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Diagnostic Validity and Reliability of Ultrasound in Pediatric Appendicitis

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Abstract

Introduction: Acute appendicitis is the most common surgical cause of abdominal pain in children. Its clinical diagnosis is difficult. Ultrasound has proven useful for the diagnosis of this pathology.

Purpose: To determine the validity and reliability of ultrasound in acute appendicitis in children.

Methods: Retrospective analysis of a cohort of children younger than 15 years old with acute abdominal pain who underwent abdominal ultrasound for suspected acute appendicitis. To estimate the diagnostic validity and reliability of the ultrasound we used the sensitivity, specificity, accuracy and the Kappa coefficient.

Results: Of the 353 patients, 183 were boys and 170 were girls, whose average age was 9.8 years. Ultrasound diagnosed appendicitis in 143 patients. 154 appendectomies were performed, of which 92 were uncomplicated appendicitis and 62 were complicated appendicitis. The appendicular perforation rate was 25%. The pathological diagnosis of appendicitis occurred in 147 children. The negative appendectomy percentage was 4.5%. The ultrasound showed sensitivity: 85%, specificity: 90%, diagnostic accuracy: 88% and Kappa coefficient: 0.8, $p<0.05$. The reliability of ultrasound in boys was 0.74 and in girls: 0.75, $p>0.05$. Kappa coefficient was 0.8 in preschoolers, 0.8 in schoolchildren and 0.6 in adolescents, $p<0.05$.

Conclusion: Ultrasound proved to be reliable and useful in the diagnosis of appendicitis. Its performance was not modified according to sex, however as the age increased, the ultrasound decreased its diagnostic value.

Keywords: Acute appendicitis; Abdominal ultrasound; Children; Diagnostic reliability; Validity

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Introduction

Abdominal pain is a common complaint in children and a reason of frequent emergency-room visits. The cause of abdominal pain may be medical or surgical, with appendicitis being the most frequent surgical cause [1]. Clinical diagnosis is difficult and challenging, both because the symptomatology is nonspecific and because of the limited collaboration of the patient in the anamnesis and physical exam, among others [2,3]. The early diagnosis of appendicitis prevents complications such as perforation, peritonitis, sepsis and intestinal obstruction; it also reduces the length of hospital stay [4].

The laboratory tests and ultrasound are the tests that are most frequently used in order to improve the diagnostic certainty of appendicitis in the event of acute abdominal pain in the child. The results of the blood tests are variable and nonspecific and have not demonstrated greater diagnostic utility [5,6,7].

Some studies have shown that ultrasound increases diagnostic certainty of appendicitis, allowing early diagnosis, reducing complications and lowering the negative appendectomy rate from 15% to 40% to 3% to 7% [8,9]. Ultrasound is recommended as an initial imaging study in all children with suspected acute appendicitis [10]. However, other studies conclude that, despite their use, the percentages of appendicular perforation and negative laparotomies have not decreased, and that the routine use of this test is associated with an increase in hospital expenses [11,12].

The main objective of our study was to analyze the diagnostic reliability of ultrasound in children with abdominal pain and suspected acute appendicitis.

Table 1: Ultrasound, intraoperative and anatomopathological diagnosis, of patients operated on with suspicion of appendicitis.

	n (%)
Ultrasound Diagnosis	
Positive for appendicitis	143 (40.5)
Negative	203 (57.5)
Indeterminate/Not conclusive	7 (2)
Appendectomies	154 (44)
Intraoperative Diagnosis	
Uncomplicated appendicitis	92 (60)
Complicated appendicitis	62 (40)
Perforated appendicitis percentage	38 (25)
Anatomopathological Diagnosis	
Appendicitis	147 (95.5)
Negative	7 (4.5)
Negative appendicectomy percentage	7 (4.5)

Materials and Methods

Study design and setting

This study is a retrospective analysis of a cohort of children with acute abdominal pain who underwent abdominal ultrasound for suspected acute appendicitis and were treated in the emergency department of pediatrics of the University Hospital Complex of Santiago of Compostela, Spain.

Patients and data collection

Only children younger than 15 years with acute abdominal pain who received abdominal ultrasound as the initial imaging were included. Patients with traumatic abdominal pain, medical origin of the abdominal pain (such as acute gastroenteritis, constipation, etc.), with abdominal ultrasound requested for other causes and those who did not receive imaging were excluded.

Definitions and variables

Histopathological analysis was our gold standard for diagnosing appendicitis and to compare with ultrasound findings. Due to the lack of uniformity criteria to establish the pathological diagnosis of the type of appendicitis, only a positive or negative diagnosis was considered. The study variables included ultrasound diagnosis, intraoperative features and pathological diagnosis. The Ultrasound diagnosis considered 3 results: Positive, negative and indeterminate.

Positive: Acute appendicitis was diagnosed when an inflamed appendix (non-compressible tubular structure of more than 6 mm in diameter) was visualized non-visualization of the inflamed appendix but presence of secondary signs of appendicitis (increased echogenicity of periappendiceal fat, free fluid, periappendiceal fluid collection, fecalith and dilated bowel loops with altered peristalsis).

Negative: A normal appendix was diagnosed when a normal-size appendix was observed without secondary signs. In cases when appendix was not visualized, the absence of secondary signs or identification of another disease was considered as negative diagnosis.

Indeterminate: Partial visualization of appendix or an appendix of 6 mm without any other signs. In these cases, the further decision on treatment was based on clinical grounds and/or Computed Tomography scan (CT). Intraoperative Diagnosis (in case of appendectomy): Defined according to the description of the macroscopic characteristics of the appendix made by the surgeon during the surgical intervention.

Uncomplicated appendicitis: Includes simple and phlegmonous appendicitis. Complex appendicitis: Includes gangrenous and perforated appendicitis, plastron, abscess and peritonitis.

Histopathological diagnosis

Positive or negative diagnosis was considered, depending on the presence or absence of microscopic signs of inflammation. Negative Appendectomy was defined as an operation with a preoperative diagnosis of appendicitis and absence of acute inflammatory cells in appendiceal biopsy.

Statistical analysis

An analysis was made through decision trees. Descriptive statistics using frequencies and percentages were used for qualitative variables. Means and 95% confidence intervals were used for quantitative variables. The independent t-test or Mann-Whitney U test was used to compare means. The comparison of proportions was done with Chi-square or Fisher's exact test.

The diagnostic reliability of abdominal ultrasound of the acute appendicitis and its possible variation according to age and sex, was determined by calculating the Kappa concordance coefficient, sensitivity, specificity, positive and negative predictive value and diagnostic accuracy. For the calculation, the epiR package and SPSS 15 were used. Statistical significance was proven with a $p<0.05$.

Results

Our study population was 353 children. For the analysis of the reliability of ultrasound, the 7 patients with an in determined ultrasound diagnosis were not included. Of the 353 patients, 183 were boys and 170 were girls. The average age was: 9.8 years. Ultrasound diagnosed acute appendicitis in 143 patients, normal appendix in 203 children and in 7 cases the ultrasound finding was undetermined. An appendectomy was performed in 154 children. The histopathological diagnosis of appendicitis occurred in 147 cases. The percentage of appendicular perforation was 25% and the percentage of negative appendectomies was 4.5% (Table 1). The ultrasound findings with the highest reliability and accuracy diagnostic were appendicular diameter greater than 6 mm and rarefaction of periappendiceal fat (Table 2). Ultrasound showed 85% sensitivity, 90% specificity, diagnostic accuracy of 88% and Kappa coefficient: 0.8, $p<0.05$ (Table 3). The reliability of ultrasound according to sex, showed a Kappa coefficient of 0.74 in boys and 0.75 in girls, $p>0.05$ (Table 4). Kappa coefficient calculated by age group was of 0.8 in preschoolers, 0.8 in schoolchildren and 0.6 in adolescents, $p<0.05$ (Table 5).

Discussion

Our results allow us to affirm that ultrasound should be used routinely in every child with abdominal pain and suspected appendicitis. The percentage of negative appendectomies in our analysis was 5% compared to 16% and even 30% to 60% in those cases without imaging techniques [13,14]. The use of ultrasound as a routine imaging test in children suspected of having acute appendicitis reduces the negative appendectomy rate without increasing radiation-based imaging and without increasing the perforation appendicular rate [15,16]. The percentage of appendicular perforation in our study was 25%. The literature describes figures that vary from 18% to 60% [17].

Table 2: Diagnostic reliability and accuracy of the ultrasound findings.

	S (%)	E (%)	PPV (%)	NPV (%)	Accuracy (%)	Kappa
No compressible structure	75 (67-82)	91 (86-94)	85 (78-91)	84 (78-88)	84 (80-88)	0.04
Diameter >6 mm	71 (63-78)	91 (87-95)	85 (78-91)	81 (76-86)	83 (78-87)	0.6
Increased echogenicity fat	61 (52-69)	96 (93-85)	92 (84-96)	77 (72-82)	81 (77-85)	0.6
Fecalith	16 (10-23)	100 (97-100)	96 (79-100)	62 (57-68)	64.6 (59-70)	0.2
Wall hypervascularization	4 (15-87)	99 (97-100)	75 (35-97)	59 (54-64)	60 (54-65)	0.04
Free fluid	57 (497-65)	83 (77-88)	71 (62-79)	73 (67-79)	72 (67-77)	0.4
Adenopatías	37 (29-45)	57 (50-64)	38 (30-46)	56 (49-63)	48 (43-54)	-0.07

S: Sensitivity; E: Specificity; PPV: Positive Predictive Value; NPV: Negative Predictive Value

Table 3: Measures of the validity and reliability of abdominal ultrasound in the diagnosis of acute apendicitis with 95% confidence interval.

Table 3a:

Ultrasound	Acute Appendicitis		
	Yes	No	Total
Positive	122 (85.3%)	21 (10.3%)	143 (41.3%)
Negative	21 (14.7%)	182 (89.7%)	203 (58.7%)
Total	143 (100%)	203 (100%)	346 (100%)

Table 3b:

Sensitivity	85 (78-91)
Specificity	90 (85-94)
Positive predictive value	85 (78-91)
Negative predictive value	90 (85-94)
Diagnostic accuracy	88 (84-91)
Kappa Coefficient	0.8 (0.6-0.9)

Table 4: Reliability of ultrasound in the diagnosis of appendicitis according to sex.

	Appendicitis		
Sex	**Yes**	**NO**	**Total**
Boys	12 (14.3%)	82 (88.2%)	94 (53.1%)
	72 (85.7%)	11 (11.8%)	83 (46.9%)
Total	84 (100%)	93 (100%)	177 (100%)
Girls	9 (15.3%)	100 (90.9 %)	109 (64.5%)
	50 (84.7%)	10 (9.1%)	60 (35.5%)
Total	59 (100%)	110 (100%)	169 (100%)

Table 5: Reliability of ultrasound in the diagnosis of appendicitis according to age group.

	Appendicitis		
Age group	**YES**	**NO**	**Total**
Preschoolers	3	31	34
	17	3	20
Total	20	34	54
Schoolchildren	13	115	128
	88	10	98
Total	101	125	226
Adolescents	5	36	41
	17	8	25
Total	22	44	66

Coefficient Kappa Preschoolers: 0.8; Schoolchildren: 0.8; Adolescents: 0.6

Garcia Peña et al. [18] showed that the implementation of an imaging protocol using ultrasound and CT resulted in a marked decrease in the perforation rate from 35.4% to 15.5% and the negative appendectomy rate decreased from 14.7% to 4.9%. In our study, the sonographic findings of presence of a non-compressible tubular structure, a diameter greater than 6 mm and the rarefaction of periappendiceal fat presented the highest diagnostic accuracy. Of these ultrasound findings, having a diameter greater than 6 mm and the rarefaction of the periappendiceal fat reached a moderate reliability. Gracey et al. [19] in their study found that the transverse diameter of the appendix greater than 6 mm was the most important ultrasound predictor of appendicitis. The presence of inflamed echogenic periappendiceal fat and appendicolith were supportive features.

Pedram et al. [20] found that appendix diameter greater than 6 mm had a sensitivity of 68%, specificity of 58% and an area under the curve of 0.853. In our study, the ultrasound showed a sensitivity of 85%, a specificity of 90%, a positive predictive value of 85%, a negative predictive value of 90%, a diagnostic accuracy of 88% and a good reliability with a Kappa coefficient of 0.8, similar results to other studies [21,22]. So, the ultrasound had a good reliability and correlated well with the histopathological diagnosis of appendicitis, which allows us to say that it is a useful and valid instrument in the diagnosis of appendicitis and should be used in cases of children with suspected appendicitis.

We found no variation based on sex in the reliability of ultrasound findings used to diagnose appendicitis. Ultrasound was less reliable in diagnosing appendicitis in adolescents. One explanation is because adolescents have a greater amount of body fat, which would decrease the performance of the ultrasound.

Multiple studies have shown that the imaging study of choice in adults with suspected appendicitis is abdominal CT, since it is not limited by body fat [23,24]. Wang et al. [3] recommend CT in children who are overweight or obese otherwise it will be misdiagnosed. Bachur et al. [25] in their study on the effect of age and sex on the usefulness of ultrasound found that the impact of imaging studies on appendicitis varies according to age and sex.

Ultrasound has proven to be a diagnostic tool of high reliability for appendicitis, but it is still under discussion as to when it is indicated. Some authors conclude that imaging tests in the suspicion of acute appendicitis should be used as a diagnostic complement in selected cases [11,12,26]. Other authors, however, believe that ultrasound could also improve the management of patients with a clear clinical diagnosis of appendicitis and affirm that it is reliable as a routine diagnostic study [21,27,28]. The Dutch task force on appendicitis published new guidelines in 2010 and proposed a mandatory pre-operative ultrasound to confirm or exclude appendicitis in

clinically suspected patients. In case of an inconclusive ultrasound, additional imaging such as CT or magnetic resonance imaging was recommended. De Castro et al. [15] examined the results after the implementation of the guidelines. They showed that mandatory preoperative imaging in children clinically suspected of having appendicitis, has resulted in a significant decrease of the negative appendectomy rate without increasing radiation based imaging, and that the strategy is equivalent in terms of costs.

In summary, ultrasound is reliable and useful in the diagnosis of acute appendicitis. Reduces the rate of negative appendectomy and the percentage of appendicular perforation. The ultrasound performance was not modified according to sex, however, its diagnostic value decreased when age increased.

Limitations

Our study was retrospective and had some limitations an inherent selection bias affected our results due to only children with acute abdominal pain who received abdominal ultrasound as the initial imaging were included. There was a lack of uniformity criteria to establish the pathological diagnosis of the type of appendicitis, so, only a positive or negative diagnosis was considered. Some radiology readings were accompanied by statements such as: If there is suspicion for appendicitis, please correlate clinically. In these cases, we spoke with the radiologist for further explanation. Another limitation was that patients with equivocal ultrasound were excluded in the diagnostic reliability analysis.

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References

1. Stringer MD. Acute appendicitis. J Pediatr Child Health. 2017;53(11):1071-6.
2. Almaramhy HH. Acute appendicitis in young children less than five years: Review article. Ital J Pediatr. 2017:43(1):2-9.
3. Wang ZH, Ye J, Wang YS, Liu Y. Diagnostic accuracy of pediatric atypical appendicitis. Medicine (Baltimore). 2019;98:e15006.
4. Bhangu A, Soreide K, Di Saverio S, Assarsson JH, Drake FT. Acute appendicitis: Modern understanding of pathogenesis, diagnosis, and management. Lancet. 2015;386(10000):1278-87.
5. Stefanutti G, Ghirardo V, Gamba P. Inflammatory markers for acute appendicitis in children; are they helpful? J Pediatr Surg. 2007;42(5):773-6.
6. Kwan KY, Nager AL. Diagnosing pediatric appendicitis: Usefulness of laboratory markers. Am J Emerg Med. 2010;28(9):1009-15.
7. Vissers RJ, Lennarz WB. Pitfalls in appendicitis. Emerg Med Clin North Am. 2010;28(1):103-18.
8. Krishnamoorthi R, Ramarajan N, Wang NE, Newman B, Rubesova E, Mueller CM, et al. Effectiveness of a staged US and CT protocol for the diagnosis of pediatric appendicitis: reducing radiation exposure in the age of ALARA. Radiology. 2011;259(1):231-9.
9. Nah SA, Ong SS, Lim WX, Amuddhu SK, Tang PH, Low Y. Clinical relevance of the nonvisualized appendix on ultrasonography of the abdomen in children. J Pediatr. 2017;182:164-9.
10. Holscher HC, Heij HA. Imaging of acute appendicitis in children: EU versus US… or US versus CT? A European perspective. Pediatr Radiol. 2009;39(5):497-9.
11. Wong KKY, Cheung TWY, Tam PKH. Diagnosing acute appendicitis: Are we overusing radiologic investigations? J Pediatr Surg. 2008;43(22):2239-41.
12. Unlu C, De Castro SMM, Tuynman JB, Wust AF, Steller EPh, Van Wagensveld BA. Evaluating routine diagnostic imaging in acute appendicitis. Int J Surg. 2009;7(5):451-5.
13. Raja AS, Wright C, Sodickson AD, Zane RD, Schiff GD, Hanson R, et al. Negative appendectomy rate in the era of CT: An 18-year perspective. Radiology. 2010;256(2):460-5.
14. Khan U, Kitar M, Krichen I, Maazoun K, Althobaiti RA, Khalif M, et al. To determine validity of ultrasound in predicting acute appendicitis among children keeping histopathology as gold standard. Ann Med Surg. 2019;38:22-7.
15. De Castro SMM, Geerdink TH, Macco S, Van Veen RN, Jensch S, Vrouenraets BC. Mandatory imaging in the work-up of children suspected of having appendicitis reduces the rate of unnecessary surgeries. J Pediatr. 2018;53(10):2028-31.
16. Bolmers MD, Van Rossem CC, Gorter RR, Bemelman WW, Van Geloven AAH, Heij HA, et al. Imaging in pediatric appendicitis is key to a low normal appendix percentage: A national audit on the outcome of appendectomy for appendicitis in children. Pediatr Surg Int. 2018;34(5):543-51.
17. Ponsky TA, Huang ZJ, Kittle K, Eichelberger MR, Gilbert JC, Brody F, et al. Hospital and patient-level characteristics and the risk of appendiceal rupture and negative appendectomy in children. JAMA. 2004;292(16):1977-82.
18. Garcia Peña BM, Taylor GA, Fishman SJ, Mandl KD. Effect of an imaging protocol on clinical outcomes among pediatric patients with appendicitis. Pediatrics. 2002;110(6):1088-93.
19. Gracey D, McClure MJ. The impact of ultrasound in suspected acute appendicitis. Clin Radiol. 2007;62(6):573-8.
20. Pedram A, Asadian F, Roshan N. Diagnostic accuracy of abdominal ultrasonography in pediatric acute appendicitis. Bull Emerg Trauma. 2019;7(3):278-83.
21. Doria AS, Moineddin R, Kellenberger CJ, Epelman M, Beyene J, Schuh S, et al. US or CT for diagnosis of appendicitis in children and adults? A Meta analysis. Radiology. 2006;241(1):83-94.
22. Chen SC, Chen KM, Wang SM, Chang KJ. Abdominal sonography screening of clinically diagnosed or suspected appendicitis before surgery. World J Surg. 1998;22(5):449-52.
23. Hahn HB, Hoepner FU, Kalle T, MacDonald EB, Prantl F, Spitzer IM, et al. Sonography of acute apendicitis in children: 7 years of experience. Pediatr Radiol. 1998;28(3):147-51.
24. Van Randen A, Bipat S, Zwinderman AH, Ubbink AT, Stokker J, Boermeester MA. Acute appendicitis: Meta-Analysis of diagnostic performance of CT and graded compression US related to prevalence of disease. Radiology. 2008;249(1):97-106.
25. Bachur RG, Hennelly K, Callahan MJ, Chen C, Monuteaux MC. Diagnostic imaging and negative appendectomy rates in children: Effects of age and gender. Pediatrics. 2012;129(5):877-84.
26. Schupp CJ, Klingmuller V, Strauch K, Bahr M, Zovko D, Hannmann T, et al. Typical signs of acute appendicitis in ultrasonography mimicked by other diseases? Pediatr Surg Int. 2010;26(7):697-702.
27. Strouse PJ. Pediatric appendicitis: An argument for US. Radiology. 2010;255(1):8-13.
28. Ramachandran P, Sivit CJ, Newman KD, Schwartz MZ. Ultrasonography as an adjunct in the diagnostics of acute appendicitis: A 4-year experience. J Pediatr Surg. 1996;31(1):164-67.