International Journal of Science and Research (IJSR)
ISSN: 2319-7064
Impact Factor 2024: 7.101

Comparison of Diagnostic Accuracy of Ultrasonography and Sonoelastography in Detection of Acute Appendicitis in Relation with Operative Findings

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Abstract: ***Acute appendicitis is a common emergency condition requiring surgery, often diagnosed based on clinical symptoms. However, some cases present atypically, making imaging techniques crucial for accurate diagnosis. This study compared the diagnostic accuracy of ultrasound (US) and elastography (ES) in detecting acute appendicitis by correlating imaging findings with surgical outcomes. A total of 170 patients with suspected appendicitis underwent both US and ES before surgery. The results showed that ES had higher sensitivity and specificity than US alone, particularly in cases with subtle inflammation or tip appendicitis. ES effectively assessed the stiffness of the appendix, helping to distinguish between normal and inflamed tissue. The study concluded that combining ES with US improves diagnostic accuracy, reduces unnecessary surgeries, and aids in determining the severity of appendicitis, making it a valuable tool for clinical decision-making. Objective: The objective of the present study was to compare diagnostic accuracy of USG and ES in detection of acute appendicitis in correlation with operative findings. Materials and methods: A total of 170 patients who fulfilled the selection were enrolled in the study.***

Keywords: acute appendicitis, ultrasound, elastography, diagnostic accuracy, inflammation

1. Introduction

Acute appendicitis is one of the most common diagnoses that requires surgery, for patients who present to the emergency department with acute non traumatic abdominal pain. Acute appendicitis occurs when the appendiceal lumen is obstructed, leading to fluid accumulation, luminal distension, inflammation and finally perforation. Although the diagnosis is often based on clinical characteristics, many patients have atypical presentations and multiple diagnosis that may not require surgery, may mimic the symptoms of appendicitis. Thus, early and accurate diagnosis plays an essential role in preventing the progression of the disease i.e. peritonitis, perforation and minimizing negative appendicectomies. Ultrasound and CT are effective imaging modalities, although certain limitations to both techniques are apparent. The major disadvantages of CT include use of ionizing radiation and potential allergic reactions. Ultrasound can be limited by variation in the technical skills of sonographer, patient habitus and at times inaccessible position of the appendix.

Elastography is a new emerging imaging tool that can be combined with ultrasound and it noninvasively assess the elastic properties of tissue. In view of this background, we aimed to compare diagnostic accuracy of USG and ES in detection of acute appendicitis in correlation with operative findings.

2. Materials & Methods

Study design

This is a hospital based validational type of study conducted between May 2014 and March 2015.

Patient Selection and Inclusion criteria

The study included patients referred from department of surgery with acute right iliac fossa pain having a provisional diagnosis of acute appendicitis, willing to undergo sonography and elastography and have given informed written consent.

Exclusion criteria consisted of obese, uncooperative or unstable patients and those who have undergone ultrasound and elastography but haven't undergone surgery (excluded from final analysis)

Instruments and image analysis

A total of 170 patients who fulfilled the selection criteria were enrolled in the study.

After briefing them about nature, purpose of study and obtaining their written informed consent. All patients were subjected to sonography and elastography. Then depending upon the final diagnosis patient underwent surgery. The findings were confirmed and compared by surgical findings.

Ultrasound was performed on GE Logiq P9 using 4MHz convex and 7MHz linear transducer.

Grey scale US was performed using graded compression technique with the patient in the supine position. A routine US examination of the upper abdomen and pelvis was performed followed by a focussed examination of the right lower quadrant using graded compression technique with a 7MHz linear transducer. The radiologist recorded US features consisting of an incompressible, blind ended aperistaltic tubular structure originating from the base of cecum which is >6 mm in diameter with hyperemic walls, hyperechoic periappendiceal fat, peritoneal fluid and appendicolith.

This was followed by real time ES with gentle compression to look for increased stiffness of the appendix. Colour coded scale includes red and green colors for softer tissue and blue colour for stiff harder areas.

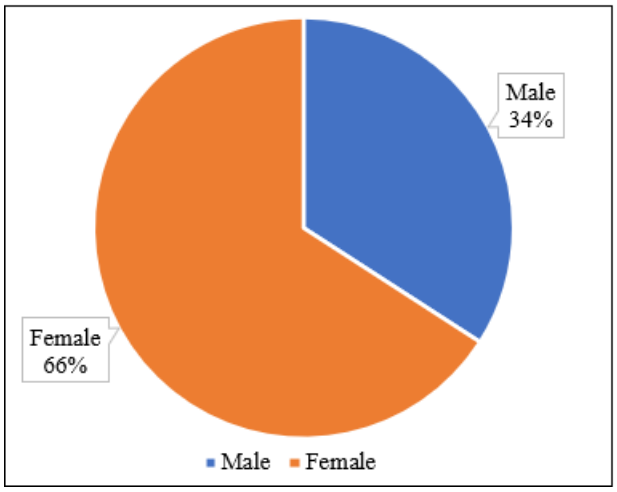
To measure strain ratio, we compare the strain in two regions of interest (ROIs): a reference ROI (zone 2) placed in the surrounding normal tissue and target ROI (zone 1) placed in the focal lesion, preferably at the same depth. Strain ratio (SR) is measured as the average strain in the reference area divided by average strain in the lesion. The higher the SR, the higher the likelihood of severity is. A normal appendix was <6 mm in diameter and ovoid with no area of increased stiffness in its wall, whereas an inflamed appendix was a round structure with areas of increased stiffness shown as blue on the strain map in the appendiceal wall. Periappendiceal inflammation was shown as areas of blue/increased stiffness around the appendix and was graded as mild, moderate, or severe depending on the distance of involvement of the abnormal stiffness from the outer wall of the appendix. All patients with a positive diagnosis underwent surgery, and the ES findings were confirmed by surgical findings. The size of the appendix, inflammation/ hyperemia in the wall, the presence of appendicoliths, periappendiceal inflammation/ adhesions, the status of the omentum and mesoappendix, and regional fluid were noted on surgery. These findings were then correlated with the findings seen on ES.

3. Statistical Analysis

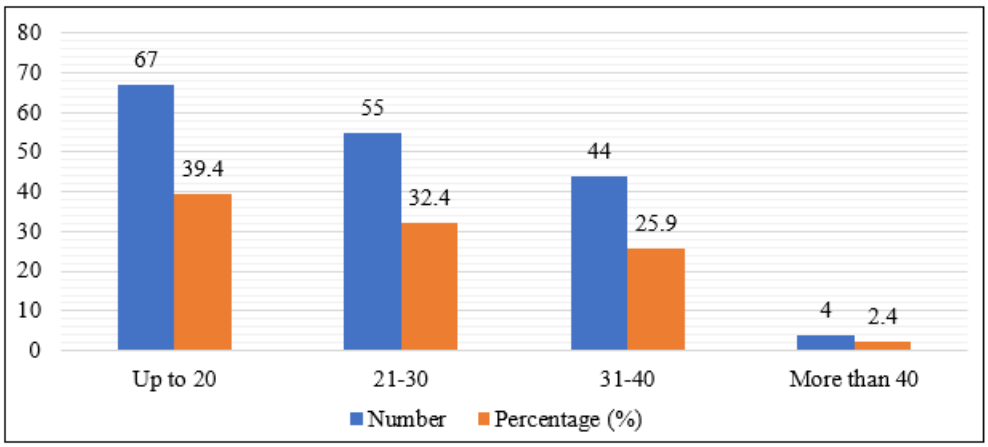
The data obtained was coded and entered into Microsoft Excel Worksheet (Annexure III) and has been subjected for statistical analysis. Sensitivity, specificity, PPV and NPV were calculated for US and ES.

4. Results

The cross-sectional study was carried on 170 patients who met the selection criteria with a mean age of 22.6+ 10.6(SD) years. Of these 112 were men and 58 were women. The male to female ratio was 2:1.

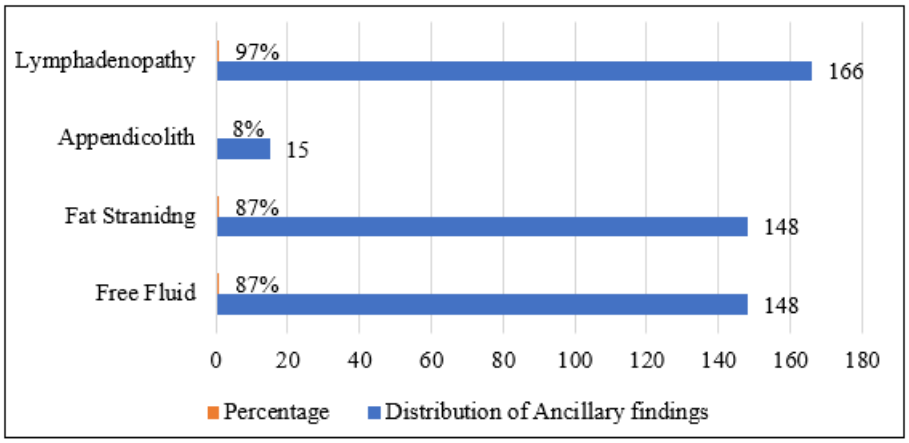


Graph 1: Sex Distribution



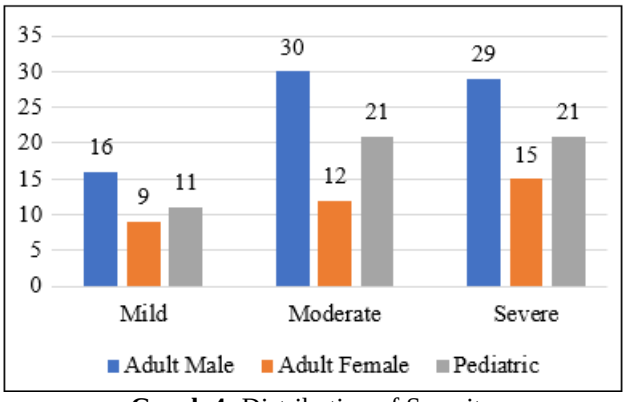
Graph 2: Age (In Years)

Lymphadenopathy was present in most of the patients (97.6%). Other findings observed were presence of free fluid and echogenic fat stranding, which were seen in 87%. In very few patients (8%) finding of appendicolith was observed.



Graph 3: Distribution of Ancillary findings

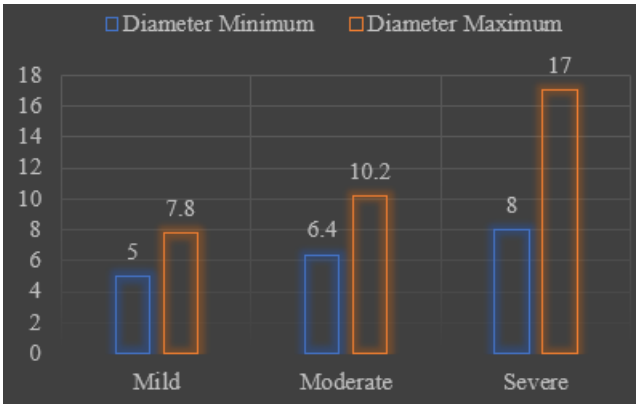
In our study, majority of the patients presented with severe appendicitis 39% followed by moderate severity (38 %). Only 21 % patients were diagnosed with mild appendicitis. Among adult male majority of patients suffered from moderate severity (n=30) followed by severe appendicitis (n=29). Maximum of adult female patients were having severe appendicitis (n=15) followed by moderate severity (n=12). Whereas in paediatric group number of patients with moderate and severe was equal. 11 children were having mild appendicitis.



Graph 4: Distribution of Severity

In the present study, diameter >6mm was noted in 94% (n=160) of the patients out of which appendicitis was found in 96% (n=154) and 4% (n=6) were negative at elastography. 4.7% (n=8) patients were presented with an appendix of diameter <6mm but were positive at elastography and histopathology.

Diameter of appendix increased with severity of appendicitis increased ranging in between 8 to 17, maximum of 17mm in severe and 5 to 7.8 mm in mild appendicitis.



Graph 5: Diameter of Appendix Range

In the present study, strain ratio was calculated to assess the stiffness which also increased as the severity increased. Strain ratio was < 1 in mild appendicitis among which maximum was 0.74. Strain ratio extended between 1.2 to maximum value of 2.5 in moderate appendicitis. And it was > 3 in severe appendicitis where maximum value of 27.4 was noted.

Correlation of elastography and surgical findings is seen in table no 2

Table 1: Sensitivity and specificity of sonography

USG diagnosis	HPR (Operative)		Total
	Positive	Negative	
Positive	156	6	162
	96.3%	3.7%	100.0%
Negative	8	0	8%
	100%	0.0%	100.0%
Total	164	6	170
	96.5%	3.5%	100.0%

Table 2: Sensitivity and specificity of elastography

USG diagnosis	HPR (Operative)		Total
	Positive	Negative	
Positive	164	0	164
	100 %	0.0 %	100.0%
Negative	0	6	6%
	0.0 %	100.0%	100.0%
Total	164	6	170
	96.5%	3.5%	100.0%

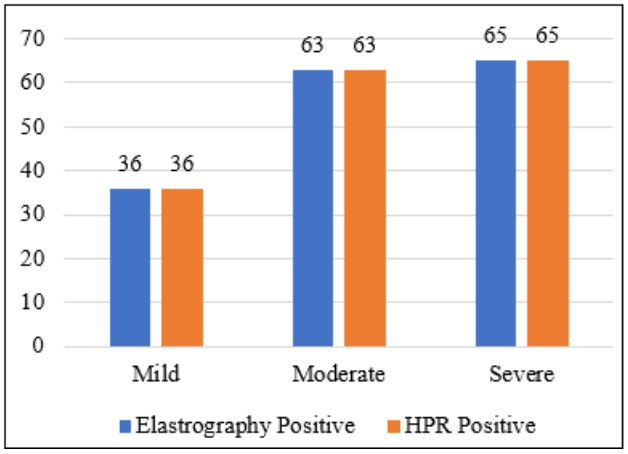
Table 3: Comparison between sonography and elastography

	Sonography	Elastography
Sensitivity	98.70%	100%

Specificity	100%	100%
NPV	75%	100%
PPV	100%	100%
Accuracy	98.80%	100%
+likelihood ratio	9999	9999
-likelihood ratio	0.01	0

Table 4: Correlation of elastography and surgical findings

			Severity			Total
			Mild	Moderate	Severe	
Elastography	Positive	0	36	63	65	164
		0.0%	22%	38.4%	39.6%	100%
	Negative	6	0	0	0	6
		100%	0.0%	0.0%	0.0%	100%
HPR	Positive	0	36	63	65	164
		0.0%	22.0%	38.4%	39.6%	100%
	Negative	6	0	0	0	6
		100%	0.0%	0.0%	0.0%1	100%



Graph 6: Correlation of elastography and Surgical Findings

5. Discussion

Suspected acute appendicitis is one of the most common diagnostic dilemmas encountered in clinical practice. This essentially requires a comprehensive clinical history coupled with a complementary imaging tool which plays an important adjunctive role in confirming the diagnosis when the clinical presentation is inconclusive.

The age distribution analysis showed a wide range with the youngest patient 4 years of age and the eldest of 45 years of age. The maximum numbers of patients were up to 20 years of age while the second largest group of patients belonged to the age group between 21-30 yrs with a median age of 23.5years. The age distribution in our study is similar to the results of previously carried out studies by Addiss et al [2] who estimated that approximately 250,000 cases of appendicitis occur annually in a population of about 300 million and the highest incidence of appendicitis was found in those aged 10-19 years with males having higher rates of appendicitis than females for all age groups. The lifetime risk of appendicitis is 8.6% for males and 6.7% for females.

In the present study, diameter>6mm was noted in 94% (n=160) of the patients out of which 96% (n=154) were positive and 4% (n=6) were negative at ES and HPE. This finding correlated with a study done by Park et al (2007) which has shown that fecal impaction of the appendix increases the MOD, frequently leading to a misdiagnosis of acute appendicitis.

We found that 4.7% (n=8) patients presented with RIF pain but on ultrasound diameter of appendix was <6mm but were positive at elastography and histopathology. This discrepancy was because of the fact that in such cases only the tip of the appendix was inflamed, therefore missed on ultrasound.

The findings in our study are in agreement to the study conducted by Cemil goya et al (2014) in which US revealed no evidence of appendicitis in the remaining 12 patients. However, histopathological analysis demonstrated the presence of appendicitis in eight patients. Among patients with false-negative US three patients had tip appendicitis and five patients had inflammation of the appendix with a diameter <6 mm. Among patients with true-negative US, two patients had lymphadenitis and two patients had colitis. US showed 83.3% sensitivity, 80% specificity, 97.6% PPV, and 33.3% NPV in the diagnosis of acute appendicitis.
Similarly, these findings were in accordance of the study conducted by Benjaminov O et al (2002) and Giuliano et al (2005) where it has been stated that US is ineffective in the diagnosis of appendicitis when the diameter of the appendix is <6 mm, corresponding to 15% of appendicitis cases. Technological advances permit the visualization of the appendix in 88% of healthy subjects; however, differentiation between healthy and inflamed tissue is difficult when the diameter is <6 mm.

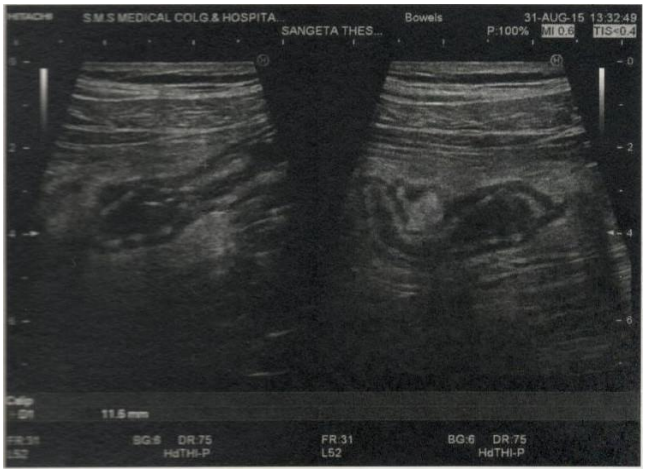
In our study elastography showed 100% sensitivity and 100% specificity with positive likelihood ratio of 9999. In the present study, stain histogram and strain ratio were utilized in combination to measure appendix wall stiffness both qualitatively and semi quantitatively. These modalities were highly advantageous for the differentiation between healthy and inflamed tissue, in cases involving normal appendix with distended diameter (n=6) or tip appendicitis (n=8).

Increases in the size and severity of inflammation are presumed to progressively increase strain ratio. Disease stratification according to strain map findings was significantly correlated with surgical findings. Elastography enable rapid and accurate diagnosis of appendicitis in cases with reduced inflammation, such as nondistended and tip appendicitis. Overall, diagnostic sensitivity is remarkably improved with the combined use of US imaging.

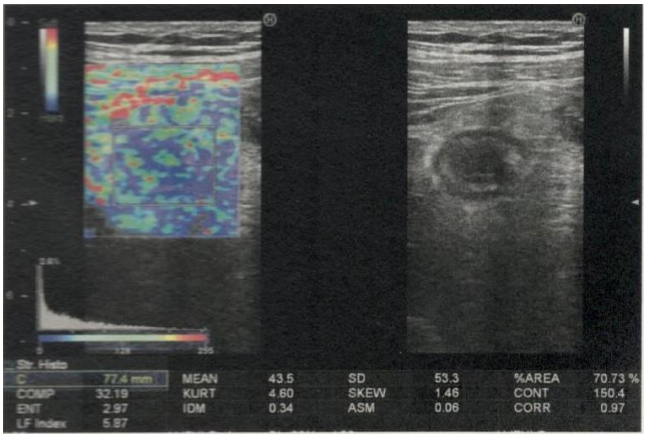
6. Conclusion

Combined application of US and ES increase sensitivity while maintaining comparable specificity in the diagnosis of acute appendicitis, relative to US alone. Furthermore, ES imaging is an effective means for determining the severity of acute inflammation of the appendix with obvious utility in guiding the clinical management.

Case 1

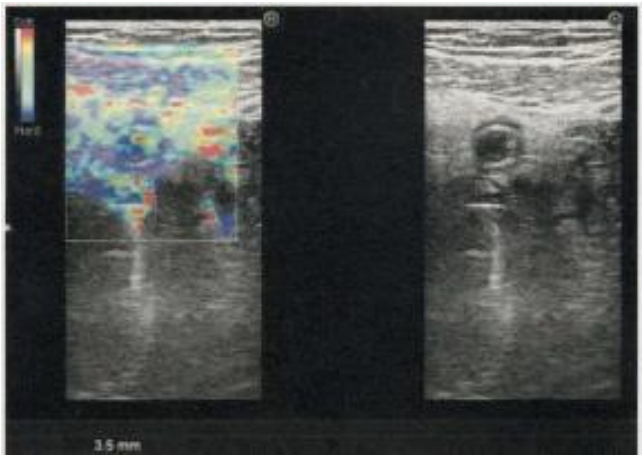


1a) Enlarged non compressible appendix with an outer diameter of 11.6 mm

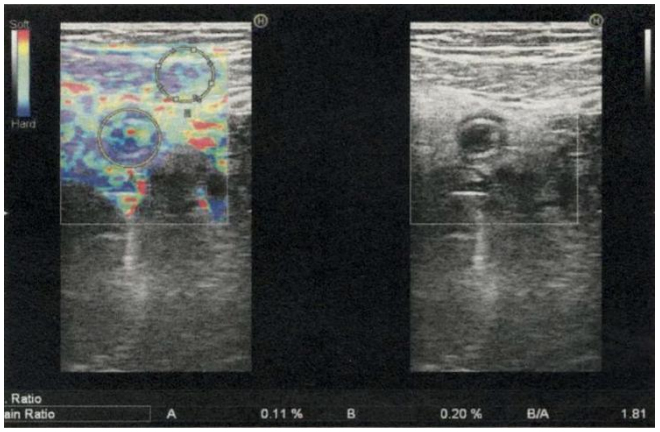


1 b) Sonogram (Left) and elastogram (Right) showing a distended thickened appendix and periappendicular inflammation in blue.

Case 2



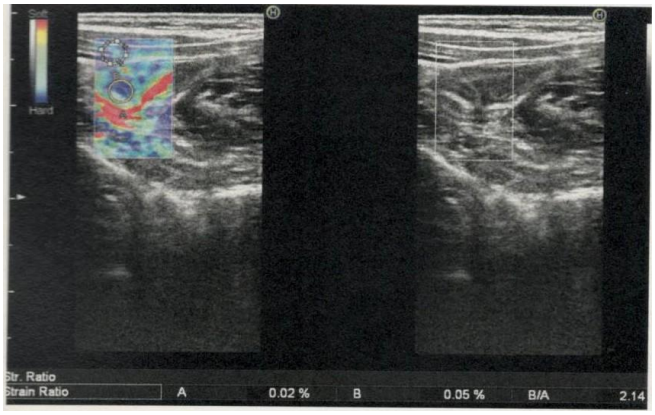
2 (b) Moderate inflammation shown as blue extending for <2 cm



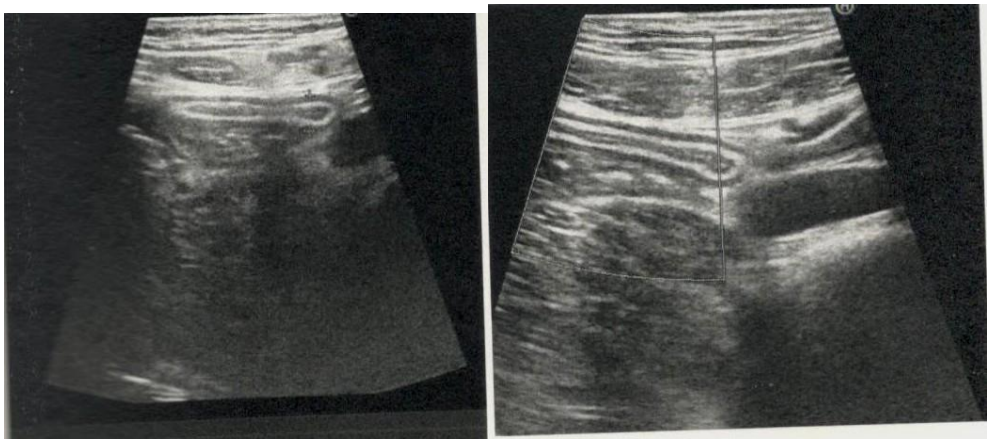
2 (c) sonogram and corresponding elastograms show moderate inflammation with strain ratio 1.8

3 (a) increased vascularity in the wall

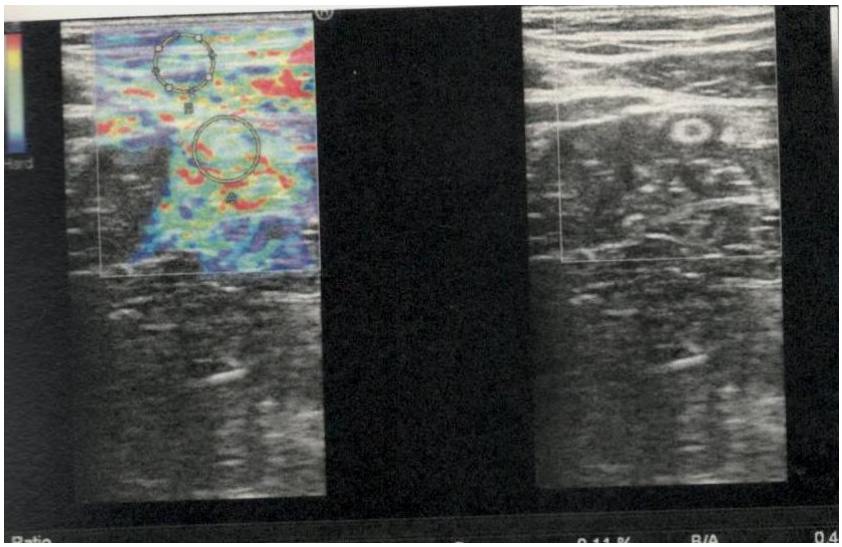
3 (b) enlarged non-compressible appendix with diameter of 8.2 mm



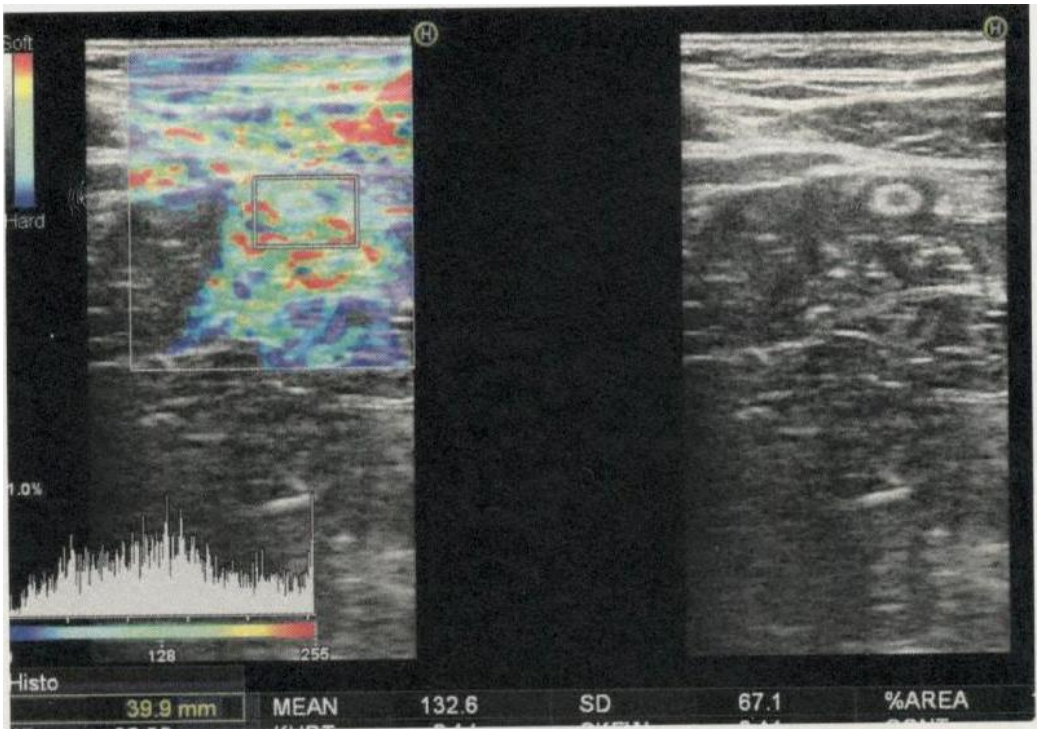
3 (c) sonogram and corresponding elastrograms showing moderate inflammation as blue color



4 (a), 4 (b) sonography shows a non-inflamed distended appendix diameter of 6.7 mm



4 (c) Elastrogram showing low strain ratio



4 (d) Elastogram showing green color in wall and surrounding suggestive of noninflamed appendix