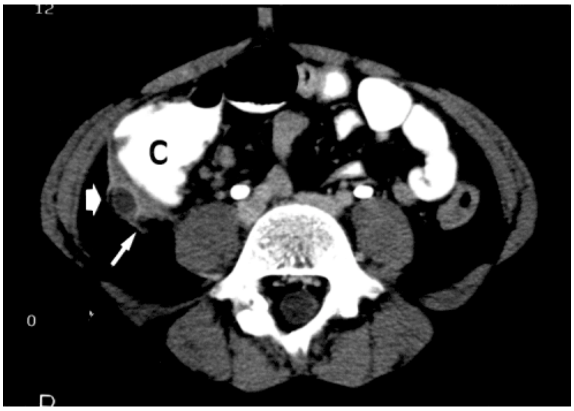

Fig. 3 Acute appendicitis. CT image demonstrating a swollen, retrocaecal appendicitix with a rim-enhancing wall (arrowhead). There is stranding of the peri-caecal fat (arrows). c = caecum.

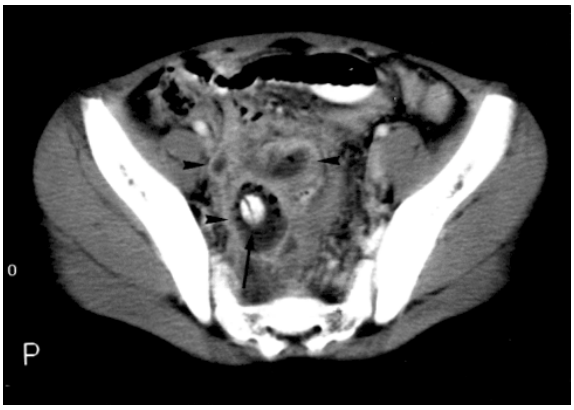

Fig. 4 Appendiceal abscesses. CT image demonstrating inter-loop abscesses (arrowheads) in the pelvis due to a ruptured appendix. An appendicolith can be seen in one of the abscesses (a).

right iliac fossa was performed using the graded compression technique described by Puylaert[8]. This technique displaces overlying bowel gas and fluid from the right iliac fossa and reduces the distance between the transducer and the appendix. A 5.0 to 10.0 MHz linear array transducer (Advanced Technology Laboratories, Bothell, WA) was used to perform the graded compression scan. The rest of the abdomen was scanned using a 4.0 to 7.0 MHz curved array transducer. US findings were recorded on a checklist at the end of the procedure. Criteria for the diagnosis of acute appendicitis was based on the detection of a swollen (>6mm wall-to-wall thickness) (Fig. 1), non-compressible appendix and/or the presence of an appendicolith. The presence of peri-caecal inflammation or the identification of a complex mass or abscess (Fig. 2), in the absence of a normal appendix were taken as strongly suggestive of, but not specific for a ruptured appendicitis. The US findings were made known to the surgeon. The decision to proceed to surgery, conservative treatment or further imaging with CT was made based on the discretion of the referring clinician. Further imaging with CT was performed in cases where the clinical picture was incompatible with the US findings or where the US was sub-optimal due to technical difficulties. These included patients with large body habitus or patients with markedly tender abdomens, which prevented satisfactory graded compression studies. The CT was performed within 24-hours of the US in all cases. The US and CT were independently interpreted by different staff radiologists. CT examinations were performed with a Picker PQ 5000 (Highland Heights, Ohio) scanner. Prior to the CT, patients greater than 12 years old received an oral dose of 250 mls of 2.2% barium sulphate (Medescan, Artarmon, Australia) 1 hour before the scan. A second dose of 250 mls was given 20 minutes before the scan. A third dose of 125 mls was given to the patient just prior to the scan. For patients less than 12 years old, 2 hall-strength doses were given orally at 1 hour and at 20 minutes before the scan. The amount of oral contrast given was equivalent to the average amount of feed the patient took during normal mealtimes. An intravenous bolus of Iohexol 240 mgI/ml (Omnipaque 240, Nycomed, Oslo, Norway) at a dose calculated to the patient's body weight (Body weight x 2.5 mls, up to 50mls) was administered by hand injection. Helical scanning of the upper abdomen and lower pelvis was then performed

Table I. Summary of results in each clinical group and the overall study population.

Clinical Groups	Number of Patients	Ultrasound Findings	Final Result	Comments
High likelihood	16	11 positive	11 appendicitis	
		2 NSAI*	1 terminal ileitis, 1 serosal inflammation	
		1 choledochal cyst	choledochal cyst	
		2 unsatisfactory exams	1 appendicitis, 1 negative	CT performed in both cases. Appendicitis diagnosed in 1 case; 1 true negative
Intermediate likelihood	30	8 positive	7 appendicitis, 1 negative	 False negative
		5 NSAI	5 ruptured appendix abscesses	1 CT-confirming positive US
		15 negative	15 negative	1 CT-confirming negative US
		1 intussusception	intussusception	
		1 soft tissue mass (see text)	1 gangrene of the appendices epiplocae	
Low likelihood	83	3 positive	3 appendicitis	
		76 negative	2 appendicitis 74 negative	Both retrocaecal appendicitis CT performed in 7 patients – all negative
		3 ovarian cysts	1 luteal cyst, 2 dermoid cysts	
		1 unsatisfactory exam	appendicitis	CT performed-retrocaecal appendiceal abscess confirmed at surgery
Overall	129	22 positive	21 appendicitis	1 false positive
		7 NSAI	5 appendicitis	2 false positive
		91 negative	89 true negative	2 false negative
		6 other pathology	As above	
		3 unsatisfactory	2 appendicitis	

**Non-specific abdominal inflammation*

at 8 x 8-mm collimation. A 10-13 cm interval of the right iliac fossa was scanned at 3 x 3-mm collimation. This interval was determined from the CT pilot radiograph and began at the lower level of the L3 vertebral body. Criteria for the diagnosis of acute appendicitis on CT was based on the detection of an enlarged (>6mm in outer diameter), non-opacified appendix with adjacent inflammatory changes (Fig. 3). Peri-caecal inflammatory changes or abscesses, without the visualisation of an appendix, were considered suggestive of, but not specific for acute appendicitis[7] (Fig. 4). The US and CT were interpreted as being (a) positive for appendicitis, (b) presence of non-specific intra-abdominal inflammation suggestive of, but not specific for ruptured appendicitis, (c) negative for acute appendicitis or (d) other diagnosis. Patho-histological examination and clinical follow-up established the final diagnoses, which were correlated with the imaging findings.

Unsatisfactory US studies due to technical limitations (e.g. patients with large body habitus or patients with markedly tender abdomens preventing adequate graded compression studies) were excluded from statistical analysis of the US results. Patients with other diagnoses detected on US, which accounted for the patients' symptoms, were considered as being truly negative for appendicitis. Scans that showed evidence of non-specific intra-abdominal inflammation, which were suggestive of, but not specific for ruptured appendicitis, were considered as being indicative of acute appendicitis.

RESULTS

There were 129 patients in the study (68 males, 61 females). The age range was 2 to 15 years (mean 8.8 years).

High clinical likelihood subgroup

There were 16 patients in this group (Table I). All patients in this group underwent surgery. 11 patients had true-positive ultrasound scans. At surgery all of these patients had inflamed appendices removed. There were 2 false-positive studies. These 2 patients had US evidence of intra-abdominal inflammation but no definite evidence of appendicitis. At surgery, one of these patients had terminal ileitis and the other had non-specific serosal inflammation. Both patients had normal appendices removed. Another patient had a large choledochal cyst identified on US. This was confirmed on CT and at surgery. 2 patients in this group had unsatisfactory US scans and these cases were excluded from statistical analysis of the US results. One patient had a large body habitus, and the other had a markedly

Table II. Statistical results for the 3 clinical subgroups, the overall study population and the CT subgroup.

Clinical Groups	Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV(1) (%)	NPV(2) (%)
High	100.0	33.0	85.7	84.6	100.0
Intermediate	100.0	94.4	96.7	92.3	100.0
Low	60.0	100.0	97.6	100.0	97.5
Overall	92.9	96.9	96.0	89.7	97.9
CT	100.0	100.0	100.0	100.0	100.0

(1) Positive predictive value *(2) Negative predictive value*

Table III. Table illustrating the reasons for CT, the CT findings and final results.

Reasons for CT	No.	CT Findings	Final Results
US negative but patient still symptomatic	8	All negative	All negative
US positive but patient improving clinically	1	Appendicitis	Appendicitis
Obese patient, sub-optimal US	1	Negative	Negative
Markedly tender right lower quadrant, sub-optimal US	2	Both appendicitis	Both appendicitis
Total	12	9 negative 3 positive	9 negative 3 positive

tender right iliac fossa. Adequate graded-compression scans could not be performed in both patients. CT scans were performed instead. In the patient with the large body habitus, the CT showed no evidence of appendicitis. The patient's clinical condition did not improve and surgery was performed. At operation, a normal appendix was removed. The CT scan in the other patient revealed an inflamed appendix, which was confirmed pathologically.

The statistical results of the 3 clinical subgroups, the entire study population and CT are summarised in Table II.

Low clinical likelihood subgroup

There were 83 patients in the low likelihood group (Table I). 77 patients had true negative scans; including 3 patients with large, torsed ovarian cysts (1 luteal, 2 dermoid cysts) which were removed surgically. 2 patients with true-negative US scans had worsening of symptoms and underwent surgery; both had normal appendices removed. The remaining 72 patients recovered on conservative treatment. 7 of these patients had CT scans because of persistent symptoms. The CT scans in these patients were also normal. US was falsely negative in 2 patients. In both patients, the clinical condition of the patients worsened after the US scans and at surgery, inflamed retrocaecal appendices were removed. There were 3 true-positive US studies. US was sub-optimal in 1 patient due to a markedly tender right iliac fossa. A satisfactory graded compression study could not be performed and a CT was performed instead. This revealed a retrocaecal peri-appendiceal abscess, which was confirmed at surgery.

Intermediate clinical likelihood subgroup

There were 30 patients in the intermediate likelihood group (Table I). There were 12 true-positive US scans. 5 of these patients had evidence of non-specific intra-abdominal inflammation but no definite evidence of appendicitis. One patient had a subsequent CT scan because her condition appeared to improve after the US. The CT confirmed the US findings of multiple inter-loop abscesses in the right lower quadrant and pelvis. Surgery confirmed the imaging findings. In the other 4 cases, ruptured appendiceal abscesses were found at surgery. There was 1 false-positive scan where the patient recovered on conservative treatment. 17 patients had true-negative US scans for appendicitis including 2 patients with alternative diagnoses detected on the US. One patient had an ileo-colic intussusception in the ascending colon, which was reduced with an air enema procedure. Another patient had a soft tissue mass measuring one centimetre in diameter, situated just beneath the anterior abdominal wall of the right lower quadrant. At surgery a gangrenous piece of appendices epiplocae fat was removed. The appendix was also removed and was normal. Of the remaining 15 patients with negative US, 12 recovered on conservative treatment. 3 patients underwent surgery and had normal appendices removed. One of these patients had a CT scan because of persistent symptoms incompatible with the negative US findings. Both the US and CT showed no evidence of appendicitis; several small lymph nodes were identified in the right lower quadrant compatible with mesenteric adenitis. The patient continued to be symptomatic and at surgery a normal appendix was removed. Several small right lower quadrant lymph nodes were found confirming the US and CT findings. The appendix was normal.

Overall Result

The results of the entire study population are summarized in Tables I and II. The overall US sensitivity was 92.9%, specificity 96.9%, accuracy 96.0%, positive predictive value 89.7% and negative predictive value 97.9%.

CT scan results

In the entire study population, CT scans were performed in 13 patients (Table III). The patient with the choledochal cyst had a CT scan but is excluded from statistical analysis.

The reasons for the CT scans are summarised in Table III. Overall, there were 9 true-negative studies, 3 true-positive and no false-negative nor positive studies. The sensitivity, specificity, accuracy, positive predictive value and negative predictive values were all 100.0%. The sample size of patients in this group was small and further study is needed to obtain a better picture of its accuracy.

DISCUSSION

Acute appendicitis is the most common surgical emergency in children[1]. It may often be difficult to diagnose clinically for reasons already described above. Early diagnosis is important in order to prevent the complications of perforation, sepsis and death. Accurate diagnosis and treatment will also decrease the length of hospitalisation for observation and hence medical costs. It can also decrease the negative laparotomy rate, which has been as high as 20% in some studies[9]. Imaging modalities such as US and CT can help in early and accurate diagnosis of acute appendicitis. In our study population, US was technically successful in 97.7% of cases. Unsatisfactory scans were encountered in only 3 patients, one had a large body habitus and the other 2 had markedly tender right lower quadrants. It is interesting that 2 of these 3 patients had acute appendicitis. All 3 patients had CT scans; CT provided the correct diagnosis in these 3 patients. Therefore, in patients with large body habitus or severely tender abdomens, further imaging with CT should be considered if the US is unsatisfactory or non-diagnostic.

Our study showed that US is able to accurately diagnose or exclude acute appendicitis in most cases (Table II). This is consistent with the results in other studies[2-4]. An objective of this study was to determine a clinical algorithm incorporating clinical assessment, US and CT, resulting in a more targeted imaging strategy. The aim of this algorithm would be to maximise health care resources and save on health care costs without compromising on the quality of health care provided to our patients. We divided our patients into 3 clinical subgroups on the basis of how likely they were to suffer from appendicitis. We then analysed the results of imaging these patients with US, and in some cases, with CT, to determine how imaging would have changed the management of these patients. The accuracy of US and CT in each of these subgroups and in the overall population were also calculated.

Our results showed that US had a limited role to play in patients with a high likelihood of acute appendicitis. Of the 16 patients in this group, 13 patients had pathologically-proven acute appendicitis consistent with the high clinical suspicion. In the 2 false-positive cases, the clinical findings were severe enough to warrant surgery even though no specific evidence of appendicitis was detected. US therefore did not affect the decision to operate in these patients. The only case which benefited from an US in this group was the patient with the choledochal cyst; emergency surgery was not needed and the patient was first treated with a course of intravenous antibiotics. The subsequent midline surgical incision was also different from that of a simple appendicectomy incision.

The use of US in the low likelihood group is debatable and depends on the resources available in the individual institution. There is a case for arguing against the use of US in this group because of the high proportion of true-negative results 77/82 (93.9%). However, the clinical findings of appendicitis in children are often not classical and may be difficult to diagnose. In our study, there were 6 cases of appendicitis and 3 ovarian lesions in this group. In an institution such as ours, where US is inexpensive, quick to perform, accurate and readily available on a 24-hour basis, a negative US gives our clinicians greater confidence in excluding appendicitis and in treating these patients conservatively. US also has the added benefit of detecting pathology other than appendicitis which mimic appendicitis clinically. The use of US in this group thus depends on the availability of resources in an individual institution.

US was most beneficial in the subgroup with equivocal clinical findings where it played a significant role in the management of patients. A positive scan in this group correctly guided the clinicians towards surgery in 12/13 (92.3%) cases. Similarly, a negative scan correctly predicted the absence of appendicitis in all 17 cases with negative US findings. Only 3 patients underwent negative laparotomies. It was in this group of patients with equivocal clinical signs, that US was most useful.

Overall, our study showed that US is an accurate modality in diagnosing acute appendicitis. However, there are pitfalls in the use of US and these are highlighted in the 3 false-positive and 2 false-negative cases. 2 of the false positive patients had non-specific US findings of intra-abdominal inflammation but no definite evidence of appendicitis. However, a perforated appendicitis could not be excluded. At surgery, 1 patient had terminal ileitis and the other had serosal inflammation. The diagnosis of ruptured appendicitis on US is difficult because a ruptured appendix decompresses and is no longer visualised. Instead, only non-specific findings of increased serosal echogenicity and occasionally fluid collections representing inflammatory purulent fluid and abscesses may be identified. The diagnosis of acute appendicitis is therefore more difficult and the sensitivity and specificity drops to 86% and 60% respectively[10]. In our study population, there were 7 patients with non-specific US findings of intra-abdominal inflammation and all underwent surgery. Besides the 2 false positive studies, there were 5 ruptured appendices. Further imaging with CT could have been helpful in providing more accurate diagnosis in this group, but this should not delay surgery if clinically warranted. Another pitfall of US is highlighted in our remaining false positive study. A review of the images showed that the structure identified as the inflamed appendix was probably the terminal ileum. This known pitfall in the diagnosis of appendicitis on US[2] illustrates the operator-dependency of US. With further training and experience, the false-positive rate should decrease. The 2 false-negative cases in our study turned out to have retrocaecal appendicitis. Diagnosing retrocaecal appendicitis may be difficult especially if the overlying ascending colon and bowel are filled with gas[2]. Adequate graded compression should be performed but this may sometimes be difficult if the patient has a markedly tender right iliac fossa. These pitfalls highlight the fact that although US is accurate in diagnosing acute appendicitis in children, the findings must always be correlated with the clinical picture as false positive and negative results may still occur.

The advent of CT in recent years has improved the diagnosis of acute appendicitis in adults by overcoming the difficulties of US. In a comparison study between US and CT, it was shown that CT was more accurate than US in diagnosing acute appendicitis in adults[7]. In our small number of cases, CT was able to accurately exclude or diagnose appendicitis in all 12 cases (Table III). Despite the improved accuracy of CT over US, CT is not the first line investigation of right lower quadrant pain in children in our institution. This is because US has no ionizing radiation, is quick to perform, accurate and less expensive than CT. We have reserved the use of CT in cases which are difficult to US, or in cases which the clinician has felt that the US findings are inconsistent with the clinical findings and further imaging is required. CT should not delay surgery unnecessarily.

In conclusion, the evaluation of patients with suspected appendicitis remains a clinical one. However, greater confidence in the diagnosis can be made with the help of imaging modalities in a well-defined clinical algorithm. Our study has shown that US and CT are accurate modalities for diagnosing acute appendicitis in children. Other illnesses, which mimic appendicitis, can also be diagnosed. US is most useful in patients who have equivocal clinical features of appendicitis as it is able to correctly guide clinicians onto the right management pathway in most cases. Its use in patients with high and low clinical likelihood for appendicitis is limited, as it does not alter the clinical management in most cases. Its role in the latter group also depends on the resources available in the institution.

If US is readily available and can be expertly performed, a negative result will give clinicians greater confidence in treating their patients conservatively. CT is reserved for patients who are difficult to US or whose clinical signs are inconsistent with the US findings. However, CT should not delay surgery if this is clinically warranted. This clinical algorithm, combining clinical evaluation and the selective use of imaging, maximises the use of imaging resources and is an accurate method of evaluating children with suspected appendicitis.

REFERENCES

1. Janik JS, Firor HV. Paediatric appendicitis: A twenty-year study of 1640 children at Cook County Hospital. Arch Surg 1979; 114:717-9.
2. Wong ML, Casey SO, Leonidas JC, Elkowitz SS, Becker J. Sonographic diagnosis of acute appendicitis in children. J Paediatr Surg 1994; 29(10):1356-60.
3. Hahn HB, Hoepner FU, Kalle TV, MacDonald EBM, Prantl F, Spitzer IM, et al. Sonography of acute appendicitis in children: 7 years experience. Pediatr Radiol 1998; 28:147-51.
4. Vignault F, Filiatrault D, Brandt ML, et al. Acute appendicitis in children: Evaluation with US. Radiology 1990; 176:501-4.
5. Sivit CJ, Newman KD, Boenning DA, Nussman-Blask AR, Bulas DI, Bond SJ, et al. Appendicitis: Usefulness of US in diagnosis in a Pediatric population. Pediatr Radiol 1992; 185:549-52.
6. McColl. More precision in diagnosing appendicitis. Editorial. N Eng J Med 1998; 338:190-1.
7. Balthazar EJ, Birnbaum BA, Yee J, Megibow AJ, Roshkow J, Gray C. Acute Appendicitis: CT and US correlation in 100 patients. Radiology 1994; 190:31-5.
8. Puylaert J. Ultrasound of appendicitis and its differential diagnosis. New York, NY, Springer-Verlag, 1990.
9. Rao PM, Rhea JT, Novelline RA, et al. Effect of computed tomography of the appendix on treatment of patients and the use of hospital resources. N Eng J Med 1998; 338:141-6.
10. Rao PM, Rhea JT, Rattner DW, et al. Introduction of appendiceal CT: impact on negative appendectomy and appendiceal perforation rates. Ann Surg 1999; 229(3):344-9.