Open Journal of Surgery

Research Article

Interobserver Variability in Ultrasound Scan Interpretation for Suspected Acute Appendicitis: a Cross-Sectional Cohort Study

Bamidele Johnson Alegbeleye*

Department of Surgery, St Elizabeth Catholic General Hospital, Shisong, P.O Box 8, Kumbo-Nso, Bui Division, Northwestern Region, Cameroon

***Address for Correspondence:** Bamidele Johnson Alegbeleye, Department of Surgery, St Elizabeth Catholic General Hospital, Shisong, P.O Box 8, Kumbo- Nso, Bui Division, Northwestern Region, Cameroon, Tel: +237-670-628-857; ORCID ID: 0000-0001-7440-1032;
E-mail: drbalegbeleye@gmail.com

Submitted: 06 April 2019; **Approved:** 08 May 2019; **Published:** 10 May 2019

Cite this article: Alegbeleye BJ. Interobserver Variability in Ultrasound Scan Interpretation for Suspected Acute Appendicitis: a Cross-Sectional Cohort Study. Open J Surg. 2019;3(1): 001-009.

ABSTRACT

Background: There is a global resolve among Clinicians towards adoption of imaging modalities in the evaluation of appendicitis because clinical algorithms have been disappointing. We sought to determine the authenticity of interobserver variability in ultrasound scan interpretation in a resource-constrained mission hospital settings, northwestern region of Cameroon.

Methods: In this study, we reviewed the standardized diagnostic approach in acute appendicitis and also performed prospective cross observational qualitative testing using sensitivity, specificity, positive predictive value, negative predictive value, and accuracy to determine the interobserver variability of ultrasonography using the medical database of the two Mission Hospitals, northwestern region of Cameroon from January 2012 to December 2016. A sequential non-randomized convenient sampling was used and data was analyzed using the Statistical Package for the Social Sciences version 22.

Results: A total of 103 patients who had pre-operative evaluation with Ultrasound scan and subsequently underwent surgery with histo-pathological examination of the removed appendix were analyzed. Their ages ranged from 15 to 65 years with a mean age of 30.6 ± 18. There were 62 males and 41 females with a ratio of 1.5:1. Of the 103 patients, (n = 90; 87.4%) cases were diagnosed as AA by histopathology while (n = 9; 8.7%) cases were negative. Ultrasound was positive in (n = 75; 72.8%) cases, equivocal in (n = 16; 15.5%), and negative in (n = 10; 10.4%) cases. Sensitivity of ultrasound from this study when compared with ultrasound as the gold standard was 90.2% with a specificity of 85.6%; while Overall accuracy was 72.4%. The calculated kappa scores for inter-observer variability among radiologists were 0.13 to 0.28. Age and gender had no significant relationship with the accuracy of ultrasound in this study (*p* value = 0.2 and 0.7 respectively).

Conclusion: Ultrasound scan is more useful in detecting than in ruling out appendicitis. The radiological criteria for acute appendicitis, the accuracy of various imaging modalities and the limitations of the available research are described in this series. The interobserver variability in the ultrasonography interpretation of appendicitis is of significant impact in resource- limited surgical emergency settings like ours, which is a rural tropical population in the developing country.

Keywords: Appendicitis; Computed tomography; Inter-observer variability; Ultrasonography; Resource- limited settings

ABBREVIATIONS

AA: Acute Appendicitis; NPV: Negative Predictive Value; PPV: Positive Predictive Value; SPSS: Statistical Package for the Social Sciences; STROBE: The Strengthening The Reporting of Observational Studies in Epidemiology Statement: Guidelines For Reporting Observational Studies; STROCSS: The Strengthening the Reporting of Cohort Studies in Surgery

BACKGROUND

Appendicitis is a common and important clinical problem that afflicts 8.6% of male and 6.7% of female Americans. There are 250,000 to 300,000 appendectomies, including 60,000 to 80,000 involving children, and more than one million patient-days of hospitalization for appendicitis, each year in the United States [1-3]. There have been reports of increasing incidence of appendicitis in African countries by some authors in the last few decades [4-6]. Changing to a Western lifestyle, including diets have been held responsible for this [7]. It is generally reported to be more common in males [5,8,9] and usually occurs in the age range of 10 to 30 years [5,8,9]; although Mangete from Port-Harcourt in Nigeria found a significantly higher incidence in females [9]. Higher incidences have been reported in the summer months by many authors [4]. Ashley has reported an excess during spring, implicating a high prevalence of viral infections among others during these months [10], but Sanda et al [11], have suggested intense challenge to the mucosa-associated lymphoid tissue from allergens in the dust, during the sandstorms of the spring months, in the Arabian Peninsula. There are problems with the current methods of diagnosis, which are based mainly on the clinical history, physical examination and simple laboratory tests. The classic presentation includes vague mid-abdominal pain, anorexia and nausea, followed by localized Right Lower Quadrant (RLQ) abdominal pain and guarding, and leukocytosis. Up to 45% of cases, however, have atypical symptoms and/or signs [12]. The clinical diagnosis of acute appendicitis is accurate only 70% to 80% of the time [13,14]. Delays in diagnosis often lead to perforation [7], which occurs in 8% to 39% of cases [2,6,8,9]. To prevent perforation, the surgeon may adopt liberal criteria for surgery, which results in negative appendectomy rates of 15% to 22% [6]. Unnecessary surgery causes pain and inconvenience for patients; wastes precious health care resources and can lead to serious complications [9,14]. Appendicitis is especially difficult to diagnose, and the consequences of error are greater in children, pregnant women and elderly patients [10-14]. These difficulties are due to physiological factors, variations in clinical presentation and, in some cases, problems with communication. Most surveys have found an inverse relationship between rates of perforation and rates of negative appendectomy [15-19]. Therefore, attempts to reduce the rate of unnecessary surgery often lead to unacceptable perforation rates, while a reduction in the latter is generally achieved at the expense of diagnostic accuracy [20-22]. For example, Law et al. [18] reviewed 216 patients with a preoperative diagnosis of appendicitis, and reported a high rate of diagnostic accuracy (89%), together with a high perforation rate (29%).

In contrast, Andersen et al. [19] reviewed 454 patients and reported a much lower perforation rate (8%) at the expense of a lower accuracy rate (67%). This dilemma has been addressed in four ways: This include: (1) Adoption of standardized diagnostic criteria; (2) Observation in hospital of patients with equivocal clinical presentations; (3) Application of diagnostic tests, including radiological imaging; and (4) Use of diagnostic laparoscopy. Several strategies have been employed to improve the accuracy of the diagnosis of appendicitis and to reduce the associated perforation rate [20-22]. Plain abdominal x-rays are nonspecific, barium enema examination has relatively low accuracy, scintigraphy scans require considerable time and are difficult to interpret, and magnetic resonance imaging is relatively unstudied [20-22]. The most promising modalities are graded compression sonography and computed tomography. In expert hands, these techniques can achieve a high degree of accuracy. Nevertheless, most published studies have been marred by methodological difficulties [20-22].

In this study, we reviewed the standardized diagnostic approach in AA and also performed prospective cross observational qualitative testing using Sensitivity, Specificity, Positive Predictive Value (PPV),

Negative Predictive Value (NPV), Accuracy and Kappa score to determine the Interobserver variability in the ultrasonographic interpretation in our resource- limited mission hospital.

METHODS

Study design and setting

In this study, we reviewed the standardized diagnostic approach in acute appendicitis and also performed prospective cross observational qualitative testing using sensitivity, specificity, PPV, NPV, accuracy and kappa score to determine the interobserver variability of ultrasonography using the medical database of the two Mission Hospitals, northwestern region of Cameroon from January 2012 to December 2016. Hospital A is a 200-bed Mission Hospital (with 50 surgical beds), while Hospital B is a 250-bed Mission Hospital (with 70 surgical beds). Both Mission Hospitals serve as the main referral centers covering a population in excess of 8 million and a land area with a radius of over 80 km. Also as Medical and Nursing training centers, the hospitals have modeled themselves to attain excellence in standards and its pathology department has no equal in the entire northern half of Cameroon.

Study population and procedure

A sequential non-randomized convenient sampling was used to prospectively select the study population which consist of operative and laboratory paper-based registers by searching for the keywords appendix and appendectomy. The studied population included patients with age 15 years and above who had appendectomy, with preoperative ultrasound examination and histo-pathological report of the removed appendix. The exclusion criteria were the following:

i. Patients who did not have pre-operative ultrasound scan

ii. Patients with any other causes of peritonitis such as ruptured appendix, traumatic perforations, tuberculosis enteric perforations, etc., were excluded from the study.

iii. All patients with suspected acute appendicitis for whom a laparotomy and histopathological assessment was not performed.

Further information was retrieved from patient records, specifically from the surgeon's operation notes and the histopathology report for all operations undertaken at the Hospitals during this study period covering a period of five years. Information retrieved for each case include the name of the patient, medical record number, age, gender, month of admission, place of domicile, preoperative diagnosis, hospitals where operation was done, the date of the operation, the operative findings including incidental findings and whether or not appendectomy was done as a primary or secondary operation as well as intra-operative diagnosis as recorded in the surgeons operative notes and the histo-pathology report. All the slides of appendectomy cases were retrieved and reviewed. Where slides are missing, fresh sections were taken from tissue cassettes. A positive diagnosis of appendicitis is considered where histologic diagnosis is confirmed whether or not the operative findings concur. A negative histologic diagnosis is taken as normal appendix regardless of the findings in the surgeon's operative notes. The data were compiled in tabular form and remarks were made to explain peculiarities of individual data. Three staff individually took turns to cross check the data for completeness, accuracy and consistency. Pathologically confirmed specimens of appendicitis were analyzed against demographic data of the patients.

Indications for surgery

According to the general concession by surgeons globally for a liberal attitude to exploration with an accompanying high rate of negative results (up to 50% in women); this has been accepted generally in the hope of preventing perforation of any suspected inflamed appendix [23]. In this respect, perforating and non-perforating appendicitis seemed to be different entities, and spontaneously resolving appendicitis was common [23]. The readiness to explore influences the detection of resolving appendicitis and may explain variations in incidence of appendicitis and perforation rate. Perforation rate is irrelevant as a tool for measuring the quality of management in suspected appendicitis [23].

Statistical analysis

All data were entered in an excel database (Excel 2007, Microsoft corporation®) and analyzed using the Statistical Package for the Social Sciences (SPSS) version 22 where applicable. Calculations include sensitivity, specificity, positive PPV, NPV, Accuracy and Kappa score to determine the interobserver variability of ultrasonography in the study.

Ethical considerations

Ethical approval was obtained from the Caritas Foundation Healthcare Ethical Review Committee. Approval No: DTAD/10 /482/ 140/ 2019. Confidentiality was ensured by not writing the names of patients on proforma in accordance the Helsinki declaration.

Reporting

The STROBE/ STROCSS guidelines were used in reporting this study [24,25].

RESULTS

A total of 103 patients who had pre-operative evaluation with ultrasound scan and subsequently underwent surgery with histo-pathological examination of the removed appendix were analyzed. Their ages ranged from 15 to 65 years with a mean age of 30.6 ± 18. There were 62 males and 41 females with a ratio of 1.5:1. Of the 103 patients, (n = 90; 87.4%) cases were diagnosed as AA by histopathology while (n = 9; 8.7%) cases were negative. Ultrasound was positive in (n = 75; 72.8%) cases, equivocal in (n = 16; 15.5%), and negative in (n = 10; 10.4%) cases.

Of the 75 with positive ultrasound findings, 68 correlated with histopathology while of the sixteen patients who had equivocal ultrasound findings, 12 had histopathological diagnosis of AA with only four being negative. There were ten patients whose ultrasound was either reported as normal (10 cases), or misdiagnosed as ovarian cyst (2 cases). When compared with the histopathology report, only two of the patients were truly negative while the remaining eight had histo-pathological diagnosis of AA. Sensitivity of ultrasound from this study when compared with ultrasound as the gold standard was 90.2% with a specificity of 85.6%; while Overall accuracy was 72.4%. Age and gender had no significant relationship with the accuracy of ultrasound in this study (p value = 0.2 and 0.7 respectively). The calculated kappa scores for inter-observer variability among radiologists were 0.13 to 0.28.

DISCUSSION

Alvarado scoring system

Of the many standardized scoring systems for the diagnosis of acute appendicitis, the Alvarado criteria [26], which generate the

MANTRELS score (Table 1), appear to be the most effective [26]. A score of more than seven points has a relatively high sensitivity (88% to 90%), but the specificity is generally no better than 80%, and is especially low in women [26-28]. Modifications have included removing the leukocyte count criteria or reducing the threshold to five points, but these modifications further impair the specificity of the system, particularly in pediatric patients [27-30]. While these and other criteria may assist junior staff and nonsurgical personnel in identifying patients with appendicitis, they are not likely to be helpful for experienced surgeons who possess astute clinical judgment.

The normal-appearing appendix can be left in situ, thus reducing the rate of negative appendectomy [31-33]. Appendectomy can be carried out safely and quickly with this technique [34-36]. Some authorities recommend that the appendix be removed in all cases, however, because a normal macroscopic appearance does not exclude the presence of histological appendicitis with certainty [37-39]. Moreover, it has been suggested that recurrent pain can arise from appendices that have neurochemical or immunological abnormalities even in the absence of overt inflammation [40,41]. A substantial proportion of patients report a history of recurrent episodes of pain before appendectomy (recurrent appendicitis) or of prolonged pain, which may or may not be accompanied by histological evidence of fibrosis or of chronic inflammation (chronic appendicitis) [42-44].

Ultrasonography and appendicitis

Pre-operative evaluation: In a related study by Alegbeleye BJ in 2019 entitled "Ultrasound Scan in the Evaluation of AA in the Tropics" [45]. A retrospective cross-sectional study which assessed the accuracy of preoperative ultrasound scans in the evaluation of patients with suspected AA. One hundred-and-three adult patients with suspected AA who underwent preoperative ultrasound scan of the abdomen and subsequently appendectomy; had the histopathology reports compared with their operative findings [45]. Seventy-five patients of the study population had ultrasound diagnosis of AA, 68 of which correlated well with histopathology. There were 16 patients with equivocal ultrasound findings while ten patients had normal scans and two patients had a misdiagnosis of ovarian cyst. Of the ten, eight had histopathological features of AA [45]. The sensitivity of ultrasound in the study was 90.2% while specificity was 85.6%. The conclusion of the findings from the Alegbeleye B.J study, showed that ultrasound scan in patients with suspected AA provides a high sensitivity and specificity in the diagnosis and therefore a formidable tool for diagnosing AA in low resource center [45].

Diagnostic accuracy of ultrasound scan in appendicitis: The usefulness of ultrasonography in the diagnosis of appendicitis has been known since the early 1980s. It is safe (including during pregnancy) and relatively inexpensive, and can be performed quickly and repeatedly, using portable equipment [46]. The patient can indicate the point of maximal tenderness, to which the transducer can be applied. This can facilitate the diagnosis when the appendix is in an atypical location [46]. Children, because of the relative paucity of intra-abdominal fat and young women, who are susceptible to gynecological disorders, are especially good candidates for sonography. Sonography has, however, several limitations. Some of the limitations are nonspecific: obesity, intestinal gas, patient cooperation, quality of equipment, and the skill and experience of the technician [46]. Other limitations are particularly relevant to AA (Table 2). Some of these limitations have been circumvented by using graded compression, a technique by which the transducer is applied with gradually increasing pressure to the area of McBurney's point. Continuous, steadily increasing pressure from the transducer, unlike intermittent application of the device, is tolerated relatively well by patients with AA [46]. Gas artifacts are reduced, because the transducer either compresses or displaces uninflamed loops of bowel. Specifically, compression can expel intraluminal contents from the normal appendix, but not if it is distended and thickened due to inflammation. This technique also brings the transducer closer to the area of the appendix, which allows the use of high-frequency transducers with short focal ranges (such as 5.0 or 7.5 MHz linear-array transducers) [46]. Obesity is still a major problem for sonography. Because it is difficult to approximate the transducer to the appendix, low-frequency transducers (which have long focal ranges but poor resolution) must be used, and it is difficult to apply sufficient pressure to compress the bowel adequately. Furthermore, cases of retrocecal appendicitis can easily be overlooked because of the inability to see through the cecum. Special techniques, such as oblique imaging from a laterally placed transducer [47], may be required in such cases. Pelvic (transvaginal) sonography is also helpful in distinguishing appendicitis from gynecological disorders, especially if transabdominal approaches are inconclusive [48,49]. Disease is confined to the tip of the appendix (distal appendicitis) in 5% to 8% of cases, and can be missed if the entire length of the appendix is not visualized [50-52]. In most normal appendices, ultrasonography can demonstrate an echogenic layer (arising from the submucosa) surrounded by a hypoechoic layer (the muscularis propria) [50]. In some cases, additional luminal, epithelial, subepithelial and serosal structures can be identified and give rise to a 'target' appearance. The definition of these layers especially that of the echogenic submucosal layer, is lost with transmural extension of edema, inflammatory infiltrate and necrosis [50-53]. The normal appendix resembles the terminal ileum sonographically, except that the former generally lacks peristalsis, has a blind end, is less than 6 mm in diameter, is round instead of oval in cross-section, and does not change in configuration with time [48]. The key sonographic finding of acute appendicitis is a dilated and non-compressible

Table 1: Alvarado Scoring System Data [22].

Clinical or laboratory feature	Points
Migration of pain from the mid-abdomen to right lower quadrant	1
Anorexia or acetonuria (a surrogate marker of food avoidance)	1
Nausea and vomiting	1
Tenderness in the right lower quadrant	2
Rebound tenderness	1
Elevated temperature (≥ 38°C)	1
Leukocytosis (> 10,400 cells/ mm3)	2
Shifted white blood cell count (> 75% neutrophils)	1
Total possible points 10	10
C° = Degree Celsius; MM^3 = Cubic millimeters.	

Table 2: Limitations of sonography in the diagnosis of acute appendicitis

1.	Dilation of loops of bowel in the right lower quadrant can obscure the inflamed appendix
2.	The inflamed appendix can be difficult to distinguish from the terminal ileum
3.	The patient may not tolerate application of the transducer to the painful area
4.	The transducer may not have enough spatial resolution to visualize such a small structure as the early inflamed appendix

appendix with a thickened wall. An appendicolith, which can be identified by its acoustic shadow, is found in up to 29% to 36% of cases [50]. The loss of the submucosal echogenic layer, as well as the presence of hyperechoic periappendiceal fat and of a loculated pericecal fluid collection, are said to be indicative of perforation [54-56]. The inflamed appendix is less likely than the normal appendix to contain luminal air [57]. Mesenteric lymphadenopathy is sometimes apparent but can be confused with mesenteric adenitis in children [55, 58-64]. Most authorities have stated that the normal appendix can be visualized by ultrasonography less than 5% of the time [58-60]; therefore, it is easier to establish the diagnosis of appendicitis than to exclude it. There has been considerable discussion about appendiceal diameter, the most widely used diagnostic criterion. Most authorities use a threshold of 6 or 7 mm for appendicitis [46,50,56,58-62], and dilation is often quite obvious [63]. A dilated appendix is not, however, a specific sign of appendicitis [64], because the healthy appendix can dilate in the presence of metabolic disturbances or inflammatory processes elsewhere in the abdomen or pelvis. An appendiceal wall diameter of 3 mm or greater may be more predictive, but effacement of the wall of a much dilated appendix may occur just before rupture [50,51,63]. Moreover, a dilated non-compressible appendix is much less frequently seen after perforation [65,66], probably because of collapse or even disintegration. For this reason, sonography is actually less able to detect perforated than non-perforated AA, although the recent use of more refined techniques has partially overcome this problem [58,66]. Table 2 is a summary of some limitations of ultrasonography use in the diagnosis of acute appendicitis. Many investigators have studied the diagnostic accuracy of ultrasonography for patients suspected of having appendicitis. Some of the largest and best designed of the prospective studies are summarized in table 3. In most cases, graded compression technique was used, but the use of pelvic ultrasonography was usually not discussed specifically. Diagnostic accuracy seems to be similar in women and men [53,67,68], although most investigators have not reported their results separately according to sex. It is also accurate in pregnant women [62]. Comparable performance characteristics are observed with adult and pediatric patients (Table 3), but it is less sensitive in patients with a body mass index of 25 or greater than in lean patients [62,69]. Some investigators have stated that ultrasonography is more accurate than clinical assessment in diagnosing acute appendicitis [70-71], while others have found that it offers no advantage [65,72]. It has been suggested that the use of ultrasonography would reduce the negative appendectomy rate to 7% or even lower, but the perforation rate is not decreased [65,66,70,73-76]. Many studies may have been biased in favour of sonography. The radiological tests were performed after the initial clinical assessment with which they were compared, and thus after the illness had progressed. Not all patients underwent surgery, and it was not always clear that the ultrasound results did not influence the decision to operate. These factors introduce possible verification bias. The interactive nature of sonography could also have introduced additional biases, in that patients with localized pain and tenderness (i.e., those with a high pretest probability of a surgical condition) would be more likely to have a definitive ultrasonography result than those without localizing symptoms or signs [77,78]. Ultrasonography was generally performed and interpreted by experts in the field, whereas clinical assessments were often performed by junior surgeons, surgical residents or others using clinical scoring systems [70,72,76,79].

Interobserver variability

In this series, the calculated kappa scores for inter-observer variability among radiologists were 0.13 to 0.28 which was comparable to other study where the kappa scores for intra and inter observer variability among radiologists were only 0.39 to 0.42 and 0.15 to 0.20, respectively [80]. This reinforces the common assertions that sonography is highly dependent on technical expertise and the nature of the equipment, however, and it is unlikely to perform as well in non-specialized centers as in research centers [47,81-84]. A shortcoming that is common to all of these investigations is the failure either to apply strict histological criteria for the diagnosis of appendicitis or

Table 3: Prospective studies of sonography in the diagnosis of acute appendicitis.

Author, year (reference)	n	Acute Appendicitis (%)	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Puylaert et al, 1987 (58)	60	47	89	100	89	91	95
Abu-Yousef et al, 1987 (54)	68	37	80	95	91	89	90
Jeffrey et al, 1988 (53)	250	36	90	96	93	94	94
Schwerk et al, 1990 (105)	857	23	90	98	94	97	96
Davies et al, 1991 (86)	152	27	96	94	96	94	95
Rioux, 1992 (102)	170	26	93	94	86	98	94
Sivit et al, 1992 (106)*	180	29	88	82	90	79	86
Chen et al, 1998 (103)	191	75	99	68	90	97	92
Schulte et al, 1998 (104)*	1285	9	92	98	90	98	98
Sivit et al, 2000 (100)*	315	26	78	93	79	92	89
Douglas et al, 2000 (73)	129	46	95	89	88	95	91
Poortman et al, 2003 (5)	199	70	76	79	90	64	78
Peixoto et al, 2011 (99)	156	55	65	72	92	28	70
Subash et al, (98)	125	70	95	89	98	80	82
Alegbeleye, 2018 **	103	75	90	86	76	73	72

*Studies comprised exclusively pediatric patients (other studies comprised mainly adults).
NPV- Negative predictive value; **PPV**- Positive predictive value
** (Study comprised exclusively of adult patients in this PhD Thesis)

to estimate the interobserver variability for pathologists or for the radiologists. Variability in the histological criteria can affect the sensitivity and specificity of the tests [85]. Moreover, entry criteria are often vague, and patients with a wide range of pretest likelihood of having acute appendicitis may be included. Most surgeons urgently operate on patients with typical clinical findings of appendicitis, and do not appreciate the delay caused by obtaining a sonogram [48,49]. It appears that a substantial minority (8% to 26%) of patients with clinically typical appendicitis have false-negative ultrasonography scans [75,86-89]. Sonography may be more useful in equivocal cases. Orr et al. [90] undertook a meta-analysis of 17 studies (including 3358 patients) published between 1986 and 1995, and categorized patients according to their likelihood of appendicitis-high, intermediate and low (with disease prevalence of 80%, 40% and 2%, respectively). They found that, in the high-risk group, the positive predictive value of ultrasonography was 97.6% but the negative predictive value was only 59.5%; in the low risk group, on the other hand, the negative predictive value was 99.7% but the positive predictive value was only 19.5%. They concluded that sonography was most useful for patients with intermediate clinical risk of appendicitis. Other investigators have found that ultrasonography is cost effective only for patients with equivocal clinical findings [91-93]. Another fundamental weakness of most ultrasonography studies is the failure to address inconclusive test results adequately. Sometimes, the failure to visualize the appendix is regarded as evidence against the diagnosis of appendicitis [65]; however, this assumption may not be valid. In other studies, inconclusive results (such as an appendix of 5 to 7 cm in diameter) lead to further radiological investigation (e.g., CT scanning or Doppler ultrasonography). It would be preferable if investigators acknowledged the proportion of indeterminate tests.

Another problem occurs when the sonogram suggests the presence of appendicitis (i.e., a dilated, non-compressible appendix), but the patient's illness resolves spontaneously [52,66,94,95]. Are these cases of self-limited AA, or do they represent false-positive ultrasonography results? Such patients generally are not subjected to immediate surgery, although some have further episodes of pain and ultimately undergo appendectomy. It has been suggested that the risk of eventual recurrence is higher in patients with previous episodes of typical pain and in those with appendicolithiasis [94-97]. When surgery is not performed in patients who have undergone radiological investigation, it is crucial for the investigator to ensure sufficient follow-up to detect cases of recurrent or chronic appendicitis. Studies vary in the extent to which this has been done; and Table 3 is a classical illustration of the various prospective studies of sonography in the diagnosis of acute appendicitis and their outcomes in terms of sensitivity, specificity, PPV, NPV, and accuracy as a determinant of the interobserver variability in the interpretation and reporting of ultrasonographic findings in patients with suspected AA (5,58,59,73,86,97-106). The kappa score further reinforced our findings that two sonologists produce a statistically significant variability in the interpreted reports. Even if symptoms do not recur, the failure to operate on all patients with positive (or negative) scans interferes with the ability to determine the true sensitivity and specificity of the imaging modality. This radiological picture above is often not the case in reality (in most clinical settings) with management of AA. A few of the patients were managed basically non-operatively with antibiotics. Others eventually had different diagnoses for which they were invariably managed; for instance, torsion of the right ovarian cyst, right tubal ectopic gestation either ruptured or concealed.

CONCLUSION

Ultrasound scan is more useful in detecting than in ruling out appendicitis. The radiological criteria for acute appendicitis, the accuracy of various imaging modalities and the limitations of the available research are described in this series. Even in well establish centers worldwide, there are obviously differences in interpretation of ultrasonographic findings amongst radiologists or sonologists also termed interobserver variability. However, this interobserver variability in the ultrasonography interpretation of appendicitis is of significant impact in resource- limited surgical emergency settings like ours, which is a rural tropical population in the developing country.

DECLARATIONS

Acknowledgements: Many thanks to Professor Charles Adisa for supervising the Doctorate Thesis entitled: "Acute Appendicitis in A Tropical African Population" and also profound gratitude to my Teachers at Bircham International University.

Funding: No record of funding for this Clinical Research Study declared.

Availability of Data and Materials: All data generated or analyzed during this study are included in this published article and can also be accessed via http://dx.doi.org/ 10.6084/m9.figshare.7940726

Disclosures: This clinical research is an extract from the Author's Doctorate Dissertation.

Authors' Contributions: The author conceived of the study and participated in its design and coordination as well as helped to draft the manuscript; the author also read and approved the final manuscript.

Ethics Approval and Consent to Participate: Ethical approval was obtained from the Caritas Foundation Healthcare Ethical Review Committee. Approval No: DTAD/10/482/140/2019. Confidentiality was ensured by not writing the names of patients on proforma in accordance with the Helsinki declaration. A copy of the written Approval is available for review by the Editor-in-Chief of this journal.

Consent for Publication: Written informed consent was obtained from the patient for publication of this clinical research study and any accompanying images. A copy of the written consent is available for review by the Editor-in-Chief of this journal. Trial Registration also with Pan African Clinical Trial Registry unique identification number for the registry is PACTR201903475913135.

REFERENCES

1. Addiss DG, Shaffer N, Fowler BS, Tauxe RV. The epidemiology of appendicitis and appendectomy in the United States. Am J Epidemiol. 1990; 132: 910-925. https://bit.ly/2H2lSX3

2. Körner H, Söndenaa K, Söreide JA, Andersen E, Nysted A, Lende TH, et al. Incidence of acute nonperforated and perforated appendicitis: age-specific and sex-specific analysis. World J Surg. 1997; 21: 313-317. https://bit.ly/2LpNwml

3. Lund DP, Murphy EU. Management of perforated appendicitis in children: a decade of aggressive treatment. J Pediatr Surg. 1994; 29: 1130-1134. https://bit.ly/2ViM7CI

4. Al Omran M, Mandani M, McLeod RS. Epidemiologic features of acute appendicitis in Ontario, Canada. Can J Surg. 2003; 46: 263-268. https://bit.ly/2vIvi4C

5. Poortman P, Lohle PN, Schoemaker CM, Oostvogel HJ, Teepen HJ, Zwinderman KA, et al. Comparison of CT and sonography in the diagnosis of acute appendicitis: a blinded prospective study. AAJR Am J Roentgenol. 2003; 181: 1355-1359. https://bit.ly/2J7T5Uz

6. Osman AA. Epidemiological study of appendicitis in Khartoum. Int Surg. 1974; 59: 218-223. https://bit.ly/2J7tP0G

7. Burkitt DP, Walker AR, Painter NS. Effect of dietary fiber on stools and transit-times, and its role in the causation of disease. Lancet. 1972; 30: 1408-1412. https://bit.ly/2PNOck3

8. Freud E, Pilpel D, Mares AJ. Acute appendicitis in childhood in the Negev region: some epidemiological observations over an 11-year period (1973-1983). J Pediatr Gastroenterol Nutr. 1988; 7: 680-684. https://bit.ly/2JoQBAy

9. Luckmann R, Davis P. The epidemiology of acute appendicitis in California: Racial, gender, and seasonal variation. Epidemiology. 1991; 2: 323-330. https://bit.ly/2VNW7TQ

10. Ashley DJ. Observations on the epidemiology of appendicitis. Gut. 1967; 8: 533-538. https://bit.ly/2J35uJv

11. Sanda RB, Zalloum M, El-Hossary M, Al-Rashid F, Ahmed O, Awad A, et al. Seasonal variation of appendicitis in northern Saudi Arabia. Ann Saudi Med. 2008; 28: 140-141. https://bit.ly/2WsXZhW

12. Poole GV. Appendicitis. The diagnostic challenge continues. Am Surg. 1988; 54: 609-612. https://bit.ly/2HbTO4Z

13. Lewis FR, Holcroft JW, Boey J, Dunphy E. Appendicitis: a critical review of diagnosis and treatment in 1000 cases. Arch Surg. 1975; 110: 677-684. https://bit.ly/2VLWRZH

14. Silberman VA. Appendectomy in a large metropolitan hospital: retrospective analysis of 1,013 cases. Am J Surg. 1981; 142:615-618. https://bit.ly/2vFBbQi

15. Temple CL, Huchcroft SA, Temple WJ. The natural history of appendicitis in adults: a prospective study. Ann Surg. 1995; 221: 278-281. https://bit.ly/301Elq1

16. Von Titte SN, McCabe CJ, Ottinger LW. Delayed appendectomy for appendicitis: causes and consequences. Am J Emerg Med. 1996; 14: 620-622. https://bit.ly/2JpedET

17. Andersson RE, Hugander A, Thulin AJ. Diagnostic accuracy and perforation rate in appendicitis: association with age and sex of the patient and with appendicectomy rate. Eur J Surg. 1992; 158: 37-41. https://bit.ly/2VjrPJl

18. Law D, Law R, Eiseman B. The continuing challenge of acute and perforated appendicitis. Am J Surg. 1976; 131: 533-535. https://bit.ly/2JnQcy0

19. Andersen M, Lilja T, Lundell L, Thulin A. Clinical and laboratory findings in patients subjected to laparotomy for suspected acute appendicitis. Acta Chir Scand. 1980; 146:55-63. https://bit.ly/2J7Z2kn

20. Jess P, Bjerregaard B, Byrnitz S, Holst-Christensen J, Kalaja E, Lund-Kristensen J. Acute appendicitis: prospective trial concerning diagnostic accuracy and complications. Am J Surg. 1981; 141: 232-234. https://bit.ly/2vJ3Dkg

21. Velanovich V, Satava R. Balancing the normal appendectomy rate with the perforated appendicitis rate: implications for quality assurance. Am Surg. 1992; 58: 264-269. https://bit.ly/2LrzY9M

22. Alvarado A. A practical score for the early diagnosis of acute appendicitis. Ann Emerg Med. 1986; 15: 557-564. https://bit.ly/2JnIgwM

23. Andersson R, Hugander A, Thulin A, Nystrom PO, Olaison G. Indications for operation in suspected appendicitis and Incidence of perforation. BMJ. 1994; 308:107-110. https://bit.ly/2WsY0ST

24. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP; STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. J Clin Epidemiol. 2008; 61: 344-349. https://bit.ly/2H6aBGD

25. Agha RA, Borrelli MR, Vella-Baldacchino M, Thavayogan R and Orgill DP; STROCSS Group. The STROCSS Statement: strengthening the reporting of cohort studies in surgery. Int J Surg. 2017; 46: 198-202. https://bit.ly/2V9Yvjb

26. Ohmann C, Yang Q, Franke C. Diagnostic scores for acute appendicitis. Abdominal Pain Study Group. Eur J Surg. 1995; 161: 273-281. https://bit.ly/2H6tpVZ

27. Bond GR, Tully SB, Chan LS, Bradley RL. Use of the MANTRELS score in childhood appendicitis: a prospective study of 187 children with abdominal pain. Ann Emerg Med. 1990; 19: 1014-1018. https://bit.ly/2H4F4Ve

28. Kalan M, Talbot D, Cunliffe WJ, Rich AJ. Evaluation of the modified Alvarado score in the diagnosis of acute appendicitis: a prospective study. Ann R Coll Surg Engl. 1994; 76: 418-419. https://bit.ly/2JoD7EF

29. Macklin CP, Radcliffe GS, Merei JM, Stringer MD. A prospective evaluation of the modified Alvarado scores for acute appendicitis in children. Ann R Coll Surg Engl. 1997; 79: 203-205. https://bit.ly/2vKzmBo

30. Talwar S, Talwar R, Prasad P, Malik AA, Wani NA. Continuing diagnostic challenge of acute appendicitis: evaluation through modified Alvarado score: comment. Aust N Z J Surg. 1999; 69: 821-822. https://bit.ly/2JrxhTg

31. Jones PF. Active observation in management of acute abdominal pain in childhood. Br Med J. 1976; 2: 551-553. https://bit.ly/2J9LPro

32. Putnam TC, Gagliano N, Emmends RW. Appendicitis in children. Surg Gynecol Obstet. 1990; 170: 527-532. https://bit.ly/2LqOG0H

33. Olsen JB, Myren CJ, Haahr PE. Randomized study of the value of laparoscopy before appendicectomy. Br J Surg. 1993; 80: 922-923. https://bit.ly/2vMe0nu

34. Laine S, Rantala A, Gullichsen R, Ovaska J. Laparoscopic appendectomy – Is it worthwhile? A prospective, randomized study in young women. Surg Endosc. 1997; 11: 95-97. https://bit.ly/2Wwyegu

35. Reiertsen O, Larsen S, Trondsen E, Edwin B, Faerden AE, Rosseland AR. Randomized controlled trial with sequential design of laparoscopic versus conventional appendicectomy. Br J Surg. 1997; 84: 842-847. https://bit.ly/2YcnAMr

36. Croce E, Olmi S, Azzola M, Russo R. Laparoscopic appendectomy and minilaparoscopic approach: a retrospective review after 8-years' experience. JSLS. 1999; 3: 285-292. https://bit.ly/2LwptSR

37. Grunewald B, Keating J. Should the "normal" appendix be removed at operation for appendicitis? J R Coll Surg Edinb. 1993; 38:158-160. https://bit.ly/2PVS1DF

38. Connor TJ, Garcha IS, Ramshaw BJ, Mitchell CW, Wilson JP, Mason EM, et al. Diagnostic laparoscopy for suspected appendicitis. Am Surg. 1995; 61: 187-189. https://bit.ly/2VmPLeR

39. Wilcox RT, Traverso LW. Have the evaluation and treatment of acute appendicitis changed with new technology? Surg Clin North Am. 1997; 77: 1355-1370. https://bit.ly/2VbNSfO

40. Lau WY, Fan ST, Yiu TF, Chu KW, Suen HC, Wong KK. The clinical significance of routine histopathologic study of the resected appendix and safety of appendiceal inversion. Surg Gynecol Obstet. 1986; 162: 256-258. https://bit.ly/2VTKpad

41. Jones MW, Paterson MG. The correlation between gross appearance of the appendix at appendicectomy and histological examination. Ann R Coll Surg Engl. 1988; 70: 93-94. https://bit.ly/2LuG3SQ

42. Dymock RB. Pathologic changes in the appendix: a review of 1000 cases. Pathology. 1977; 9: 331-339. https://bit.ly/2H8csL5

43. Grossman EB Jr. Chronic appendicitis. Surg Gynecol Obstet. 1978; 146: 596-598. https://bit.ly/2PSa6T8

44. Savrin RA, Clausen K, Martin EW Jr, Cooperman M. Chronic and recurrent appendicitis. Am J Surg. 1979; 137: 355-357. https://bit.ly/2PPpLCA

45. Alegbeleye BJ. Ultrasound scan in the evaluation of acute appendicitis in the Tropics. CPQ Medicine. 2019; 6: 1-8. https://bit.ly/2JrRJDl

46. Puylaert JB. Acute appendicitis: US evaluation using graded compression. Radiology. 1986; 158: 355-360. https://bit.ly/2H6pFma

47. Birnbaum BA, Wilson SR. Appendicitis at the millennium. Radiology. 2000; 215: 337-348. https://bit.ly/2LtNhqh

48. Pelsang RE, Warnock NG, Abu-Yousef M. Diagnosis of acute appendicitis on transvaginal ultrasonography. J Ultrasound Med. 1994; 13: 723-725. https://bit.ly/2DWbqQh

49. Puylaert JBCM. Transvaginal sonography for diagnosis of appendicitis. AJR Am J Roentgenol. 1994; 163: 746. https://bit.ly/2E7d7un

50. Sivit CJ. Diagnosis of acute appendicitis in children: spectrum of sonographic findings. AJR Am J Roentgenol. 1993; 161: 147-152. https://bit.ly/2PPqJic

51. Lim HK, Lee WJ, Lee SJ, Namgung S, Lim JH. Focal appendicitis confined to the tip: diagnosis at US. Radiology. 1996; 200: 799-801. https://bit.ly/2H5h1V7

52. Simonovský V. Sonographic detection of normal and abnormal appendix. Clin Radiol. 1999; 54: 533-539. https://bit.ly/2vMrPCo

53. Jeffrey RB Jr, Laing FC, Lewis FR. Acute appendicitis: high-resolution real-time US findings. Radiology. 1987; 163:11-14. https://bit.ly/2LutpUc

54. Abu-Yousef MM, Bleicher JJ, Maher JW, Urdaneta LF, Franken EA Jr, Metcalf AM. High-resolution sonography of acute appendicitis. AJR Am J Roentgenol. 1987; 149: 53-58. https://bit.ly/304JDqk

55. Borushok KF, Jeffrey RB Jr, Laing FC, Townsend RR. Sonographic diagnosis of perforation in patients with acute appendicitis. AJR Am J Roentgenol. 1990; 154: 275-278. https://bit.ly/2vN5tjY

56. Quillin SP, Siegel MJ, Coffin CM. Acute appendicitis in children: value of sonography in detecting perforation. AJR Am J Roentgenol. 1992; 159: 1265-1268. https://bit.ly/2PW7IQF

57. Rettenbacher T, Hollerweger A, Macheiner P, Rettenbacher L, Frass R, Schneider B, et al. Presence or absence of gas in the appendix: additional criteria to rule out or confirm acute appendicitis-evaluation with US. Radiology. 2000; 214: 183-187. https://bit.ly/2V8mkbb

58. Puylaert JCBM, Rutgers RB, Lalisang RI, de Vries BC, van der Werf SD, Dörr JP, et al. A prospective study of ultrasonography in the diagnosis of appendicitis. N Engl J Med. 1987; 317: 666-669. https://bit.ly/2VcPWV4

59. Jeffrey RB Jr, Laing FC, Townsend RR. Acute appendicitis: sonographic criteria based on 250 cases. Radiology. 1988; 167: 327-329. https://bit.ly/2PSZsf0

60. Skaane P, Amland PF, Nordshus T, Solheim K. Ultrasonography in patients with suspected acute appendicitis: a prospective study. Br J Radiol. 1990; 63: 787-793. https://bit.ly/2W0jZ6Z

61. Siegel MJ, Carel CC, Surratt S. Ultrasonography of acute abdominal pain in children. JAMA. 1991; 266: 1987-1989. https://bit.ly/2Vb06oW

62. Jeffrey RB Jr, Jain KA, Nghiem HV. Sonographic diagnosis of acute appendicitis: interpretive pitfalls. AJR Am J Roentgenol. 1994; 162: 55-59. https://bit.ly/2DUlVn2

63. Kao SCS, Smith WL, Abu-Yousef MM, et al. Acute appendicitis in children: sonographic findings. AJR Am J Roentgenol. 1989; 153: 375-379.

64. Rettenbacher T, Hollerweger A, Macheiner P, Rettenbacher L, Tomaselli F, Schneider B, et al. Outer diameter of the vermiform appendix as a sign of acute appendicitis: evaluation at US. Radiology. 2001; 218: 757-762. https://bit.ly/2vObflw

65. John H, Neff U, Kelemen M. Appendicitis diagnosis today: clinical and ultrasonic deductions. World J Surg. 1993; 17: 243-249. https://bit.ly/2JsXO2m

66. Ooms HW, Koumans RK, Ho Kang You PJ, Puylaert JB. Ultrasonography in the diagnosis of acute appendicitis. Br J Surg. 1991; 78: 315-318. https://bit.ly/2VavsMK

67. Balthazar EJ, Birnbaum BA, Yee J, Megibow AJ, Roshkow J, Gray C. Acute appendicitis: CT and US correlation in 100 patients. Radiology. 1994; 190: 31-35. https://bit.ly/2H9svIe

68. Lim HK, Bae SH, Seo GS. Diagnosis of acute appendicitis in pregnant women: value of sonography. AJR Am J Roentgenol. 1992; 159: 539-542. https://bit.ly/2H6LKB8

69. Josephson T, Styrud J, Eriksson S. Ultrasonography in acute appendicitis. Body mass index as selection factor for US examination. Acta Radiol. 2000; 41: 486-488. https://bit.ly/306GHcz

70. Wade DS, Marrow SE, Balsara ZN, Burkhard TK, Goff WB. Accuracy of ultrasound in the diagnosis of acute appendicitis compared with the surgeon's clinical impression. Arch Surg. 1993; 128: 1039-1044. https://bit.ly/2LxL2m5

71. Zielke A, Hasse C, Sitter H, Kisker O, Rothmund M. "Surgical" ultrasound in suspected acute appendicitis. Surg Endosc. 1997; 11: 362-365. https://bit.ly/2vM46lB

72. Jahn H, Mathiesen FK, Neckelmann K, Hovendal CP, Bellstrom T, Gottrup F. Comparison of clinical judgment and diagnostic ultrasonography in the diagnosis of acute appendicitis: experience with a score-aided diagnosis. Eur J Surg. 1997; 163: 433-443. https://bit.ly/2VZmNBi

73. Douglas CD, Macpherson NE, Davidson PM, Gani JS. Randomised controlled trial of ultrasonography in diagnosis of acute appendicitis, incorporating the Alvarado score. Br Med J. 2000; 321: 919-922. https://bit.ly/2VaSm6s

74. Drinkovic I, Brkljacic B, Odak D, Hebrang A. Value of ultrasound in the diagnosis of acute appendicitis. Radiol Oncol. 1995; 29: 190-193.

75. Garcia-Aguayo FJ, Gil P. Sonography in acute appendicitis: diagnostic utility and influence upon management and outcome. Eur Radiol. 2000; 10: 1886-1893. https://bit.ly/2HmmZ4f

76. Zielke A, Sitter H, Rampp T, Bohrer T, Rothmund M. Clinical decision-making, ultrasonography, and scores for evaluation of suspected acute appendicitis. World J Surg. 2001; 25: 578-584. https://bit.ly/2VRrKM5

77. Chesbrough RM, Burkhard TK, Balsara ZN, Goff WB, Davis DJ. Self-localization in US of appendicitis: an addition to graded compression. Radiology. 1993; 187: 349-351. https://bit.ly/2W0olel

78. Soda K, Nemoto K, Yoshizawa S, Hibiki T, Shizuya K, Konishi F. Detection of pinpoint tenderness on the appendix under ultrasonography is useful to confirm acute appendicitis. Arch Surg. 2001; 136: 1136-1140. https://bit.ly/2PVLIFI

79. Dilley A, Wesson D, Munden M, Hicks J, Brandt M, Minifee P, et al. The impact of ultrasound examinations on the management of children with suspected appendicitis: a 3-year analysis. J Pediatr Surg. 2001; 36: 303-308. https://bit.ly/2HcRTvP

80. Wise SW, Labuski MR, Kasales CJ, Blebea JS, Meilstrup JW, Holley GP, et al. Comparative assessment of CT and sonographic techniques for appendiceal imaging. AJR Am J Roentgenol. 2001; 176: 933-941. https://bit.ly/2H96pV8

81. Verroken R, Penninckx F, Van Hoe L, Marchal G, Geboes K, Kerremans R. Diagnostic accuracy of ultrasonography and surgical decision-making in patients referred for suspicion of appendicitis. Acta Chir Belg. 1996; 96: 158-160. https://bit.ly/2Lsj7DQ

82. Skaane P, Schistad O, Amland PF, Solheim K. Routine ultrasonography in the diagnosis of acute appendicitis: a valuable tool in daily practice? Am Surg. 1997; 63: 937-942. https://bit.ly/2WxBbh3

83. Pohl D, Golub R, Schwartz GE, Stein HD. Appendiceal ultrasonography performed by non-radiologists: does it help in the diagnostic process? J Ultrasound Med. 1998; 17: 217-221. https://bit.ly/2WszAsK

84. Styrud J, Eriksson S, Segelman J, Granström L. Diagnostic accuracy in 2,351 patients undergoing appendicectomy for suspected acute appendicitis: a retrospective study 1986-1993. Dig Surg. 1999; 16: 39-44. https://bit.ly/306HSbZ

85. Herd ME, Cross PA, Dutt S. Histological audit of acute appendicitis. J Clin

Pathol. 1992; 45: 456-458. https://bit.ly/2DXSAbv

86. Davies AH, Mastorakou I, Cobb R, Rogers C, Lindsell D, Mortensen NJ. Ultrasonography in the acute abdomen. Br J Surg. 1991; 78: 1178-1180. https://bit.ly/2H9K1MP

87. Beasley SW. Can we improve diagnosis of acute appendicitis? Ultrasonography may complement clinical assessment in some patients. Br Med J. 2000; 321: 907-908. https://bit.ly/308N0fC

88. Kang WM, Lee CH, Chou YH, Lin HJ, Lo HC, Hu SC, et al. A clinical evaluation of ultrasonography in the diagnosis of acute appendicitis. Surgery. 1989; 105: 154-159. https://bit.ly/2WwHTDP

89. Larson JM, Peirce JC, Ellinger DM, Parish GH, Hammond DC, Ferguson CF, et al. The validity and utility of sonography in the diagnosis of appendicitis in the community setting. AJR Am J Roentgenol. 1989; 153: 687-691. https://bit.ly/2Lz94gj

90. Orr RK, Porter D, Hartman D. Ultrasonography to evaluate adults for appendicitis: decision making based on meta-analysis and probabilistic reasoning. Acad Emerg Med. 1995; 2: 644-650. https://bit.ly/2YhNO0e

91. Ford RD, Passinault WJ, Morse ME. Diagnostic ultrasound for suspected appendicitis: does the added cost produce a better outcome?. Am Surg. 1994; 60: 895-898. https://bit.ly/2vN114U

92. Axelrod DA, Sonnad SS, Hirschl RB. An economic evaluation of sonographic examination of children with suspected appendicitis. J Pediatr Surg. 2000; 35: 1236-1241. https://bit.ly/2vKVawV

93. Fujii Y, Hata J, Futagami K, Hamada T, Mitsuoka H, Teramen K, et al. Ultrasonography improves diagnostic accuracy of acute appendicitis and provides cost savings to hospitals in Japan. J Ultrasound Med. 2000; 19: 409-414. https://bit.ly/2JtvME7

94. Puylaert JB, Rijke AM. An inflamed appendix at sonography when symptoms are improving: to operate or not to operate?. Radiology. 1997; 205: 41-42. https://bit.ly/2YghZEY

95. Migraine S, Atri M, Bret PM, Lough JO, Hinchey JE. Spontaneously resolving acute appendicitis: clinical and sonographic documentation. Radiology. 1997; 205: 55-58. https://bit.ly/2H9SyPu

96. Rao PM, Rhea JT, Novelline RA, Mostafavi AA, McCabe CJ. Effect of computed tomography of the appendix on treatment of patients and use of hospital resources. N Engl J Med. 1998; 338: 141-146. https://bit.ly/2JcwaYm

97. Novelline RA, Rhea JT, Rao PM, Stuk JL. Helical CT in emergency radiology. Radiology. 1999; 213: 321-339. https://bit.ly/2J84ns1

98. Subash KC, Abhijit DE, Masesh P, Bryesh B. Diagnostic role of Ultrasonography in Acute Appendicitis: a study at a tertiary care Hospital Am. J Public Health Res. 2015; 3: 23-28. https://bit.ly/2WwFPMn

99. Peixoto RO, Nures TA, Gomes CA. Indices of diagnostic abdominal ultrasonography in acute appendicitis: Influence of gender and physical constitution, time evolution of the disease and experience of radiologist. Rev Col Bras Cir. 2011; 38: 105-111. https://bit.ly/2HdC0GJ

100. Sivit CJ, Applegate KE, Stallion A, Dudgeon DL, Salvator A, Schluchter M, et al. Imaging evaluation of suspected appendicitis in a pediatric population: effectiveness of sonography versus CT. AJR Am J Roentgenol. 2000; 175: 977-980. https://bit.ly/2HfnP2m

101. Vignault F, Filiatrault D, Brandt ML, Garel L, Grignon A, Quimet A. Acute appendicitis in children: evaluation with US. Radiology. 1990; 176: 501-504. https://bit.ly/2HbPRxb

102. Rioux M. Sonographic detection of the normal and abnormal appendix. AJR Am J Roentgenol.1992; 158: 773-778. https://bit.ly/2VNsaDq

103. Chen SC, Chen KM, Wang SM, Chang KJ. Abdominal sonography screening of clinically diagnosed or suspected appendicitis before surgery. World J Surg. 1998; 22: 449-452. https://bit.ly/2VS0Ung

104. Schulte B, Beyer D, Kaiser C, Horsch S, Wiater A. Ultrasonography in suspected acute appendicitis in childhood-Report of 1285 cases. Eur J Ultrasound. 1998; 8: 177-182. https://bit.ly/2VqrvbI

105. Schwerk WB, Wichtrup B, Ruschoff J, Rothmund M. Acute and perforated appendicitis: current experience with ultrasound-aided diagnosis. World J Surg. 1990; 14: 271-276. https://bit.ly/2DYFBWZ

106. Sivit CJ, Newman KD, Boenning DA, Nussbaum-Blask AR, Bulas DI, Bond SJ, et al. Appendicitis: usefulness of US in diagnosis in a pediatric population. Radiology. 1992; 185: 549-552. https://bit.ly/2J9e611