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# Limits and advantages of abdominal ultrasonography in children with acute appendicitis syndrome

**Valentina Pastore, Raffaella Cocomazzi, Angela Basile, Marlena Pastore, Fabio Bartoli**

## ABSTRACT

**Background:** Graded compression ultrasonography (US) has become the most popular technique used in suspected appendicitis and in our prospective study, we have evaluated its contribution to the diagnosis of acute appendicitis during the period 2010-2013. **Materials and Methods:** Four hundred and eighty children underwent urgent abdominal suspected of having acute appendicitis. Patients were divided into operated groups; (220 patients) and non-operated (260 patients) the final diagnosis was established on histopathological findings in the first group and on the phone interview in the second one. US was the sole imaging modality in all the non-operated patients and in 203 out of 220 operated ones. Seven children in the operated group underwent CT, while a second US was performed in 10 patients. **Results:** Acute appendicitis was confirmed in 188 operated patients while no one in the non-operated group returned to the hospital or was operated for appendicitis. Sensitivity, specificity, positive predictive value, negative predictive value and accuracy were 79%, 78%, 95%, 39% and 79%, respectively. Negative appendectomy and perforation rates were 14% and 8%. Seventeen children in the operated group required a second diagnostic imaging: 7 CTs and 10 USs. All the seven CTs were consistent with appendicitis and 6 out of 10 USs showed ecographic signs of appendicitis. **Conclusion:** Our results support routine US in all the children with suspected appendicitis because it helps in reducing negative appendectomy and perforation rate. Moreover, a negative US does not justify a subsequent and immediate CT because clinical re-evaluation and a second US can clarify the diagnosis.

**Key words:** Acute appendicitis, children, surgery, ultrasonography

Department of Medical and Surgical Sciences, Pediatric Surgery Unit, University of Foggia, Italy

**Address for correspondence:**
Dr. Valentina Pastore,
Department of Medical and Surgical Sciences, Pediatric Surgery Unit, University of Foggia, Viale Pinto 1, 71122, Foggia, Italy.
E-mail: valentina.pastore@teletu.it

## INTRODUCTION

Acute appendicitis is the most common diagnosis suspected in children with acute abdominal pain and is the most common indication for urgent abdominal surgery. It usually occurs in older children (10-15 year old) and is rare in children <2 years, even if at this age the progression is more severe.[1] The diagnosis may be difficult if limited to patient's medical history, physical examination and laboratory findings, especially when the appendix is in aberrant position or during the early phase of the disease. Furthermore, the classical evolution of pain described by Murphy occurs only in 50–60% of patients.[2] These difficulties may delay initial diagnosis in up to 57% of cases and may be responsible for an increased risk of perforation, abscess formation, peritonitis, sepsis, bowel obstruction, infertility and death.[3] However, authors have showed that surgical indication based only on the patient's signs and symptoms results in 15-30% of cases of negative appendectomy.[4] Nowadays, the standard of care should guarantee the lowest negative and complicated appendectomy rates[5] because negative appendectomy is considered a complication itself with a related morbidity and increased hospital costs.[6] Since the first ecographic visualization of the appendix by Deutsch and Leopold in 1981[7] and the description of graded compression ultrasonography (US) introduced by Puylaert in 1986,[8] US has become the worldwide most popular investigation for the diagnosis of acute appendicitis. This diffusion has been justified by its numerous advantages such as absence of ionizing radiation, dynamic visualization of the abdomen, low cost, large diffusion, no need for sedation and interaction between patient and radiologist about pain localization.[9] The limits of US are related to the operator experience especially in obese children.[10] The aim of this study was to perform a prospective evaluation about the contribute of US to the diagnosis of acute appendicitis in children who have undergone laparoscopic appendectomy in

the Paediatric Surgery Unit of a tertiary care teaching hospital.

## PATIENTS AND METHODS

During the period 2010-2013, we prospectively studied 480 children with acute abdominal pain presenting at the Emergency Department. All patients gave informed consent and patients of both genders, aged from 1 to 16 years were included. Standard diagnostic work-up included physical examination, laboratory findings (white blood count, C-reactive protein, erythrocyte sedimentation rate) and abdominal US. All US examinations were performed by general radiologists using Puylaert's graded compression technique which applies graded compression and high-frequency transducers to visualize the vermiform appendix. US diagnosis of appendicitis was based on identifying a primary sign or two or more secondary signs. Primary signs are direct visualization of an incompressible appendix with an outer diameter >6 mm, wall thickness of 3 mm or more, target sign appearance, presence of an appendicolith and peripheral appendiceal wall hyperaemia. Secondary signs are the presence of fluid or abscess in the periappendiceal region, increased echogenicity of the adjacent periappendiceal fat, enlarged mesenteric lymph nodes, thickening and hyperechogenicity of the overlying peritoneum, dilated hyperactive small bowel and focal apical caecal pole thickening or thickening of the adjacent small bowel. Inclusion criteria, were:

a. A suspected diagnosis of appendicitis,
b. At least one US,
c. Complete chart information.

Children were divided into two groups: Patients who underwent surgery for appendicitis (operated group) versus patients not operatively managed (non-operated group). The final diagnosis was established on the basis of histopathological findings in the operated group, but in the non-operated group, patients were followed up by home phone interview for three months. All operated patients had laparoscopic appendectomy, and the diagnosis of acute appendicitis was confirmed by the presence of neutrophils in the muscular layer (transmural infiltration) of the appendicular wall. Diagnostic US was considered true-positive (TP) when it was conclusive of acute appendicitis and confirmed by pathological examination and true-negative (TN) when both abdominal US and pathological study of the appendix did not indicate acute appendicitis. Diagnostic US was considered false-positive (FP) when it was conclusive of appendicitis but not confirmed by the pathological examination and false-negative (FN) when in spite of an inconclusive US, histopathological findings were in favour of acute inflammation. A total of 480 patients underwent urgent abdominal US for suspected appendicitis and 220 of them were operated. All of the 260 non-operated children were clinically re-evaluated at least once (after 4-6 h) by a paediatric surgeon before discharge. US was the sole imaging modality in all the non-operated patients and in 203 out of 220 operated ones (92%). Seven children in the operated group underwent CT as a secondary diagnostic imaging, while a second US after 10-24 h from admission was performed in 10 patients. Descriptive statistics were applied to calculate specificity, sensitivity, positive predictive value (PPV), negative predictive value (NPV) and diagnostic accuracy. Considering age and sex distribution, $P < 0.05$ was considered to indicate a significant difference.

## RESULTS

Histopathological findings were available for all the operated patients. The pathologist diagnosed acute appendicitis in 188/220 operated children (85%) while none of the patients in the non-operated group returned to the hospital or was operated for appendicitis within 3 months. Demographic characteristics of the operated and non-operated groups are described in Table 1 (128 male and 92 female vs 101 male and 159 female). The two groups were similar in age (10.6 vs. 10.2 years; $P = 0.09$) but statistically different in sex distribution (58% vs. 39% male; $P < 0.05$) [Figure 1]. Considering only the first US examination, it diagnosed acute appendicitis in 149/188 (TP) patients, with a sensitivity of 79% while it showed the absence of acute appendicitis in 25/32 (TN) patients with normal pathology of appendix, specificity of 78%. There were 7/32 FP results and 39/188 FN ones, resulting in a PPV of 95% and NPV of 39%. Diagnostic accuracy was 79%. In this series, negative appendectomy rate was 14%. There were 18/188 (8%) cases of perforation. Of them, 5 were diagnosed as FN, and 13 were TP [Table 2]. Seventeen children in the operated group required a second diagnostic imaging: 7 CTs and 10 USs. All the 7 CT were consistent with appendicitis and 6 out of 10 second USs showed ecographic signs of appendicitis.

## DISCUSSION

Suspected acute appendicitis is one of the most common diagnostic dilemmas in clinical paediatric practice. The diagnosis is more often based on clinical history and physical examination as demonstrated by

**Table 1: Demographic characteristics of the operated and non-operated groups**

| Treatment type | *n* | Mean age, years (SD) | Males (%) | Females (%) |
|---|---|---|---|---|
| Operated | 220 | 10.6 (4.2) | 128 (58) | 92 (42) |
| Non-operated | 260 | 10.2 (5.4) | 101 (39) | 159 (61) |

SD: Standard deviation

**Table 2: US characteristics**

| Results | US % |
|---|---|
| Sensitivity | 79 |
| Specificity | 78 |
| PPV | 95 |
| NPV | 39 |
| Diagnostic accuracy | 79 |
| Negative appendectomy rate | 14 |
| Perforation rate | 8 |

US: Ultrasonography; PPV: Positive predictive value; NPV: Negative predictive value

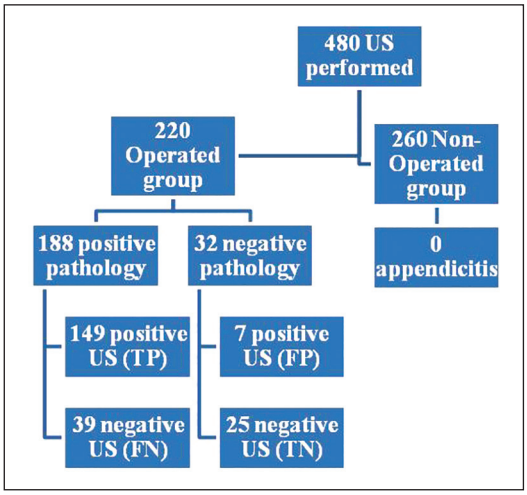



**Figure 1: Children's distribution**

Bergeron[11] who shows that surgeon's evaluation has a PPV of 83.9% in patients with the typical presentation. Furthermore, the repeated clinical examination every 4-6 h is a safe and widely used diagnostic strategy in patients with atypical clinical picture within 24-hours from clinical presentation (these children are at low risk of perforation).[8] However, the presentation can be confusing, and clinical signs and symptoms may overlap with other conditions, especially in female patients. Accurately identifying the earliest onset of symptoms is important for promptly evaluating appendicitis and minimizing delays and risk of perforation. In fact, delay in treatment for more than 36 h increases the perforation rate as high as 65%.[12] Thus, a negative appendectomy rate of 10-15% has been reported as acceptable to avoid delay leading to increased morbidity from perforation.[13] Imaging in paediatric acute appendicitis is a highly debated topic but, in our opinion, it plays an important role in the modern evaluation of abdominal pain. In general, the ideal imaging test would be readily available, fast, inexpensive, reproducible, safe and accurate and US seems to have most of these characteristics.[14] However, abdominal CT-scan has been proven to have a higher sensitivity for both the appendicitis and alternative diagnosis when compared to US[15] but it is rarely used at our Institution because it is more expensive and associated with higher radiation exposure. On the contrary, US is part of our diagnostic algorithm (after clinical history and physical examination) to detect most causes of abdominal pain. The most specific sign for the diagnosis is the identification in the right lower quadrant of a non-compressible blind-ending structure with an outer diameter greater than 6 mm[8] but we also consider positive a US in which the appendix is not visualized, but secondary signs are present. Several authors have showed a sensitivity and specificity as high as 100%, but these results are not always reproducible because US still remains an operator-dependent investigation.[9,16] In our study, all US results were compared with the pathological results and sensitivity is 79%, representing 149 children with the final diagnosis of appendicitis. This index is within the ranges reported in the literature.[17] However, in our study the specificity and diagnostic accuracy of US was lower than that reported by other authors[2] and we believe that this result is due to our emergency protocol which performs US at any time and in all patients with abdominal pain. In particular, Doria *et al*. in a meta-analysis on 26 studies in children found a pooled sensitivity and specificity for US in the diagnosis of acute appendicitis ranging from 88% and 94%, respectively.[9] As to our PPV, it is 95% and consistent with that described in the literature while NPV is 39%, lower than that usually reported.[2] The excellent PPV emphasizes that a positive US is strongly in favour of a diagnosis of acute appendicitis, and the child should undergo surgery. At US, there were 7 cases of FP, who can be attributed to a confusion between an ileal loop and appendix, by erroneous judgement of normal appendix and occurrence of appendicitis with spontaneous resolution.[18] There were 39 FN (5 of whom in perforated appendices) which were responsible for the low NPV. This finding suggests prudence in ruling out the diagnosis of acute appendicitis and discharge the children after a first negative US. In fact, US can be limited by patient body mass, abdominal rigidity, appendix position, perforation, early phase of the disease and experience of the radiologist. However, Puylaert did not find the influence of body mass index in accuracy of US for the diagnosis of acute appendicitis and suggested it is the method of choice among imaging techniques.[19]

Some authors found that there was influence of the radiologist's experience in the diagnostic US accuracy. At our Institution, all the USs were performed by general radiologists but we were not able to detect a bias factor between them. In general, the role of imaging has been demonstrated by the observation that mean negative appendectomy rate is 26% when the diagnosis is based only on clinical and laboratory findings while it drops to 6-10% when imaging studies are added.[2] In our experience, the estimated negative appendectomy rate is 14%, comparable to other studies, while the perforation rate is 8% less than in other reports.[20] We agree that all the values considered could be improved if USs were performed by dedicated paediatric radiologists. Overall, the present results are encouraging and support the diagnostic strategy that US should be routine for all children with suspected appendicitis. In fact, in case of non-visualization of the appendix at US, appendicitis can be safely ruled out if there are no secondary signs of the disease while, in our opinion, a negative US does not justify a subsequent CT, but children should be re-evaluated in the next hours and a second US may render definitive results. In fact, in 6 out of 10 patients in whom a second US was performed, ecographic signs of appendicitis appeared, and the children were promptly operated. In this series, all the CTs performed as a secondary diagnostic imaging were only due to the lack of sonographer radiologist. However, in case of persisting negative US with positivity of clinical and laboratory finding, our policy is to perform anyway a laparoscopic appendectomy. We have to say that our study has several limitations. First, we had no absolute confirmation of the absence of acute appendicitis in the non-operated children because evidence suggests that spontaneous resolution of untreated, non-perforated appendicitis is possible, and this can underestimate the FN results and overestimate the FP results. Furthermore, this study is limited by the small number of children who have just been divided into two groups according to the type of treatment they received, without adjustment for age and sex. In conclusion, imaging is increasingly important in the diagnosis and management of children with abdominal pain and suspected acute appendicitis, avoiding unnecessary surgery and delays in treatment that may lead to complications. US may be considered, in conjunction with clinical history and laboratory findings, an accurate and safe imaging modality for clinical decision making. Our Institution has an overall negative appendectomy rate similar to larger Institutions and a lower perforation rate. As a diagnostic tool, US is unique in its ability to predict positively while a low NPV suggests that particular attention should be given to children with negative US. However, also in patients with a first negative US, if symptoms persist, a second US could clarify the diagnosis.

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