



## Size matters: Computed tomographic measurements of the appendix in emergency department scans



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### ABSTRACT

**Background:** Radiologists use a size cutoff in appendiceal diameter to assist surgeons in diagnosing appendicitis, however, no consensus exists as to the size of a normal adult appendix. We aim to evaluate radial appendiceal diameter on CT in adult patients both with and without appendicitis.

**Methods:** Retrospective review of adults who underwent abdominal CT was performed. Variables collected include: demographics, BMI, WBC count at presentation, radial diameter of appendix (mm), presence of fat stranding, fecalith, and free fluid.

**Results:** During the study period, 3099 patients underwent CT. The appendix was visualized on 74% of scans. Mean appendiceal diameter was 6.6 mm ( $\pm 1.7$ ). The appendix was larger in patients with appendicitis (6.6 vs. 11.4;  $p < 0.0001$ ). Overall appendectomy incidence was 3.2%. Sensitivity and specificity of CT in diagnosing appendicitis in this cohort of patients were 90% and 94%. NPV was 99.5%.

**Conclusion:** While appendiceal diameter was larger in patients with appendicitis, >20% of patients without appendicitis had an appendiceal diameter >7 mm. Diameter alone should not be relied upon to diagnose appendicitis.

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### Background

Acute appendicitis is a common cause of acute abdominal pain and a frequent indication for emergent surgery. It is the most common diagnosis in patients with a surgical condition of the abdomen.<sup>1</sup> Approximately 8% of the population will develop appendicitis in their lifetime with the peak incidence occurring between 10 and 30 years of age.<sup>2</sup>

Acute appendicitis is known as “the great masquerader<sup>3</sup>” due to the variety of symptoms that patients may have at presentation. The diagnosis of appendicitis must be considered in the differential diagnosis of nearly every patient who presents with acute abdominal pain. “Classic” symptoms include periumbilical pain, followed by anorexia, nausea, and subsequent relocation of the pain to the right lower quadrant as the inflammation progresses to involve the parietal peritoneum.<sup>4</sup> While “classic” symptoms are common, this typical presentation only occurs in 50–60% of patients.<sup>5,6</sup> The negative appendectomy rate in males is less than 10%, whereas in females of

reproductive age in whom gynecologic pathologies are often responsible for right lower quadrant pain, the rate approaches 20%.<sup>7,8</sup> Advancements in computed tomography (CT) technology have resulted in an improved accuracy of diagnosis, with a sensitivity and specificity of greater than 90% in recent years.<sup>9,10</sup>

CT is the most frequent modality used in the evaluation of adult patients with suspected appendicitis. Among the tools employed by radiologists to diagnose appendicitis is a cutoff in the radial diameter of the appendix. Most current studies use a size cutoff of greater than 6 mm, but this number is based off of studies looking at pediatric appendicitis. More recent studies have brought into question the true normal diameter of the appendix in the adult population.<sup>5,9–12</sup> False positive CT scan can impact the clinical management of a patient with acute abdominal pain and may lead to unnecessary procedures.<sup>13</sup> Ambiguity still exists about the true size of the normal appendix in adults. The purpose of this study is to evaluate appendiceal diameter as measured on CT in adult patients both with and without appendicitis.

### Methods

A retrospective analysis of adult patients who underwent abdominal CT from May 1, 2017 to July 30, 2017 in the Emergency

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Department (ED) at Memorial Hospital in Colorado Springs was performed. This ED is the busiest in the state of Colorado with over 100,000 visits per year.

CT scans of the abdomen and pelvis were obtained with a 128-slice helical CT scanner (Siemens Somatom, Berlin, Germany). Both contrast-enhanced and non-contrast CT scans were evaluated. Variables collected include demographics, white blood cell (WBC) count at presentation, and radiologic findings including radial diameter of appendix (mm) and the presence of fat stranding, a fecalith, and/or free fluid.

The CT scans were all reviewed by a single author (EM) to ensure consistency. A CT scan was considered “positive” for appendicitis if the radiologist noted acute appendicitis in their report. In patients who underwent operative appendectomy, pathology reports were used as the gold standard to diagnose acute appendicitis and were used to calculate the sensitivity, specificity, positive and negative predictive value of CT diagnosis. All appendixes were measured by the author who reviewed all CT scans using Picture Archiving Communication System (PACS) (Agfa Healthcare, Ridgefield Park, NJ). Positive identification of the appendix required demonstration of a blind-ending tubular or curved structure arising from the cecum.

Statistical analysis was performed using Chi Square or Fischer's exact test where appropriate for categorical variables. Student's *t*-test or the Wilcoxon Rank Sum test was used to analyze continuous variables. Variables with  $p < 0.2$  were entered into a multivariable logistic regression model. Best fit was performed using the Hosmer-Lemeshow test. Stepwise backward regression was used to construct the final model until the Hosmer-Lemeshow test had  $p > 0.05$ . Simple linear regression was used to evaluate the relationship between body mass index (BMI), age, and appendiceal diameter. Simple logistic regression for pathologic confirmed appendicitis was used to construct a prediction model for appendix size. Youden's J index was then used to identify the inflection point maximizing sensitivity and specificity. A  $p < 0.05$  was considered significant. All statistical analyses were performed using SAS 9.4 (SAS Institute, Cary, NC). This study was approved by the institutional review board at UHealth.

## Results

During the three-month study period 25,645 patients were seen in the ER and 3099 patients  $\geq 18$ -years-old underwent an abdominal CT. Eight hundred and six (26%) patients were excluded due to non-visualization of the appendix, 366 of which were due to documented prior surgical resection of the appendix. Overall, the mean age was 44.9 years ( $\pm 18.8$ ) and 38.4% of the patients were male. The mean size of the appendix in all patients regardless of the presence of appendicitis was 6.6 mm.

Patients diagnosed with appendicitis ( $n = 97$ ) were younger (34.7 vs. 45.4 years;  $p < 0.0001$ ), were more likely to be male (52.6 vs. 47.4%;  $p = 0.003$ ), and had a more prominent leukocytosis (14,100 vs. 10,200;  $p = 0.0001$ ). Fat stranding (6.7%), free fluid (3.9%), or a fecalith (8%) were not common in the overall cohort, however all 3 of these radiographic findings occurred more frequently in patients with appendicitis; fat stranding (94.9 vs. 2.3%;  $p < 0.0001$ ), free fluid (29.9 vs. 2.6%;  $p < 0.0001$ ), and a fecalith (33.0 vs 6.8%;  $p < 0.0001$ ) (Table 1).

Mean appendiceal diameter was 6.6 mm ( $\pm 1.7$ ) in the overall study population and was larger in patients with appendicitis (11.4 mm vs. 6.3 mm;  $p < 0.0001$ ). Male gender was also associated with larger appendiceal diameter (6.81 mm vs. 6.43 mm;  $p < 0.0001$ ). Appendiceal diameter measured greater than 7 mm in 22.4% of patients without appendicitis, and 95.9% of patients with appendicitis had a radial diameter greater than 7 mm (Table 1).

**Table 1**

Descriptive statistics for appendix size cohort comparing patients without appendicitis to patients with appendicitis.

	Total Study n = 2038	Appy - n = 1941	Appy + n = 97	<i>p</i>
Age (years)	44.9 ( $\pm 18.8$ )	45.4 ( $\pm 18.8$ )	34.7 ( $\pm 16.6$ )	<0.0001
Male	38.4%	37.7%	52.6%	0.003
Size (mm)	6.6 ( $\pm 1.7$ )	6.3 ( $\pm 1.2$ )	11.4 ( $\pm 3.0$ )	<0.0001
BMI	28.6 ( $\pm 7.5$ )	28.6 ( $\pm 7.5$ )	28.0 ( $\pm 7.0$ )	0.467
WBC	10.5 ( $\pm 4.5$ )	10.2 ( $\pm 4.4$ )	14.1 ( $\pm 4.3$ )	<0.0001
Fat Stranding	6.7%	2.3%	94.9%	<0.0001
Fluid	3.9%	2.6%	29.9%	<0.0001
Fecalith	8.0%	6.8%	33.0%	<0.0001
Appendix $\geq 7$ mm	25.9%	22.4%	95.9%	<0.0001

Appy = appendicitis; BMI = Body mass index; WBC = White blood count.

Youden's J index was performed to identify an inflection point for size of the appendix. The Receiver Operator Curve for the model was 0.958. The inflection point was identified at 8.4 mm where the sensitivity (88.6%) and specificity (96.1%) were maximized.

The sensitivity and specificity of CT scan in diagnosing appendicitis in this cohort of patients was 90% and 94%. The positive and negative predictive value was 42.6% and 99.5% respectively. Multivariable logistic regression demonstrated that age, WBC, fat stranding, and appendix size were all independent predictors of appendicitis (Table 2). Hosmer-Lemeshow best fit was performed for this model with  $p = 0.45$ .

Our analysis also demonstrated a statistically significant association between increased BMI and appendiceal diameter; for each 1-point increase in BMI, the adult appendix increased in size by 0.02 mm ( $\beta = 0.022$ ;  $p < 0.0001$ ). While a similar trend was observed for age and appendiceal size (decreased size for each additional year of age), this did not prove to be statistically significant upon analysis ( $\beta = -0.004$ ;  $p = 0.066$ ).

## Discussion

Appendicitis is one of the first intra-abdominal disease processes to be regularly, successfully treated surgically with the first reported successful appendectomy was performed in 1886.<sup>14</sup> Likewise, appendectomy was one of the first general surgery procedures to widely employ laparoscopy after the first laparoscopic appendectomy was performed in 1982.<sup>15</sup>

The overall lifetime risk of developing appendicitis is approximately 7–8%.<sup>2,6</sup> While its diagnosis can be relatively straightforward in those patients who present with the “classic” signs and symptoms of appendicitis, including periumbilical pain shifting to the right lower quadrant, tenderness with localized peritonitis, anorexia, and nausea, only 50–60% of patients will present in this fashion.<sup>5,6</sup>

Since the diagnosis of appendicitis is not always straightforward, CT is frequently used in the evaluation of patients with suspected appendicitis. Several radiographic factors can be evaluated to determine the presence of appendicitis on CT scan. Among these factors is the radial diameter of the appendix, however, there is not good data regarding the average size of the adult appendix.

**Table 2**

Multivariable logistic regression for pathologic appendicitis.

	AOR	CI	<i>p</i>
Age	0.958	0.937–0.980	0.003
WBC	1.095	1.007–1.190	0.034
Fat Stranding	198.532	65.667–600.238	<0.0001
Appendix Size	1.355	1.163–1.578	<0.0001

Furthermore, the size at which an appendix becomes concerning for appendicitis is unknown in the adult population.<sup>5,6</sup> Data regarding the size of the pediatric appendix is more prevalent and there is consensus as to the size at which a pediatric appendix is more concerning for appendicitis, however, this has not been studied as extensively in the adult population. The average radial diameter of a normal adult appendix has been reported to range from 3.0 to 10.0 mm.<sup>6</sup> Its maximum radial diameter ranges from study to study, with significant variation reported in the literature<sup>5,6,9–12,16</sup>

In the pediatric patient with appendicitis, an appendix greater than 7.0 mm is highly predictive of appendicitis. This radial diameter “cutoff” has often been extrapolated in formulating the diagnosis of appendicitis in adults.<sup>5,9–12</sup> Trout et al. found significant variation in the size of the “normal” appendix with 39% of normal appendices measuring up to 8.7 mm.<sup>11</sup> Willekens et al., in a review of 188 adult CT scans, found that >90% of appendices were greater than 6 mm.<sup>5</sup> In this study, over 20% of adult patients without appendicitis were found to have an appendiceal diameter of greater than 7.0 mm. Clearly, using the same size cutoff in adults that has been validated in children is not appropriate. Utilizing these criteria in adults has the potential to increase the rate of false positive CT scans for appendicitis, subjecting patients to potentially unnecessary operations.

In order to identify an appropriate cut off point to optimize for maximum sensitivity and specificity when using appendiceal diameter in the diagnosis of adult appendicitis, Youden's J index was utilized. This index is a platform to summarize the performance of a diagnostic test. Values range from –1 to 1, with zero indicating a diagnostic test provides equal proportions of positive results in patients with the disease as in those without the disease. On the other hand, a value of 1 indicates an “ideal” test, with no false negatives or false positives.<sup>17</sup> Youden's J index was 0.848 for the appendiceal diameter of 8.4 mm. At this size, the sensitivity and specificity of CT in diagnosing appendicitis was 88.6 and 96.1% respectively. This is substantially higher than the cutoff point utilized in previous studies to diagnose appendicitis, when taken into consideration along with other clinical factors, including exam and laboratory findings, utilizing an appendiceal diameter of 8.4 mm may improve the prognostic ability of CT scan in diagnosing appendicitis.

While this may seem intuitive to some, given size discrepancies between males and females, this study found a statistically significant size difference between the male appendix (6.81 mm) and the female appendix (6.43 mm). This has not been reported in the literature to date. Willekens et al.<sup>5</sup> examined gender differences in appendiceal length and found statistically significant differences amongst their small cohort, but did not analyze appendiceal diameter.

False positive diagnosis by CT scan may lead to unnecessary procedures and may add to medical costs.<sup>13</sup> Gwyn et al. observed lack of relationship in terms of the size of the appendix in relation to the status of pathologic inflammation and extent of disease. In evaluation of their cohort postoperatively, the researchers found that patients who received what they termed a “false diagnosis” and subsequently underwent a negative appendectomy, in many cases had minimal supporting clinical evidence in making the diagnosis. In most of these patients, appendiceal enlargement was used as the sole criterion for diagnosis.<sup>10</sup> In their study, the positive predictive value of CT scan in diagnosing appendicitis (with appendiceal enlargement used as the sole criterion for diagnosis) was only 42.6%. Hence it can be implied, from their work, that using appendiceal diameter alone in determining need for appendectomy, will inevitably lead to non-therapeutic operations.

Appendicitis remains the most common cause of acute

abdomen in the United States.<sup>18</sup> While the complication rate of appendectomy overall remains low,<sup>19</sup> operative risks, including but limited to superficial and deep wound infections, ileus, and pneumonia,<sup>18</sup> still remain. The rate of negative appendectomy continues to decline with more frequent use of CT, and due to improvements in CT technology.<sup>20,21</sup> Nevertheless, any patient undergoing negative appendectomy is unnecessarily subjected to the aforementioned risks, and all efforts should be made to negate these risks, if possible.

The presence of appendicoliths was relatively rare in normal appendices (6.8%), but more common in appendicitis (33%). This demonstrates that while the presence of fecalith is significantly associated with the diagnosis of appendicitis, its detection alone is not sufficient to serve as the basis for diagnosing appendicitis. This parallels the findings of other studies in both the pediatric<sup>22</sup> and the adult populations.<sup>6</sup> Likewise, the presence of fat stranding and free fluid were more common patients with appendicitis (29.9% and 33.0%). These findings should not be taken in isolation, as they can be present with many other disease states.

This analysis demonstrated a statistically significant association between increased BMI and increased appendiceal diameter. The United States is plagued with an obesity epidemic where 40% of adults classified as obese in 2017<sup>23</sup> and 6.6% of adults further classified as morbidly obese.<sup>24</sup> Physical examination in the obese patient is often challenging as excess abdominal adiposity can obscure important findings.<sup>25</sup> In light of the added difficulty that obesity imparts to the clinical diagnosis of appendicitis, surgeons should bear in mind that the normal appendiceal diameter of an obese patient might be larger than what would be expected in a non-obese patient.

It was reassuring to find that the negative predictive value of CT scan in this large cohort of patients was 99.5%. This finding can serve important prognostic value in those patients who are unable to provide an accurate history or in the obtunded patient with an unreliable physical examination.

There are several limitations to this study. First, all of the data we obtained was retrospective and not specifically collected for review of appendiceal size. Second, there is variability in terms of the range of potential locations for measurements of the appendix, depending on what cross section is measured. Finally, there was no evaluation of missed appendicitis, as they can often re-present to the hospital, or present to a different ED days later.

## Conclusions

While appendiceal diameter was significantly larger in patients with appendicitis, greater than 20% of patients without appendicitis had an appendiceal diameter larger than 7 mm. Relying only on appendiceal diameter for the diagnosis of acute appendicitis may lead to an increased rate of negative appendectomies.

AOR = Adjusted odds ratio; CI = confidence interval; WBC = White blood count. Remaining significant variables fell out of the model. Best fit performed using the Hosmer-Lemeshow test ( $p = 0.45$ ). All variables in the final model independent predictors for acute appendicitis.

## Conflicts of interest

The authors have no conflicts and no reported funding.

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