



## Original Article

The current utility of ultrasound in the diagnosis of acute appendicitis<sup>☆</sup>Pedro Lourenco, Jacque Brown, Jonathan Leipsic, Cameron Hague<sup>\*</sup>

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## ABSTRACT

The purpose of this study is to evaluate the current performance of ultrasound in the diagnosis of acute appendicitis. Retrospectively, patients who presented to a single institution between 2011 and 2012 were included. Diagnostic accuracy was calculated, with surgery considered gold-standard. Our data demonstrates that US relative to surgery-confirmed appendicitis has a sensitivity and specificity of 48.4% and 97.9%, respectively. The diagnostic accuracy was further increased when there was a low pre-test probability, with a NPV of up to 96.6%. Ultrasound has a strong PPV in the diagnosis of acute appendicitis, and in equivocal cases, the NPV is reliable.

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## 1. Introduction

Acute appendicitis is a common cause of abdominal pain and has a lifetime incidence of 8.6% in men, and 6.7% in women, typically occurring within the second and third decades of life [1]. Classic presentation occurs in 50 to 60% of patients. Atypical presentations tend to occur in patients whom have variations in the anatomical location of the appendix, extremes of age or are pregnant [2].

Historically, clinical diagnosis of acute appendicitis resulted in a negative appendectomy rate of 20% [3]. In an attempt to increase diagnostic accuracy, various clinical prediction rules, such as the Alvarado [4] and the Modified Alvarado [5] scoring systems were developed. The Alvarado system attempts to risk stratify patients with suspected acute appendicitis, and offer recommendations for discharge, observation or surgical intervention.

CT is considered the primary modality in adults for establishing a diagnosis of appendicitis, as suggested by the ACR Appropriateness Criteria [6,7]. A recent meta-analysis [8] showed that the sensitivity and specificity for US diagnosis of appendicitis in adults were 83% (95% CI: 78%, 87%) and 93% (95% CI: 90%, 96%), respectively. CT studies had superior sensitivity and specificity, with 94% (95% CI: 92%, 95%) and 94% (95% CI: 94%, 96%), respectively.

Depending on clinical history and patient demographic factors, ultrasound is often utilized in a staged diagnostic approach. Staged

diagnostic protocols recommend US as the initial imaging modality, and further imaging follow-up in equivocal cases [9,10]. This approach has been credited with approximately 50% reduction in the unnecessary CT scans. However, the number of sonographically equivocal studies (i.e. those in which neither an abnormal or normal appendix is seen) are invariably high and emergency physicians and other clinicians are often uncertain how to integrate such results into a patient's management plan.

We aim to re-visit the role of US as an initial imaging modality in the diagnosis of acute appendicitis. In this retrospective cohort study, we also examine the effect of pre-test probability on the sensitivity, specificity, PPV and NPV of ultrasound in the diagnosis of acute appendicitis.

## 2. Methods

## 2.1. Study Design and setting

This study is a retrospective analysis of a patient cohort who presented to the Emergency Department (ED) and subsequently the Radiology department with clinical concern for acute appendicitis at a large quaternary hospital within the Providence Health Care authority (St. Paul's or Mount St. Joseph Hospitals) in Vancouver, BC, Canada between October 1, 2011 and September 31, 2012.

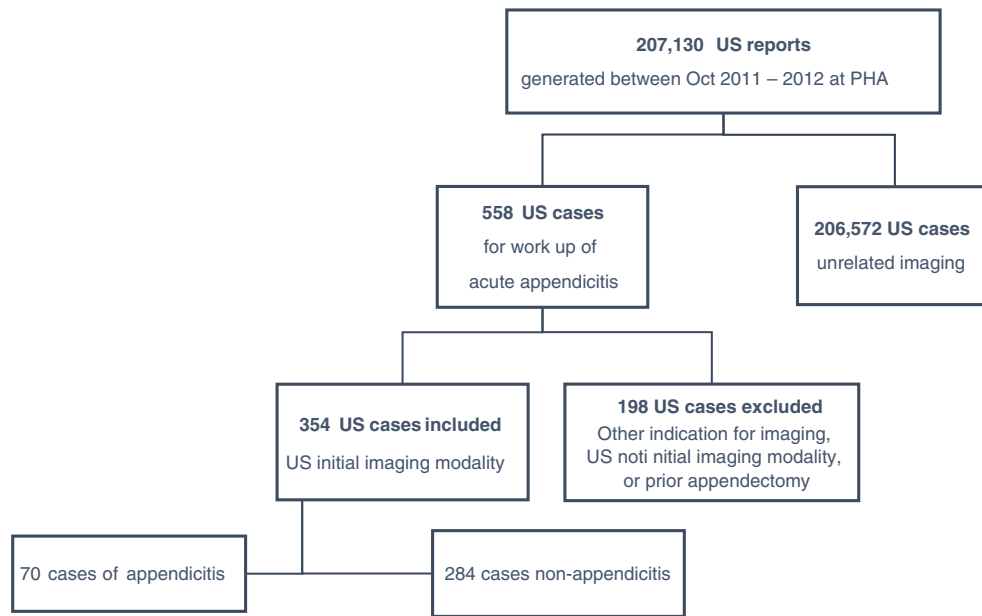
## 2.2. Patient selection and data Collection

Only adult patients who received sonographic investigation as the initial imaging modality were included; those imaged with other modalities or who did not receive imaging were excluded (Fig. 1). Included patients had their clinical charts reviewed by the authors, and results of the initial ultrasound, and any subsequent CT or MR, and abdominal

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**Fig. 1.** Selection of patients from the Providence Health Authority who underwent ultrasound (US) investigation between Oct. 2011 and 2012 for abdominal pain concerning for acute appendicitis.

surgery, including the associated pathologic specimens, were recorded. Additionally, for each patient, age at presentation, gender (male or female), presence of fever (>37.5 degrees Celsius), presence of leukocytosis (WBC>11.0 x10<sup>9</sup> cells/L) and presence of left-shift on complete blood count testing (>6 cells/μL immature neutrophils) were logged. In patients with US or CT studies negative for appendicitis, an alternative diagnosis was recorded whenever possible.

Ultrasound studies were performed by accredited sonographers during regular departmental hours (0800 to 1700 h), or by the on-call radiologist or radiology resident during afterhours (1700 to 0800). All images were interpreted by staff radiologists. Studies positive or negative for appendicitis were defined by the criteria outlined in Table 1. Ancillary findings, such as the presence of an appendicolith, periappendiceal fluid, enlarged lymph nodes and increased flow in the appendiceal wall were also recorded whenever possible. Although these did not factor in the final diagnosis, they may alter the final impression of the exam depending on other findings. Equivocal studies represent those in the appendix was not clearly identified or incompletely visualized. Based on the final radiology report, the patients were categorized as “positive,” “equivocal” or “negative” for appendicitis.

**2.3. Statistical analysis**

Sensitivity, specificity, positive predictive value (PPV), negative predictive values (NPV) were calculated comparing US to CT or MR imaging, and US to surgical results. Patients who did not undergo surgery were considered to not have had appendicitis, with discharge notes considered gold standard. Patient re-admission to hospital or

subsequent emergency visits within the subsequent 3 months were recorded. Sub-group analyses were performed. To assess if diagnostic accuracy was increased when clinical factors, well documented to increase the pre-test probability of acute appendicitis [4,11] were applied, additional sub-group analyses were performed. The pre-test probability factors include presence of fever, leukocytosis and a left-shift, as defined above. Sub-group analyses were performed in patients with 0 (zero), 1 (one) or ≥2 (two or all) pre-test features were present. Additional sub-group analyses were performed on the positive, equivocal and negative ultrasound cohorts to examine the accuracy of presence (≥1 or ≥2) or absence of pretest factors when compared to pathologically confirmed appendicitis. We used X<sup>2</sup> test to assess for significant differences in calculated values when appropriate by using a 1-tailed level of significance. A P<.05 was considered significant. Additional analysis was conducted utilizing a 3x2 method based on intent to diagnose [12,13]. No adjustments were made for multiple testing. All analyses were performed using PASW Statistics (version 18, SPSS Inc., Chicago, Illinois). The Clinical Research Ethics board at our institution (UBC) approved the study.

**3. Results**

**3.1. Patient characteristics**

A total of 558 patients with suspected acute appendicitis underwent sonographic investigations (Fig. 1). 198 patients were excluded due to having received other investigations as their initial imaging study (i.e. ultrasound was utilized to follow-up resolving peri-appendiceal abscesses), or imaging was performed for indications other than suspected appendicitis. 354 patients received an ultrasound as the initial imaging modality and this group was included in the main analysis.

The characteristics of patients suggest that the majority of patients presenting with clinical concerns for appendicitis are females (76.3%), and of reproductive age (average age of 30.5 years) (Table 2). The majority of patients had an equivocal ultrasound result (81.4%; Table 3). 288 of 354 patients had equivocal ultrasounds; from this group, 175 of 288 patients subsequently received cross-sectional imaging, and the remaining 113 of 288 equivocal patients received observation only or an

**Table 1**  
Definition of sonographic findings and criteria for diagnosis of acute appendicitis

<b>Positive</b>	6-mm or larger diameter aperistaltic, non-compressible hyperemic blind-ending structure with origin adjacent to the cecal pole
<b>Negative</b>	complete visualization of the compressible blind-ending structure with diameter less than 6 mm adjacent to the cecal pole
<b>Equivocal</b>	appendix not identified or incompletely visualized, irrespective of characteristics

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