

Use of Vertebra and Iliac Bone as References in Localization of Vermiform Appendix in Computed Tomography

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Abstract

Objectives: The vermiform appendix may assume variable anatomical positions, which can impact the diagnosis of acute appendicitis. As computed tomography (CT) is widely used for evaluation, minimizing radiation exposure is essential. This study aims to determine the typical appendix location in the general population, using CT, and to define bony reference points-vertebral levels and the right iliac crest-which may enable field of view limitation and contribute to radiation dose reduction.

Methods: Between January 2015 and January 2018, abdominal CT scans of 427 patients with abdominal pain were retrospectively analyzed. The appendix origin (Ap0), highest point (ApA), and lowest point (ApB) were measured relative to vertebral levels and the right iliac crest. The appendix course was classified as ascending or descending. The study used statistical analysis with t-test, chi-square, and Pearson correlation, considering $p < 0.05$ as significant.

Results: Among 427 patients (48.2% female, mean age 42.1 ± 19.5 ; range 18-90), the appendix had an ascending course in 90.4% of cases. The measurement of the ApA ranged from L2 to the coccyx, with values between +87.4 mm and -140.5 mm relative to the right iliac crest. Acute appendicitis was present in 15.9% of the patients and confirmed surgically. In these cases, the origin and ApA were significantly higher ($p=0.04$), while the ApB did not differ ($p=0.19$). Ap0 was lower in females ($p=0.03$). Vertebral levels correlated weakly with age, height, and body mass index (BMI).

Conclusion: The appendix location in adults was defined using vertebral and iliac bone references. It was most commonly located at the L5-S1 and S1 levels. On average, the origin was 41 mm below the right iliac crest, the ApA was 23 mm below, and the ApB was 60 mm below the right iliac crest. While vertebral-based levels varied with age, height, and BMI, iliac-based measurements remained stable. These findings may help limit CT scan range and reduce radiation exposure in suspected appendicitis.

Keywords: Appendix vermiformis, computed tomography, anatomical landmarks, iliac crest, vertebral level, radiation dose optimization

Introduction

The vermiform appendix is a small, tube-shaped organ located in the lower right part of the abdomen. It is part of the gastrointestinal system and arises from the posteromedial wall of the cecum. The average length of the appendix is around 9 cm but can vary between 2 and 20 cm.¹⁻³ The proximal origin of the appendix, which opens into the cecum, is relatively fixed, but its distal end can be found in various positions within the abdomen. Several studies have shown that the appendix is most commonly located in a retrocecal or pelvic position. Less frequently, it may be found in other positions, such as subcecal, preileal, retroileal, right paracolic, promontoric, or subhepatic.⁴⁻⁸ These anatomical variations can affect the location of pain when acute appendicitis occurs.⁵⁻⁸ For example, in cases of retrocecal appendicitis, abdominal pain might be felt on the side or back instead of the typical lower right quadrant. Wakeley's classic study, which included 10,000

autopsy cases, reported that the retrocecal position was the most common (65.3%), followed by the pelvic position (31%).⁷ However, some more recent studies suggest that the pelvic position may actually be more frequent.^{5,8}

More recent studies from different populations have shown variable distributions, such as retrocecal positions in approximately 36% and pelvic positions in about 25% among Nepalese cohorts. Imaging studies, including ultrasound and magnetic resonance imaging (MRI), have also highlighted the variability of appendix location *in vivo*. However, despite these numerous investigations, studies defining appendix localization using reproducible bony landmarks on computed tomography (CT) remain extremely limited.⁹⁻¹¹

Acute appendicitis is acute inflammation of the vermiform appendix and is the most common cause of acute abdomen requiring emergency

Cite this article as: Bingöl K, Zengin E. Use of vertebra and iliac bone as references in localization of vermiform appendix in computed tomography. Adv Radiol Imaging. 2025;2(3):45-51



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Received: 29.07.2025 **Accepted:** 08.09.2025 **Epub:** 07.10.2025 **Published:** 25.12.2025



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surgical intervention.^{12,13} It commonly occurs in adolescents and young adults, peaking in the second and third decades of life.¹⁴ Typically, acute appendicitis begins as mild visceral pain around the umbilicus. Within approximately 8 hours, the pain localizes to the right lower quadrant of the abdomen. However, some patients may experience atypical pain patterns and localization. Therefore, radiologic imaging is frequently used in the diagnosis of acute appendicitis.¹⁵

Currently, the primary imaging modalities used in suspected acute appendicitis are ultrasonography (US) and CT, while MRI can also be preferred when necessary.¹⁶ US is usually applied as the first step and can be useful in experienced hands, but it has limitations such as obesity, intestinal gas, and operator dependency.^{16,17} Regardless of these limitations, CT offers high diagnostic accuracy even in variable appendix positions. Furthermore, it can be applied even in cases of severe pain and can rule out other possible pathologies. The most significant disadvantages of CT are exposure to ionizing radiation and the risk of nephrotoxicity or allergic reactions when using contrast media.¹⁸ Reducing patient radiation exposure as much as possible in radiological applications forms the basis of the “As Low As Reasonably Achievable (ALARA)” principle.¹⁹ It is possible to reduce patient dose in CT by methods such as dose modulation, reducing kilovoltage, and narrowing the scanned area.²⁰ Studies investigating the use of low-dose CT in the diagnosis of acute appendicitis have shown that there is no significant loss in diagnostic visibility and accuracy despite dose reduction.²¹⁻²³ However, system features that can be utilized without additional expansion are essential, especially in CT scans performed with a preliminary diagnosis of appendicitis, where preserving an optimal field of view is also important. In such cases, narrowing the scan range often requires precise localization of the central region. This study aimed to precisely describe the location of the vermiform appendix relative to its bony structures to address this need.

Methods

The study was conducted with approval from the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (decision no: 2011-KAEK-27/2019-E.1900162336, date: 03.07.2024). Patients who presented to the emergency department with abdominal pain and underwent abdominal CT (with or without contrast) between January 1, 2015, and January 1, 2018, were screened for inclusion in the study. CT scans of 470 randomly selected patients were evaluated. Patients were excluded if the vermiform appendix could not be clearly visualized or if they had *situs inversus*, intestinal rotation anomalies, or previous abdominal surgery, including appendectomy (n=43). Ultimately, 427 adult patients were included in the study, and their clinical data were retrospectively reviewed. The study population predominantly represented Turkish adults, and demographic parameters such as age, sex, height, weight, and body mass index (BMI) distribution were recorded to enhance generalizability. All CT scans were evaluated in a single session by a single radiologist with 7 years of experience.

CT scans were obtained using a 64-detector multislice scanner with 120 kV, automatic mA modulation, 0.5-2 mm collimation, 0.5-1 s return slice, 3 mm cross-sectional area, and 1.5 mm reconstruction interval. All patients were scanned in the supine position with arms elevated, using the same scanner and standardized acquisition protocol. When intravenous contrast was administered, the same agent (iopromide, 300 mg/mL), 1 mL/kg, was applied.

Studies investigating the use of low-dose CT in the diagnosis of acute appendicitis have shown that there is no significant loss in diagnostic visibility and accuracy despite dose reduction. In our study, appendix origin (Ap0) was defined as the precise point where the appendiceal lumen communicates with the cecum., highest point (ApA), and lowest point (ApB) were defined as the most cranial and caudal points along the entire appendix course, irrespective of medial or lateral curvature. The method used for localization based on vertebral reference, was as follows: after identifying the highest and ApBs' of the appendix on axial CT images, multiplanar reconstructions in the coronal and sagittal planes were examined to determine the corresponding vertebral level. Vertebral levels were categorized from L1 to the coccyx using the following grouping system: L1 (L1 vertebral body or L1-L2 disc space), L2 (L2 body or L2-L3 disc space), L3, L4, L5 (L5 body or L5-S1 space), S1, S2, S3, S4, S5, and coccyx. The technique used to localize the appendix with vertebral landmarks is illustrated in Figure 1 of the original article.

A more quantitative measurement method for localization was used, using the iliac bone as a reference. The ApA, ApB, and Ap0 of the appendix were marked on axial CT scans, and the vertical distance from these points to the highest point (crista iliaca) of the right iliac bone was measured on coronal maximal intensity projection images. While measuring, the vertical distance from the appendix point to the line drawn from the highest point of the right crista iliaca to the horizontal plane was taken. The appendix point was recorded as a positive (+) value if it was above the iliac bone reference point, and as a negative (-) value if it was below. Thus, Ap0, ApA, and ApB values were obtained in millimeters for each patient (Figure 2).

The study also assessed the orientation of the vermiform appendix. If the tip of the appendix was located at a level higher than its origin at the cecum, it was classified as “ascending”; if it was lower, it was classified as “descending”. The course (ascending or descending) of the appendix was recorded for each patient. Additionally, the vertical orientation of the appendiceal lumen was specifically evaluated in the acute appendicitis group.

Demographic data and some anthropometric measurements of the patients were also recorded: age, sex, height, and weight were obtained from patient files. BMI was calculated in kg/m².

Statistical Analysis

Data were analyzed using SPSS v20.0 (IBM Corp., Armonk, NY, USA). Normality was assessed with the Kolmogorov-Smirnov test. Continuous variables were expressed as mean \pm SD, minimum-maximum, and categorical variables were expressed as numbers and percentages. The chi-square test was used to compare categorical data between the acute appendicitis and appendicitis groups. Student's t-test compared continuous variables (Ap0, ApA, ApB) between genders. Pearson's correlation evaluated the relationships between ApA/ApB and height, weight, BMI, and age. A p value <0.05 was considered statistically significant.

Results

Of the 427 patients included in the study, 206 were female (48.2%) and 221 were male (51.8%). The mean age was 42.1 \pm 19.5 years (range 18 to 90). Of the CT scans, 200 (46.8%) were performed with contrast, and 227 (53.2%) were performed without contrast. The mean BMI was 25.6 \pm 6.4 kg/m² (range 16.8-40.5).

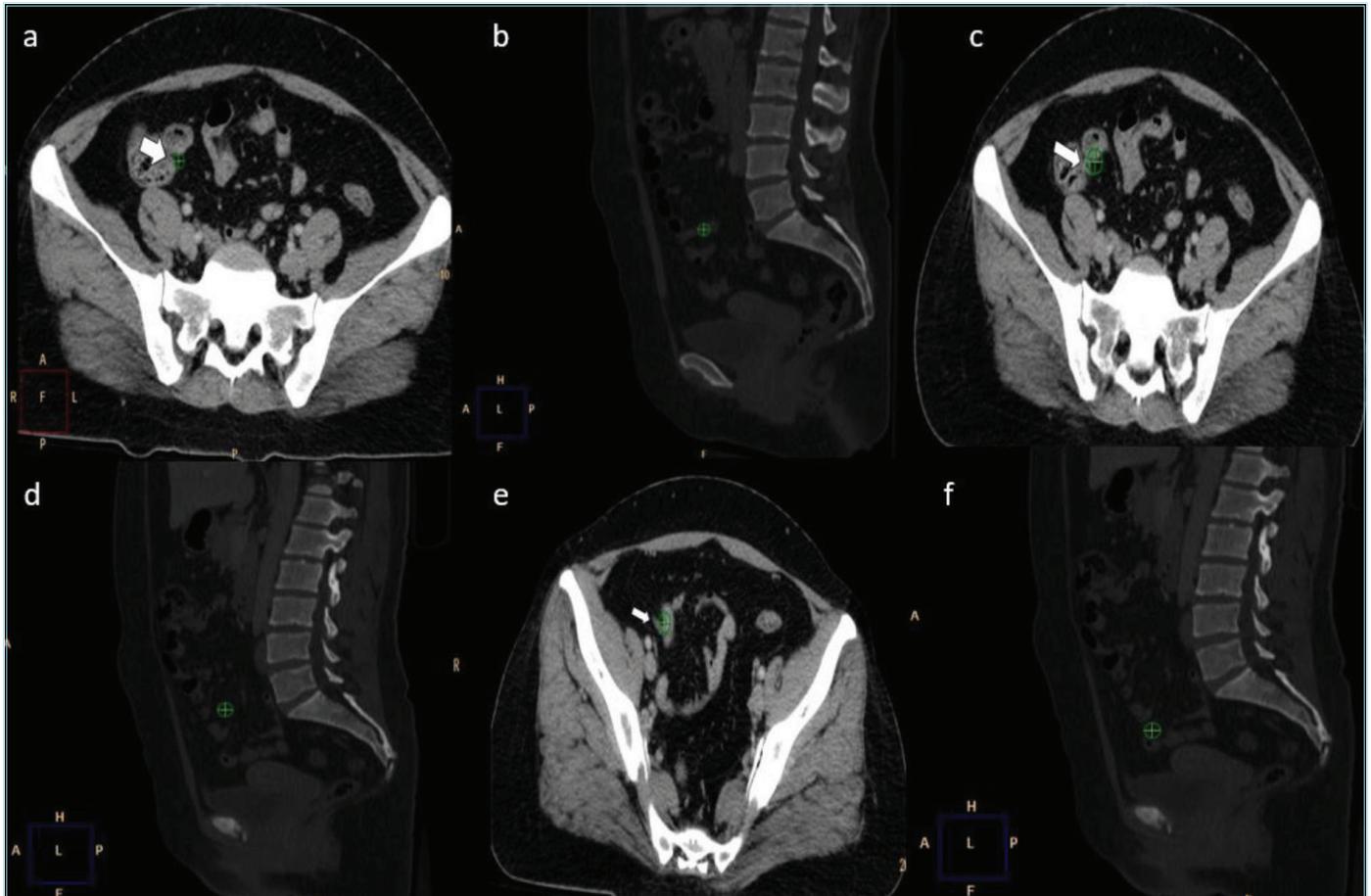


Figure 1. Method for determining the localization of the vermiform appendix using vertebral reference (example from a single patient). (a) The origin at the cecum (Ap0, white arrow) is marked on the axial CT image and corresponds to the L5-S1 intervertebral disc level on the sagittal reconstruction (b, green marker). (c) The highest point of the appendix (ApA, white arrow) is marked on the axial CT image and corresponds to the L5 vertebral body level on the sagittal reconstruction (d, green marker). (e) The lowest point of the appendix (ApB, white arrow) is marked on the axial CT image and corresponds to the S3 vertebral body level on the sagittal reconstruction (f, green marker)

CT: Computed tomography, Ap0: Appendix origin, ApA: Highest point, ApB: Lowest point

CT scans revealed signs of acute appendicitis in 68 patients (15.9%), and this diagnosis was confirmed by pathological examination of surgical specimens. In the remaining 359 patients (84.1%), the appendix appeared normal, and no appendicitis-related pathology developed in these patients during clinical follow-up. In most (more than 90%) of these patients with non-acute-appendicitis abdominal pain, the pain resolved spontaneously or with medical treatment. In a small subset of patients (8.5%), CT scan and clinical correlation revealed non-appendicitis causes of pain; these included omental infarction, sigmoid diverticulitis, epiploic appendicitis, sigmoid volvulus, mesenteric panniculitis, acute cholecystitis, inflammatory bowel disease, and ischemic colitis.

The appendix vermiformis was observed to have an ascending course in the majority of the population. Table 1 compares the course of the appendix in the acute appendicitis group and the normal appendix group. Overall, the tip of the appendix was higher (ascending) than the origin in 90.4% of cases, and the tip of the appendix terminated lower in 9.6%. Similarly, in patients with acute appendicitis, the appendix most often had an ascending course (89.7%). No statistically significant difference was found between the presence of acute appendicitis and the ascending/descending course of the appendix ($p=0.41$).

The vertical position values of the appendix measured with respect to the right iliac bone reference are summarized in Table 2. The mean, minimum, and maximum values of Ap0, ApA, and ApB measurements, in the normal appendix and acute appendicitis groups, are given in millimeters. In the acute appendicitis group, the Ap0 and ApA were found to be significantly less negative with respect to the right iliac bone reference compared to the normal population ($p=0.04$). However, no significant difference was found between the acute and normal groups with respect to the ApB ($p=0.19$).

In the analysis by gender, ApA and ApB measurements were similar between male and female patients ($p=0.08$ and $p=0.21$, respectively), however, Ap0, the level of origin of the appendix, was statistically lower in females than in males ($p=0.03$). The mean Ap0 value relative to the iliac bone reference was -48 mm in females and -34 mm in males (Table 3).

According to Table 2, the vermiform appendix is located approximately 40 mm below the reference point of the right iliac crest in the general population. The highest point of the appendix is generally below the reference point, but it has been observed to reach 87.4 mm above it in one instance (in one case, the appendix tip was found 87 mm above the reference point). The ApB of the appendix is usually below the reference



Figure 2. Method for determining the localization of the vermiform appendix using the right iliac crest as a reference (same patient as in Figure 1). The Ap0, ApA, and ApB were first marked on axial CT images (a, c, e, white arrows, green markers). For each point, the corresponding location was identified in the coronal plane (see figures b, d, f), in which the vertical distance to the horizontal line passing through the highest point of the right iliac crest was measured at a 90° angle. Distances from Ap0, ApA, and ApB to the iliac crest reference plane were 48.5 mm, 48.6 mm, and 83.7 mm, respectively.

CT: Computed tomography, Ap0: Appendix origin, ApA: Highest point, ApB: Lowest point

Table 1. Orientation of the appendiceal lumen course - general population, acute appendicitis group and normal appendiceal group (n, %)

Group	Ascending n (%)	Descending n (%)	Total n (%)
Acute appendicitis (n=68)	61 (89.7)	7 (10.3)	68 (15.9)
Normal appendix (n=359)	325 (90.5)	34 (9.5)	359 (84.1)
Total (n=427)	386 (90.4)	41 (9.6)	427 (100)

Table 2. Appendix position measurements (in mm) relative to the right iliac bone reference. The mean ± standard deviation and minimum-maximum range of each value are given in parentheses. Negative (-) values indicate positions below the reference point

Group	Ap0 (mean ± SD; min-max)	ApA (mean ± SD; min-max)	ApB (mean ± SD; min-max)
Acute appendicitis (n=68)	-34.1±29.1; (-100.8-+44.2)	-17.1±27.8; (-84.8-+48.3)	-60.9±27.9; (-121.6-+39.1)
Normal appendix (n=359)	-42.3±31.5; (-126.0-+40.1)	-24.2±34.1; (-126.0-+87.4)	-59.8±30.2; (-140.5-+44.1)
Toplam (n=427)	-41.0±32.7; (-126.0-+44.2)	-23.0±30.8; (-126.0-+87.4)	-60.0±30.2; (-140.5-+44.1)

SD: Standard deviation, min-max: Minimum-maximum, Ap0: Appendix origin, ApA: Highest point, ApB: Lowest point

Table 3. Position measurements of the appendix relative to the right iliac bone reference - comparison by gender (means, mm)

Sex	Ap0 (mean ± SD)	ApA (mean ± SD)	ApB (mean ± SD)
Female (n=206)	-48.1±30.0	-26.2±30.4	-60.4±31.1
Male (n=221)	-34.3±29.7	-20.0±29.8	-59.6±30.8
Total (n=427)	-41.0±32.7	-23.0±30.8	-60.0±30.2

SD: Standard deviation, Ap0: Appendix origin, ApA: Highest point, ApB: Lowest point

point, reaching a maximum of 140.5 mm (Table 2). In patients with acute appendicitis, the origin of the appendix, and particularly its apex, was measured higher than the reference plane than in normal patients. In other words, the appendix tended to assume a more vertical position within the abdomen when inflamed. The appendix's ApB, however, was unaffected by the inflammation.

The localization of the appendix relative to the vertebral column was assessed by the distribution of the ApA and ApB vertebral levels, determined for each case. In the population, the uppermost anatomical location of the appendix (ApA) was found at various levels, starting from the L2 corpus level and extending to the end of the sacrum and the coccyx. The ApB showed a similar distribution, extending from the L2 level to the coccyx. In the majority of cases, the highest point of the appendix was found at the L5 corpus level or the L5-S1 disc space (34.4%). The ApB of the appendix was most frequently found at the S1 corpus level (22.5%).

The highest and lowest appendix vertebral levels were calculated in all cases. When the acute appendicitis and normal appendix groups were compared, no significant difference was found in ApA and ApB levels according to the vertebral reference localization ($p=0.19$). A noteworthy finding was that the tip of the appendix was not above the level of the L3 corpus in any patient with acute appendicitis. In all cases of appendicitis, the apex of the appendix was located at or below the level of L3.

Low-level negative correlations were found between the appendix's location referenced to the vertebra and patients' anthropometric measurements. As patients' age, height, and BMI increased, the appendix's apex (ApA) and (ApB) tended to be slightly more caudal (downward) in the vertebral column (e.g., correlation coefficient between ApA and height: $R=-0.13$). On the other hand, no significant correlation was found between the appendix's vertical distance measurements referenced to the iliac crest (ApA and ApB values, mm) and these anthropometric variables ($p>0.1$, R values less than ~ 0.1). This finding suggests that appendix location remains constant relative to the iliac crest, even with variations in body structure across individuals.

Discussion

This can be achieved by defining the location of the vermiform appendix using metric reference points. For this purpose, we used the right iliac bone (pelvis) and the vertebral column as reference points. Using these reference points, we identified the location of the appendix and its variants, while also examining some anthropometric characteristics and the relationship between these locations and the presence of acute appendicitis. Our results indicated a poor correlational relationship among the location of the appendix's apex (ApA) and apex (ApB) at the vertebral levels and the patients' age, height, and BMI. In other words, as patients aged or grew taller, the appendix did not appear to be lower in relation to the spine. Conversely, the appendix's location relative to the iliac bone (ApA and ApB distance values) did not show a similar pattern of stability; variables such as age and physique did not alter the location of the appendix. In addition, while no difference was found in the distribution of the highest and ApBs' of the appendix with reference to the iliac bone between men and women, the Ap0 levels were observed to be slightly lower in one group compared to the other.

The need for imaging in medicine is growing faster than in many other fields.²⁴ Today's clinicians increasingly rely on imaging to confirm clinical predictions and plan management, even in abdominal emergencies such as acute appendicitis. Over the past 20 years, CT's success in

diagnosing appendicitis has led to a sharp increase in its frequency of use. Many centers now routinely use CT as the first choice for suspected appendicitis.²⁵ This change also means an increase in the amount of radiation to which patients are exposed. In radiology practice, the ALARA principle has gained universal acceptance to limit unnecessary radiation exposure.²⁶ Narrowing the imaging field is one practical way to reduce patient exposure. Therefore, it is important to understand the appendix's location in the population and, based on this knowledge, limit the CT scan field.²⁷ In addition to cadaveric studies, laparoscopic series have also provided valuable data on appendix localization. For instance, Ahmed et al.¹¹ observed that the pelvic position was the most frequent (51%), while the retrocecal location accounted for only 20%, highlighting the variability of appendix position across different study methods and populations. There are various studies in the literature on the CT imaging rate of the appendix vermiformis, the distribution of its tip positions, and its rare localizations.²⁸⁻³⁰ However, to our knowledge, the number of studies defining the localization of the appendix by reference to bony structures is extremely limited. In the existing literature, only one study by Davis et al.,³¹ conducted in a pediatric population, aimed to localize the apex of the appendix relative to the vertebral column. In that study, the highest point of the appendix (our definition of ApA) in pediatric patients was most frequently found at the level of the L5 vertebra. Similarly, in our adult population, ApA was most frequently found at the L5-S1 level. Furthermore, our study demonstrated that the highest level of the appendix in patients with acute appendicitis did not extend above L3, supporting the findings of Davis et al.'s³¹ pediatric series in adults. We also demonstrated that in the adult population, the position of the appendix relative to the spine is inversely related to variables such as height and age. This can be interpreted as a relative downward shift in the abdominal position of the appendix during the transition from childhood to adulthood with body growth.

For the first time in the literature, our study defines the location of the appendix in the adult population using the right iliac bone as a reference. Our findings indicate that although the appendix can exhibit a wide range of positions relative to the right iliac crest reference (ranging from +87 mm to -140 mm), the average appendix position relative to this reference does not vary significantly from patient to patient. In the acute appendicitis group, the origin and apex of the appendix were found to be slightly higher compared to the iliac crest; however, this mean difference was small (~ 7 mm) and, although statistically significant, may fall within the range of measurement variability. Therefore, this finding should be interpreted with caution and considered a subtle statistical observation rather than a clinically meaningful shift. Interestingly, in the acute appendicitis group, the origin and apex of the appendix were found to be higher than the reference point, indicating that the appendix assumes a more vertical position during inflammation. Alternative explanations, such as peritoneal fluid, patient positioning, or shallow breathing, may also account for this apparent cranial displacement. Thus, the observed difference, while noteworthy, should not be overinterpreted as a physiological mechanism. Indeed, in our study, the tip of the appendix in patients with appendicitis was found to be approximately 7 mm higher than in normal cases (Table 2). While this difference was not statistically detectable, in the vertebra-based assessment, it was found to be significant in the millimetric iliac bone reference measurements. This suggests that the iliac bone reference may be more sensitive in assessing appendiceal position changes in conditions such as inflammation. Furthermore, it can be argued that factors such as vertebral height may mask millimetric

changes, and therefore, the effect of appendicitis at the level of the appendix is not statistically significant when the vertebra reference is used. Furthermore, the appendix position relative to the iliac bone reference being independent of characteristics such as patient height or BMI offers a significant advantage. From this perspective, the right crista iliaca may be a more reliable reference point for identifying the area to search for the appendix in cases of suspected acute appendicitis.

Study Limitations

This single-center, retrospective study has limitations, including lack of interobserver analysis, exclusion of pediatric cases, and lack of a surgical reference standard. CT-based measurements may vary in larger samples; prospective studies are needed to evaluate diagnostic accuracy and radiation reduction.

Conclusion

This study mapped the radiological anatomy of the vermiform appendix in an adult population. The highest point of the appendix was most frequently found at the L5 corpus-L5/S1 intervertebral disc level (34.4%), and the ApB was most frequently found at the S1 corpus level (22.5%). Using the right iliac crest as a reference point, the origin of the appendix opening into the cecum was located an average of 41 mm below the appendix's origin, with the highest point 23 mm below, and the ApB 60 mm below. While localization analyses based on the vertebral column showed variations based on patient anthropometric characteristics, no such variation was observed in analyses based on the iliac bone. Our study findings, by demonstrating the anatomical positioning of the appendix using bone structure as a reference, pave the way for future research to optimize imaging in cases of suspected acute appendicitis and thereby reduce unnecessary radiation exposure.

Ethics

Ethics Committee Approval: The study was conducted with approval from the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (decision no: 2011-KAEK-27/2019-E.1900162336, date: 03.07.2024).

Informed Consent: Since the study was a retrospective study, informed consent was not required by the ethics committee.

Footnotes

Authorship Contributions

Surgical and Medical Practices: K.B., E.Z., Concept: K.B., E.Z., Desing: K.B., E.Z., Data Collection or Processing: K.B., E.Z., Analysis or Interpretation: K.B., E.Z., Literature Search: K.B., E.Z., Writing: K.B., E.Z.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study received no financial support.

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