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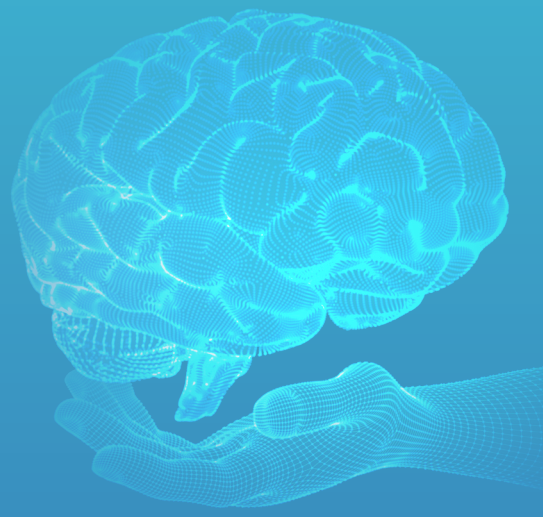

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RESEARCH ARTICLE

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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

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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. Owever, 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 ± 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±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±6.4 kg/m² (range 16.8-40.5).

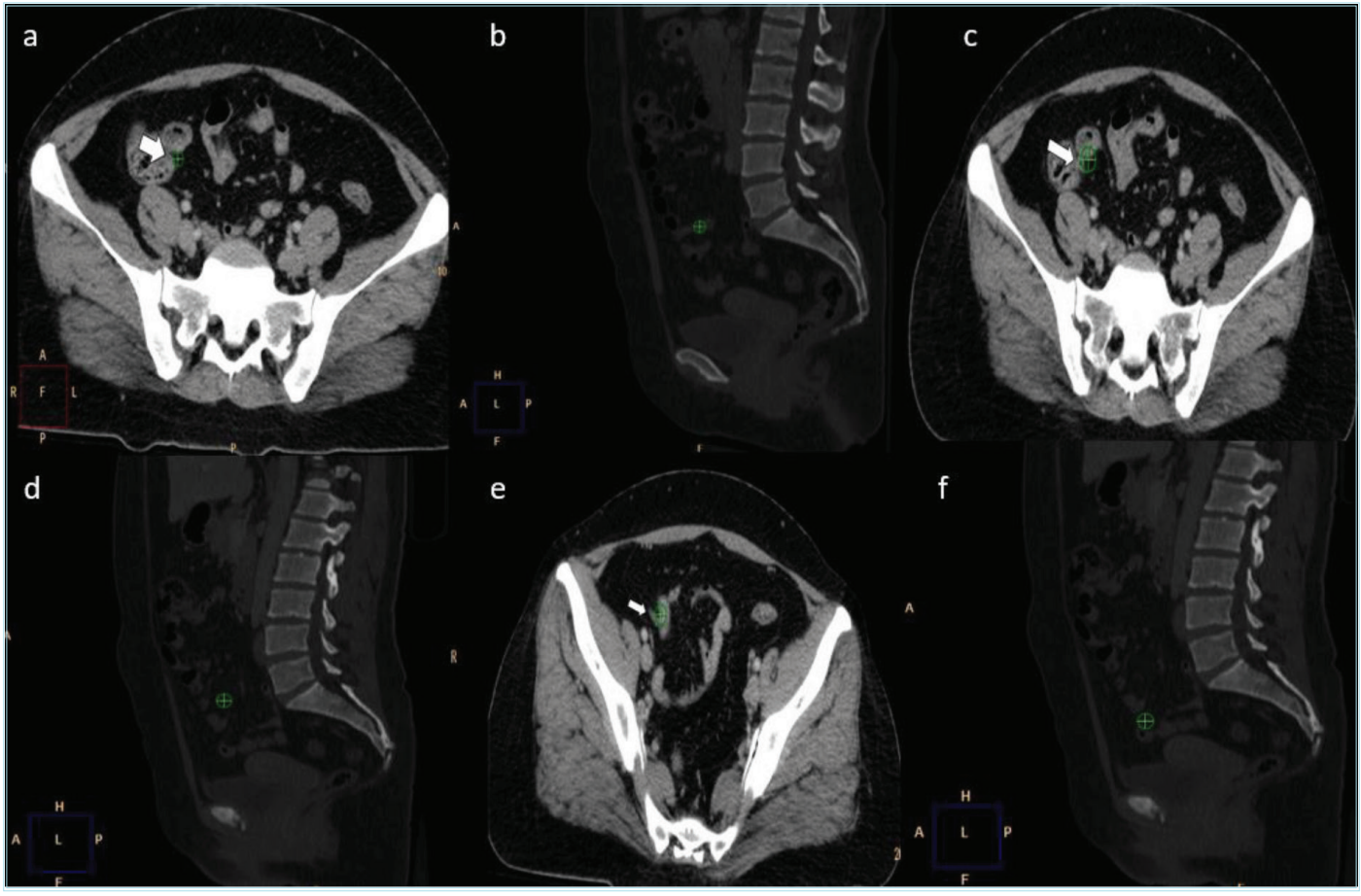

Figure 1. Method for determining the localization of the vermiform appendix using vertebral reference (example from a single patient). (a) The origin at the cecum (Ap0, white arrow) is marked on the axial CT image and corresponds to the L5-S1 intervertebral disc level on the sagittal reconstruction (b, 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

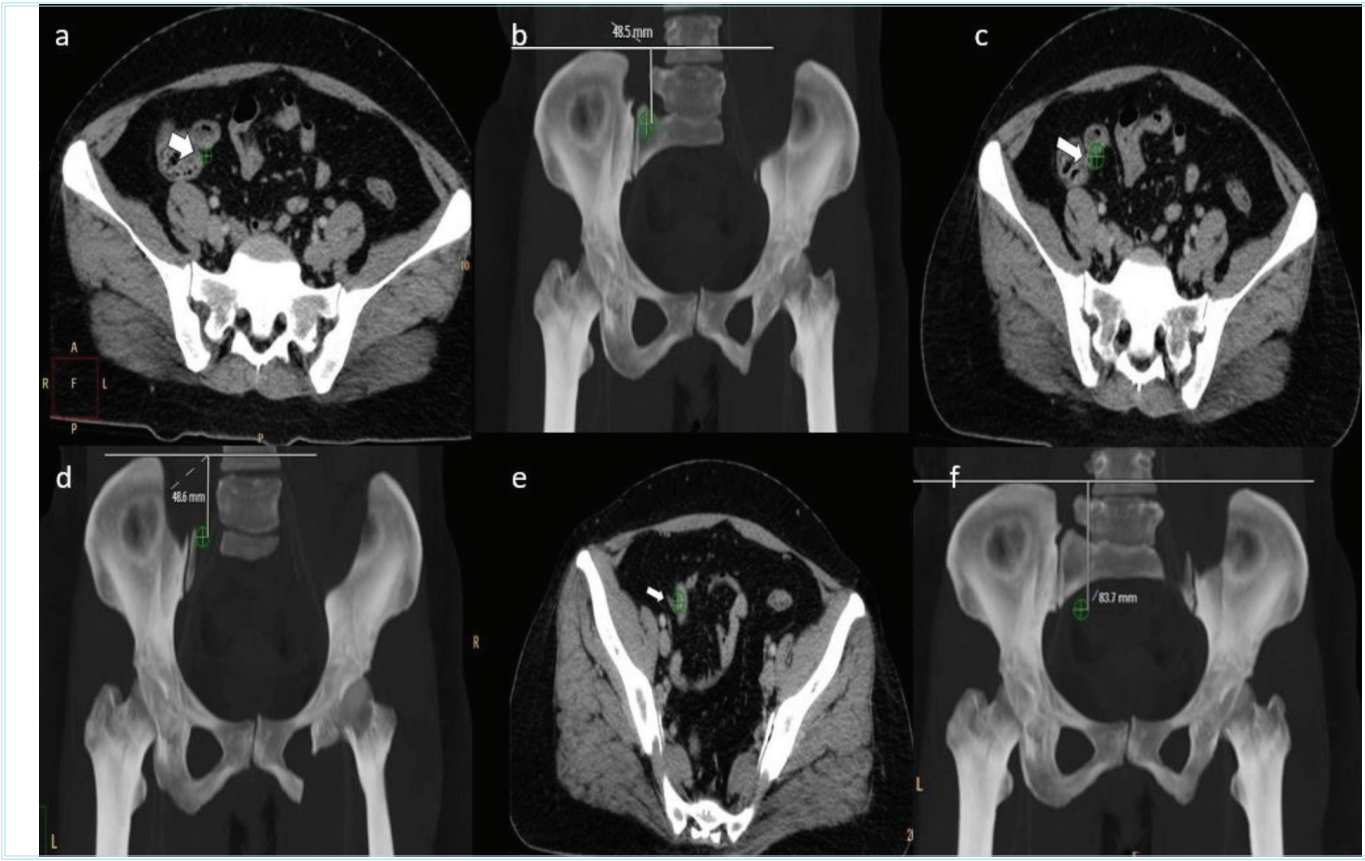

Figure 2. Method for determining the localization of the vermiform appendix using the right iliac crest as a reference (same patient as in Figure 1). The Ap0, ApA, and ApB were first marked on axial CT images (a, c, e, white arrows, green markers). For each point, the corresponding location was identified 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.'s[31] 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.

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References

1. Aminova GG. [Structure and cytoarchitectonic of the lymphoid tissue of the Appendix of man in elderly and senile ages.]. Adv Gerontol. 2018;31:273-9. Russian.
2. Ghorbani A, Forouzesh M, Kazemifar AM. Variation in anatomical position of vermiform appendix among iranian population: an old issue which has not lost its importance. Anat Res Int. 2014;2014:313575.
3. de Souza SC, da Costa SRMR, de Souza IGS. Vermiform appendix: positions and length – a study of 377 cases and literature review. Journal of Coloproctology. 2015;35:212-6.
4. Wakeley CP. The position of the vermiform appendix as ascertained by an analysis of 10,000 cases. J Anat. 1933;67:277-83.
5. Denjalić A, Delić J, Delić-Custendil S, Muminagić S. Varijacije polozaja i mjesta nastanka appendix vermiformis utvrdene tokom klasicne apendektomije [Variations in position and place of formation of appendix vermiformis found in the course of open appendectomy]. Med Arh. 2009;63:100-1. Bosnian.
6. Di Saverio S, Podda M, De Simone B, et al. Diagnosis and treatment of acute appendicitis: 2020 update of the WSES Jerusalem guidelines. World J Emerg Surg. 2020;15:27.
7. Deshmukh S, Verde F, Johnson PT, Fishman EK, Macura KJ. Anatomical variants and pathologies of the vermix. Emerg Radiol. 2014;21:543-52.
8. Schumpelick V, Steinau G, Schlüper I, Prescher A. Surgical embryology and anatomy of the diaphragm with surgical applications. Surg Clin North Am. 2000;80:213-39.
9. Hodge BD, Kashyap S, Khorasani-Zadeh A. Anatomy, abdomen and pelvis: appendix. 2023.
10. Kim K, Kim YH, Kim SY, et al. Low-dose abdominal CT for evaluating suspected appendicitis. N Engl J Med. 2012;366:1596-605.
11. Ahmed I, Asgeirsson KS, Beckingham IJ, Lobo DN. The position of the vermiform appendix at laparoscopy. Surg Radiol Anat. 2007;29:165-8.
12. Paul UK, Naushaba H, Begum T, Alam MJ, Alim J, Akther J. Position of vermiform appendix: a postmortem study. Bangladesh Journal of Anatomy. 2009;7:34-6.
13. Constantin M, Petrescu L, Mătanie C, et al. The vermiform appendix and its pathologies. Cancers (Basel). 2023;15:3872.
14. Bhangu A, Søreide K, Di Saverio S, Assarsson JH, Drake FT. Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management. Lancet. 2015;386:1278-87.
15. Hardin DM Jr. Acute appendicitis: review and update. Am Fam Physician. 1999;60:2027-34.
16. Hwang ME. Sonography and computed tomography in diagnosing acute appendicitis. Radiol Technol. 2018;89:224-37.
17. Love BE, Camelo M, Nouri S, Kriger D, Ludi D, Nguyen H. Ultrasound accuracy in diagnosing appendicitis in obese pediatric patients. Am Surg. 2017;83:1063-7.
18. Bahrami M, Mirgaloyebayat H, Mohajeri Z, et al. The diagnostic value of the computed tomography scan and ultrasonography in acute appendicitis. Am J Nucl Med Mol Imaging. 2023;13:11-7.
19. Frane N, Bitterman A. Radiation safety and protection. [Updated 2023 may 22]. In: StatPearls [Internet]. Treasure island (FL): StatPearls publishing; 2025.
20. Dixon MT, Loader RJ, Stevens GC, Rowles NP. An evaluation of organ dose modulation on a GE optima CT660-computed tomography scanner. J Appl Clin Med Phys. 2016;17:380-91.
21. Keyzer C, Tack D, de Maertelaer V, Bohy P, Gevenois PA, Van Gansbeke D. Acute appendicitis: comparison of low-dose and standard-dose unenhanced multi-detector row CT. Radiology. 2004;232:164-72.
22. Fefferman NR, Bomsztyk E, Yim AM, et al. Appendicitis in children: low-dose CT with a phantom-based simulation technique--initial observations. Radiology. 2005;237:641-6.
23. Sippola S, Virtanen J, Tammilehto V, et al. The accuracy of low-dose computed tomography protocol in patients with suspected acute appendicitis: the OPTICAP study. Ann Surg. 2020;271:332-8.
24. Bercovich E, Javitt MC. Medical imaging: from roentgen to the digital revolution, and beyond. Rambam Maimonides Med J. 2018;9:e0034.

25. Debnath J, George RA, Ravikumar R. Imaging in acute appendicitis: what, when, and why? Med J Armed Forces India. 2017;73:74-9.

26. Winder M, Owczarek AJ, Chudek J, Pilch-Kowalczyk J, Baron J. are we overdoing it? Changes in diagnostic imaging workload during the years 2010-2020 including the impact of the SARS-CoV-2 pandemic. Healthcare (Basel). 2021;9:1557.

27. Vogiatzi T, Menz R, Verna C, Bornstein MM, Dagassan-Berndt D. Effect of field of view (FOV) positioning and shielding on radiation dose in paediatric CBCT. Dentomaxillofac Radiol. 2022;51:20210316.

28. Altunkas A, Aktas F, Ozmen Z, Albayrak E, Demir O. The normal vermiform appendixin adults: its anatomical location, visualization, and diameter at computed tomography. J Anat Soc India. 2022;71:225-33.

29. Turkoglu H, Onur MR, Poyraz AK, Kocakoc E. Evaluation of normal appendix vermiformis in adults with multidetector computed tomography. Clin Imaging. 2012;36:758-62.

30. Zacharzewska-Gondek A, Szczurowska A, Guziński M, Sąsiadek M, Bladowska J. A pictorial essay of the most atypical variants of the vermiform appendix position in computed tomography with their possible clinical implications. Pol J Radiol. 2019;84:e1-8.

31. Davis J, Roh AT, Petterson MB, et al. Computed tomography localization of the appendix in the pediatric population relative to the lumbar spine. Pediatr Radiol. 2017;47:301-5.

RESEARCH ARTICLE

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Prevalence and Distribution of Coronary Artery Origin Anomalies: A Comparative Review of MDCT-Based Studies (2015-2025)

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Abstract

Objectives: Coronary artery origin variations are uncommon congenital anomalies, but their recognition is critical due to potential clinical consequences such as myocardial ischemia or sudden cardiac death. An original 2019 Turkish multidetector computed tomography (MDCT) study reported a 2.5% prevalence of coronary origin variations among 1,238 patients. We aim to update these findings with recent large-cohort data from the past decade, comparing prevalence rates and patterns of coronary origin anomalies across populations.

Methods: Large cohort studies and systematic reviews reporting the prevalence of anomalies of coronary artery origin in adult populations evaluated by coronary computed tomography angiography, between 2015 and 2023, were reviewed. The types and frequencies of variations in the selected studies were comparatively analyzed according to the classification used in the original Turkish study.

Results: In recent MDCT-based studies, the prevalence of anomalous coronary origin in adults has generally been reported as 1-3%. The most common variants are a separate left anterior descending artery - left circumflex artery ostia and right coronary artery arising from the contralateral sinus.

Conclusion: As demonstrated by the conducted studies, the prevalence of coronary artery origin anomalies is low but not negligible. Clinicians and radiologists should remain aware of these variations and utilize advanced imaging modalities to guide appropriate management or intervention when necessary.

Keywords: Coronary artery, variation, anomaly, MDCT, CTA, prevalence

Introduction

Coronary arteries are among the most common sites of vascular anatomical variants in the human body.[1] A coronary artery "anomaly" of origin is typically defined as a congenital variation in the origin and/or course of a coronary artery that deviates from normal anatomy.[1] In the general population, such anomalies are uncommon, with older invasive angiography data suggesting rates close to 1%.[2] Reports over the past several decades indicate that prevalence can vary widely - from below 0.5% to as high as 5-6%- depending on the study population and the imaging technique used. Autopsy studies tend to yield lower estimates (~0.2-0.3%), whereas dedicated imaging studies can detect higher rates (up to a few percent).[1] Clinically, most coronary origin anomalies are asymptomatic and discovered incidentally, but certain variants have serious implications. Anomalous coronary origins that course between the aorta and pulmonary trunk (interarterial course) or originate from the pulmonary artery [e.g. anomalous left coronary artery from the pulmonary artery (ALCAPA) or anomalous right coronary artery (RCA) from the pulmonary artery] can lead to myocardial ischemia, arrhythmias, or even sudden cardiac death - especially during exertion in young athletes. Indeed, coronary anomalies are recognized as a notable cause of sudden death in the young. Thus, identifying these variants before they cause complications is important.[1]

Multidetector computed tomography (MDCT) coronary angiography has emerged as a preferred noninvasive diagnostic tool for evaluating coronary anatomy. MDCT offers high-resolution, three-dimensional visualization of the coronary origins and course, enabling precise identification of anomalies that might be challenging to appreciate on conventional angiograms. The increasing use of coronary computed tomography (CT) in both the workup of chest pain and in health screenings has consequently led to more frequent recognition of incidental coronary variants.[3]

In 2019, Güven and Kantarcı[4] conducted a single-center Turkish study using MDCT to evaluate coronary artery origin variations in 1,256 adults. They identified 31 patients with anomalies, achieving a prevalence of 2.5%. The variants identified included high take-off, separate left anterior ascending artery (LAD), and left circumflex artery (LCx) origins,

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opposite sinus origins, and a single coronary artery. While slightly higher than previous reports, the prevalence was consistent with the literature, which indicates approximately 2% in the general population. Their findings reinforced the importance of recognizing such variants and demonstrated the utility of MDCT in accurately characterizing them.[4]

Since 2019, numerous large cohort studies and reviews have further explored coronary artery anomalies, facilitated by the widespread use of CT angiography.[3,5-8] The present work is designed as a narrative literature review rather than an original patient-based investigation. Using the 2019 Turkish study as a reference, this article updates the incidence rates of coronary origin anomalies, compares subtype frequencies among populations, and assesses consistencies or differences with recent evidence.[4] By explicitly adopting a narrative review format, the aim is to synthesize and contextualize the available data from recent large-cohort studies, rather than to perform a new statistical analysis. This study aims to clarify the current prevalence and dominant variants by summarizing contemporary data. Enhanced awareness will assist clinicians in recognizing these anomalies and guiding appropriate patient management.

Methods

Study Design

This study is a narrative literature review and comparative analysis. Rather than being based on a new patient cohort, this study is structured as an integrative research review and analysis. We followed a format analogous to an original investigation, using published data as our "sample". The methodology involved a systematic literature search and data extraction to characterize the prevalence of coronary artery origin variations in recent studies. The design and definitions from the original 2019 Turkish study were used solely as a reference framework to maintain consistency in anomaly categorization.

Literature Search

The literature search (PubMed, Google Scholar, 2015-2025) used terms such as "coronary artery anomaly," "variant of origin," and "CT angiography." We included adult studies reporting the prevalence of congenital coronary anomalies of origin/course, focusing on large cohorts, registries, and reviews. Key references were also searched. In total, about 50 studies were screened by title and abstract. Twelve met the criteria after full-text review, and four recent large MDCT-based cohorts from different regions were chosen for the table as they provided the most consistent prevalence data. Other important works, including large registries and meta-analyses, were not in the table but are discussed in the text.

Inclusion Criteria

We included studies that (1) evaluated coronary anatomy in a sizable population (preferably n>1,000 for robust prevalence estimates); (2) used imaging modalities capable of delineating coronary origin anatomy (such as MDCT angiography, conventional angiography, or MR angiography); and (3) reported the prevalence or number of coronary artery origin anomalies detected. If more than one study from the same population existed, the most recent and comprehensive dataset was preferred.

Data Extraction

For each eligible study, data on the sample size, study population characteristics, and number of coronary artery anomalies were extracted. Detailed breakdowns of anomaly subtypes were recorded when available. Variations in definitions (e.g., the height threshold for "high take-off") across studies were noted in the methods sections of each paper.

Statistical Analysis

The extracted data were tabulated to allow side-by-side comparison of overall anomaly prevalence and specific variant frequencies across studies. No formal meta-analysis or statistical pooling was performed, consistent with the narrative review design. Instead, a descriptive comparative approach was used. We assessed whether the differences in prevalence between studies fell within expected statistical variation (considering sample sizes) or suggested systematic factors (such as regional genetic differences or imaging modality sensitivity).

Quality and Bias Consideration

Each study was specifically assessed for selection bias (e.g., symptomatic vs. general populations). We carefully considered whether myocardial bridging was included in the study because its inclusion may increase prevalence. Our analysis focused solely on anomalies of origin. No new patient data were used, so IRB approval was not required. All included studies underwent peer review with the assumption of ethical oversight.

Ethical Considerations

All coronary CT angiography images (Figures 1-4) are original cases from the authors' institutional archive, acquired on a Siemens Somatom Definition Flash, 128-slice MDCT scanner, as part of routine diagnostic workup. Images were selected to illustrate specific anomaly types discussed in this review. No patient identifiers are present, and all images were fully anonymized prior to inclusion. The study was conducted with approval from the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (decision no: 2024-10/07, date: 03.07.2024). Written informed consent for this use was obtained during the initial review.

Statistical Notes

Where relevant, we comment on differences in prevalence in light of sample size (e.g., using the binomial confidence intervals to judge if differences are statistically significant). No new statistical tests were performed on combined data, but we cited any statistical comparisons reported in the original studies or reviews (for example, comparisons of anomaly rates between imaging modalities or populations). All numerical results from the literature are accompanied by citations to their sources.

By employing the above methods, this narrative review aims to provide a rigorous and up-to-date comparison of coronary artery origin variation data, placing recent findings in the context of previous literature rather than generating new patient-level data.

Results

Study Selection

Our search identified more than 50 studies on coronary artery anomalies published in the last decade. We selected approximately a dozen key sources reporting prevalence data, including six recent single-center CT angiography studies from various regions and two major reviews (one systematic and one narrative). Table 1 compares four of these with the 2019 Turkish reference study.[3-5,8] The selected studies for the table provide a geographic and methodological spread: two from Türkiye (including the reference study), one from Greece, and one from Iran, all using MDCT, with sample sizes ranging from ~1,200 to ~5,200 patients.[3-5,8]

Overall Prevalence

Across the surveyed literature, the prevalence of coronary artery origin anomalies detected by MDCT angiography in adult populations generally falls between about 1% and 3%. This aligns well with the reference value of ~2% often cited in the context of coronary anomalies. For instance, Graidis et al.[3] in Greece reported 60 anomalous cases among 2,572 CT patients - an incidence of 2.33%. Gräni et al.[6] in Switzerland found an incidence of 2.6% in a CT cohort of 5,634, one of the largest CT series to date. A 2022 Turkish MDCT study by Şahin and Ilgar[8], involving 5,200 patients, yielded an overall anomaly prevalence of 2.61% (136 patients), remarkably close to the smaller 2019 Turkish study's 2.5%.[4] On the other hand, slightly lower rates have been documented in some populations: Andishmand et al.[5] reported 1.26% in 3,016 Iranian patients undergoing CT, and Al-Umairi et al.[7] found 1.3% in 4,445 Omani patients. Notably, these differences might reflect sample characteristics (e.g., referral patterns or ethnic/genetic factors) or could arise from the handling of variants like myocardial bridges. In support of the latter, it's worth noting that if myocardial bridging (a common benign variant) is excluded, the prevalence numbers tend to cluster closer to ~1-2%, whereas including bridging can raise the "anomaly" rate substantially.

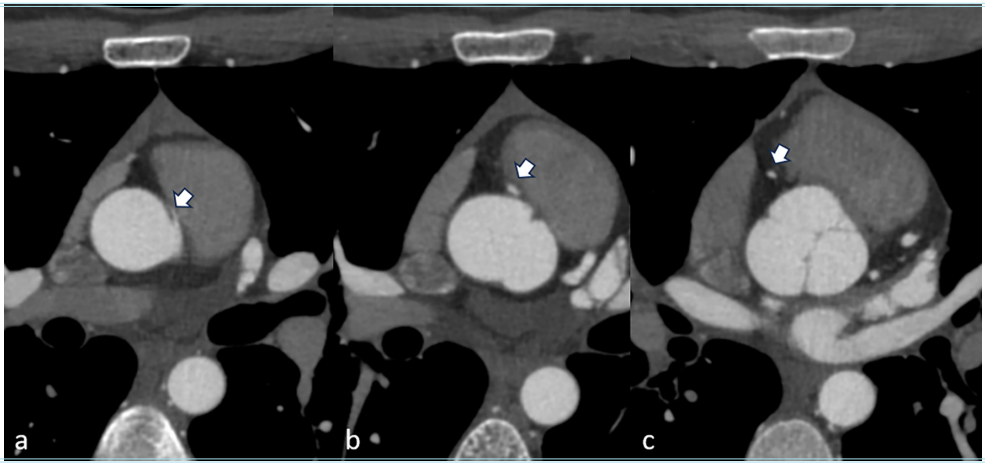

Figure 1. This is a case showing an anomalous RCA originating from the left main coronary artery and having an interarterial course. (a, b, c) Axial CT angiography images show that the RCA originates from the left main coronary artery, (white arrows) coursing between the great vessels

RCA: Right coronary artery, CT: Computed tomography

Table 1. Comparison of coronary artery origin variation frequencies across selected studies (values are % of total patients)

Study (year)	Population (N)	Any origin anomaly (%)	High take-off RCA/ LCA (%)	Separate LAD-LCx (%)	RCA from left sinus (%)	LCx (or LCA) from right sinus (%)	Single coronary (%)	Origin from pulm. A (%)
Güven and Kantarcı[4] (2019) -Türkiye	1,256 patients (CT)	2.50%	0.16/0.40	0.64	0.48	0.16 (LCx)+0.24 (LCA)*=0.40	0.08	0.00
Graidis et al.[3] (2015) - Greece	2,572 patients (CT)	2.33%	0.62/0.08**	0.58	0.35	0.23 (LCx)+0.08 (LCA)*=0.31	0.12	0.04
Şahin and Ilgar[8] (2022) - Türkiye	5,200 patients (CT)	2.61%	0.06/0 (RCA/LCA)**	0.23	0.27	0.04 (LCx)+0.02 (LCA)*=0.06	0.04	0.02
Andishmand et al.[5] (2023) - Iran	3,016 patients (CT)	1.26%	–/– **(combined not reported)**	0.33***	0.30***	0.20***	0.03***	0.00

*LCx vs LCA from right sinus: Some studies distinguished an LCx branch origin vs an entire LCA trunk origin from the right sinus. For simplicity, both are combined here as "any left-system origin from right sinus." For example, Güven and Kantarcı[4] reported 0.16% LCx-from-right and 0.24% LCA-from-right, totaling 0.40%. Graidis et al.[3] similarly noted separate LCx (0.23%) and an LCA trunk (0.08%) from the right side. Şahin and Ilgar[8] had 2 LCx (0.04%) and 1 LCA (0.02%) from the right.
LCA high take-off: Graidis et al.[3] reported a small number of high-takeoff left main cases (0.08%), whereas others had none or included them in "high take-off" combined. The Greek study also noted 0.08% had both RCA and LCA high.
Andishmand et al.[5]: Detailed breakdown was not explicitly provided in the abstract; values marked with *** are approximate, inferred from incidence statements or typical patterns. The Iranian study's total 1.26% suggests fewer anomalies across the board, roughly 0.3% for common ones. They reported the most frequent anomaly was separate LAD/LCx (~0.3%), and RCA from left in ~0.28%, consistent with the table.
RCA: Right coronary artery, CT: Computed tomography, LCA: Left anterior descending artery, LAD: Left anterior ascending artery, LCx: Left circumflex artery

Variation Types and Frequencies

The spectrum of coronary origin variations observed was comparable across studies, with some variations consistently more frequent than others. In the Turkish 2019 study, high take-off was observed in 0.16% for the RCA, and 0.40% for the left anterior descending artery (LCA), the separate LAD-LCx origins in 0.64%, and the RCA from the left sinus in 0.48%. The LCx or LCA originating from the right sinus was seen in 0.40% (0.16% LCx+0.24% LCA), a single coronary artery in 0.08% was seen, and a pulmonary artery origin in 0.00% was seen.

In the Greek 2015 cohort: high take-off was 0.62% for RCA and 0.08% for LCA, separate LAD-LCx origins 0.58%, RCA from the left sinus 0.35%, LCx/LCA from the right sinus 0.31% (0.23% LCx+0.08% LCA), single coronary artery 0.12%, and pulmonary origin 0.04%.

In the Turkish 2022 series, high take-off was 0.06% for RCA (no LCA high take-off reported), separate LAD-LCx 0.23%, RCA from the left sinus 0.27%, LCx/LCA from right sinus 0.06% (0.04% LCx+0.02% LCA), single coronary artery 0.04%; and pulmonary origin 0.02%.

In the Iranian 2023 study, the percentages for various anomalies were as follows: separate LAD-LCx was 0.33%; RCA from the left sinus, 0.30%; LCx/LCA from the right sinus, 0.20% (breakdown not specified); single coronary artery, 0.03%; and pulmonary origin, 0.06% (1 case). High take-off values were combined or not reported in detail.[3,4,8]

Table 1 presents a comparative summary of coronary origin anomaly frequencies across the reference study and three other cohorts. Despite minor variations, a consistent pattern emerges: ~0.5% for LAD/LCx arising separately, ~0.3-0.5% for RCA arising from the left sinus, ~0.1-0.3% for LCx arising from the right sinus, ~0.1-0.4% for high take-off origins, and ≤0.1% for single coronary or pulmonary artery origins. Total prevalence remains within the 1-3% range. Differences, such as a higher rate of LCA high take-off or absence of LCxfrom RCA, likely reflect sampling or reporting variations. Overall, recent studies reaffirm the original findings on prevalence and distribution.[3-5,8]

This is a case showing an anomalous RCA originating from the left main coronary artery and having an interarterial course (Figure 1a-c). Axial CT angiography images show that the RCA originates from the left main coronary artery, (white arrows) coursing between the great vessels.

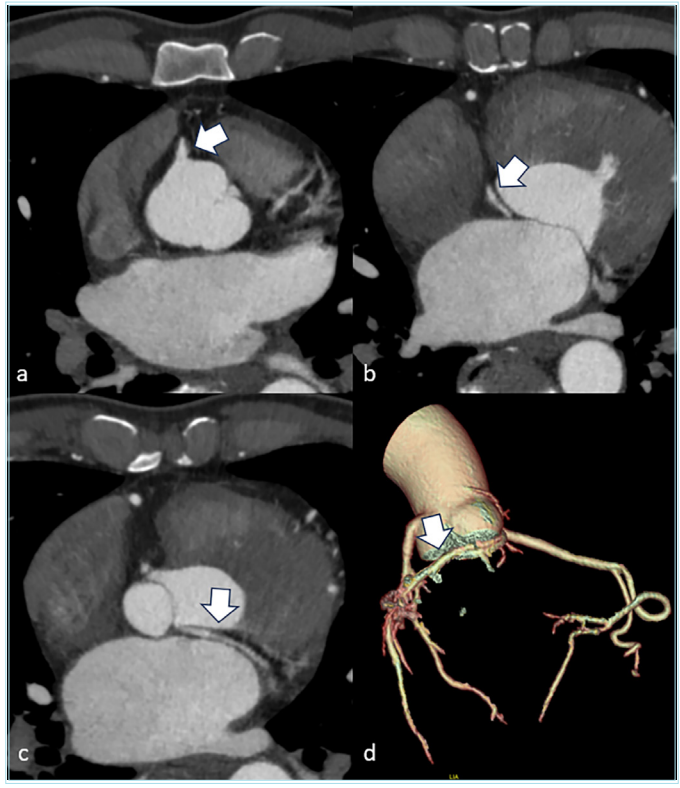

Figure 2. The patient demonstrates an anomalous LCx originating from a separate ostium in the right coronary sinus with a retroaortic course. Axial CT angiography images (a-c) and the 3D volume-rendered CT image (d) illustrate the LCx artery's path (white arrows) arising from the right coronary sinus and coursing posteriorly around the aorta

CT: Computed tomography, LCx: Left circumflex artery

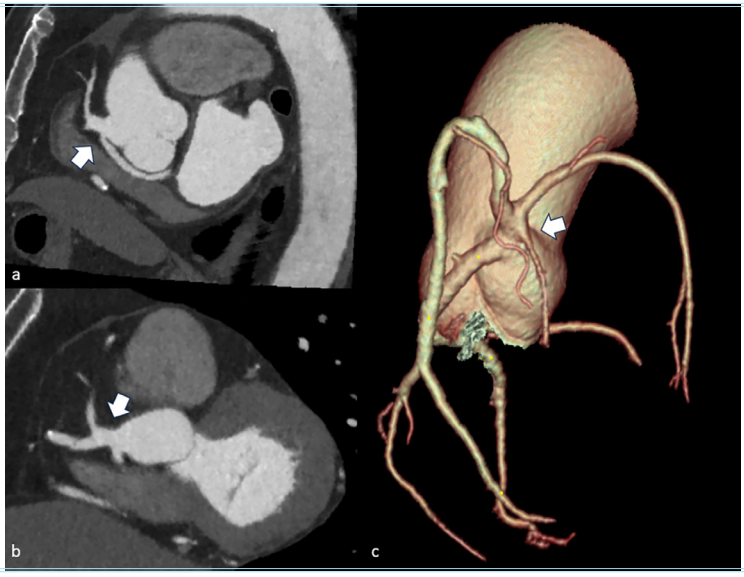

Figure 3. The patient has a single coronary ostium anomaly. (a, b) Sagittal reformatted CT angiography and (c) 3D volume-rendered CT images demonstrate all coronary arteries originating from a single ostium located in the right coronary sinus (white arrows)

CT: Computed tomography

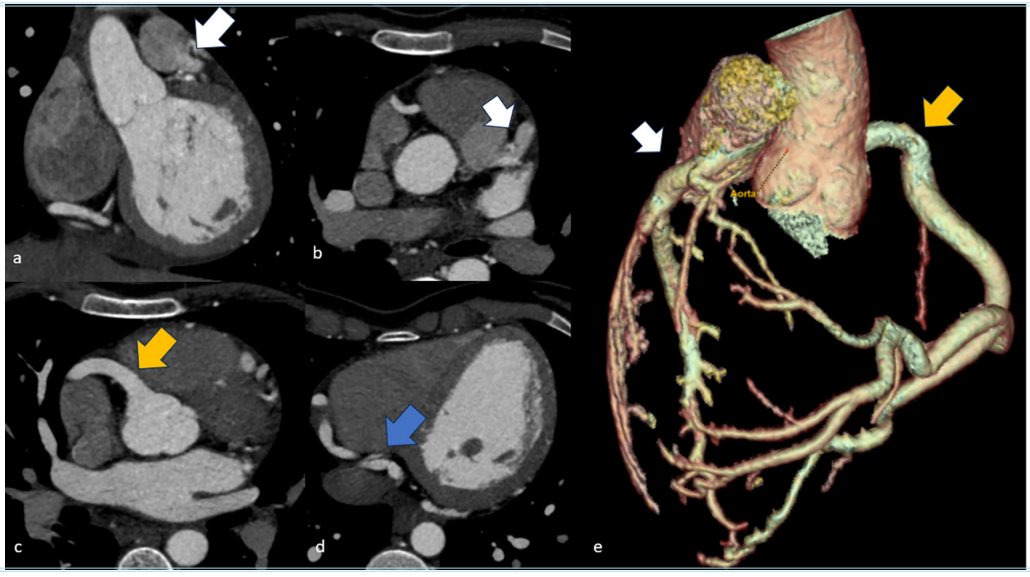

Figure 4. Case demonstrating anomalous origin of the LAD from the pulmonary artery (variant of ALCAPA). (a) Coronal and (b) axial CT angiography images show the LAD originating from the pulmonary artery (white arrows). (c) Axial image demonstrates marked dilatation of the RCA (yellow arrow). (d) Axial image reveals interarterial collateral vessels (blue arrow). (e) 3D volume-rendered CT image clearly illustrates the pulmonary origin of the LAD (white arrow) and the dilated RCA (yellow arrow)

RCA: Right coronary artery, CT: Computed tomography, LAD: Left anterior ascending artery, ALCAPA: Anomalous left coronary artery from the pulmonary artery

The patient demonstrates an anomalous LCx originating from a separate ostium in the right coronary sinus with a retroaortic course (Figure 2). Axial CT angiography images (a-c) and the 3D volume-rendered CT image (d) illustrate the LCx artery's path (white arrows) arising from the right coronary sinus and coursing posteriorly around the aorta.

The patient has a single coronary ostium anomaly (Figure 3a, b). Sagittal reformatted CT angiography and (c) 3D volume-rendered CT images demonstrate all coronary arteries originating from a single ostium located in the right coronary sinus (white arrows).

Case demonstrating anomalous origin of the LAD from the pulmonary artery (variant of ALCAPA) (Figure 4). (a) Coronal and (b) axial CT angiography images show the LAD originating from the pulmonary artery (white arrows). (c) Axial image demonstrates marked dilatation of the RCA (yellow arrow). (d) Axial image reveals interarterial collateral vessels (blue arrow). (e) 3D volume-rendered CT image clearly illustrates the pulmonary origin of the LAD (white arrow) and the dilated RCA (yellow arrow).

Discussion

The findings from our updated literature review confirm and extend the understanding of coronary artery origin variations, placing the 2019 Turkish MDCT study's results in a broader context. The slightly higher incidence found by CT can be attributed to the modality's greater sensitivity for detecting small or incidental anomalies that angiography might overlook. The original study's reported rate of 2.5% is very much in line with other MDCT-based investigations around the world.[4] In fact, several large series using contemporary CT technology have converged on prevalence figures between 1% and 3%. In addition to the four MDCT-based cohorts presented in Table 1, other large registries and recent meta-analyses have reported prevalence rates that are comparable or slightly lower, supporting the general range observed in our review. This convergence is noteworthy because older studies using different methodologies (e.g., invasive angiography, autopsy) sometimes reported lower overall rates, typically around 0.5-1.5%.[9] The slightly higher incidence found by CT can be attributed to the modality's greater sensitivity for detecting small or incidental anomalies that angiography might overlook. For example, a high-origin coronary ostium or a separate small ostium for an LCx might be missed or misinterpreted in a complex catheterization, but would be clearly seen on a 3D volume-rendered CT image. Thus, the proliferation of MDCT angiography in the last decade has likely led to more frequent recognition of otherwise quiescent coronary variants.

Despite methodological differences, the distribution of coronary anomalies remained consistent across studies and regions. The most common anomalies were benign variants, such as the separate origin of the LAD and LCx (absence of the left main artery), or origin of the RCA/LCx from the opposite sinus. Although generally asymptomatic, these variants can still have procedural relevance. For example, a high take-off coronary ostium may complicate selective cannulation during invasive angiography, and a retroaortic LCx may be at risk of inadvertent injury during aortic valve surgery. Awareness of such anatomy can prevent misinterpretation on imaging and help in pre-procedural planning.

Coronary anomalies arising from a single coronary artery or pulmonary artery are associated with serious outcomes but are extremely rare. Various studies have reported only one to two cases of a single coronary artery in several thousand patients. When identified, their course should be evaluated, as interarterial trajectories carry a higher risk and may require surgical intervention. ALCAPA, although rare in adults, requires surgical intervention due to its physiological incompatibility. In both ALCAPA and interarterial-course anomalies, early surgical correction-such as reimplantation or unroofing-is generally recommended if ischemia risk is present, even in asymptomatic individuals. Non-invasive imaging with CT or cardiac MR is preferred for defining the course and guiding management decisions. Consistent with their rarity

in elective CT populations, these high-risk anomalies were either absent or represented by isolated cases in the studied cohorts.

One interesting point of discussion is the influence of population and referral bias on reported prevalence. The 2019 Turkish study and most others were hospital-based cohorts of patients undergoing CT angiography due to suspected coronary disease or other risk factors. Such cohorts might have a slightly different anomaly prevalence than an unselected general population. One might hypothesize, for instance, that individuals with certain anomalies (particularly malignant) would either not survive to older ages or would present with symptoms that lead to early invasive investigation instead of elective CT later. However, the data did not show a dramatic difference between symptomatic cohorts and more general ones; the rates from symptomatic patient studies (like, the Iran 2023 and Türkiye 2022 studies, which were mostly patients with chest pain or risk factors) were in the same ballpark as those from broader groups.[5,8] If anything, the Iranian study's 1.26% was on the lower side, despite involving symptomatic patients, and the authors did not report any significant selection factor that would lower anomalies - this could simply be random variance, or slightly stricter criteria for what counted as an anomaly.[5] On the other hand, some reviews have suggested that because CT angiography is often performed in relatively healthy or low-risk patients (to rule out disease), it might incidentally pick up more benign anomalies than an invasive angiography series that usually focuses on people with coronary disease. Indeed, invasive angiograms historically might under-sample young healthy individuals (where anomalies might be found by chance) and over-sample older patients with atherosclerosis (where anomalies might be less frequent aside from those that cause clinically significant issues). The systematic review by Gentile et al.[1] noted that the anomaly prevalence reported in CT studies is at the higher end of the spectrum compared to that in catheter studies, supporting the notion that modality and population differences matter.

The inclusion of myocardial bridging as an anomaly in some studies is another point. Although a common coronary variant, bridging is an intramural anomaly, not an initial variant, and is usually analyzed separately. The 2019 Türkiye study focused solely on initial (ostial) anomalies, excluding bridging from the 2.5% prevalence rate.[4] However, other works, like Arjmand's 2012 CT angiography study from Iran, found bridging in 21% of patients and labeled it the most frequent variant.[10] When bridging is counted, it can dwarf the prevalence of true origin anomalies (as seen in Gilan 2025: 6.8% bridging vs 1.6% other anomalies).[11] In this article, we focused on anomalies of origin to ensure fair comparison with the reference study. This distinction is important because prevalence rates vary depending on whether bridging is included or not. While anomalies of origin remain low (approximately 1% to 3% percent), bridging can increase the total variant prevalence to approximately 5% to 8% percent. Bridging is generally benign and is not associated with ostial anomaly rates.

The clinical ramifications of detecting a coronary origin variation largely depend on the specific anomaly. Our updated review reinforces that most detected anomalies are benign , by themselves, do not necessitate intervention. Most detected coronary origin anomalies, such as high take-off, separate LAD/LCx origins, and retroaortic LCx, are benign and generally require only patient education and documentation to guide future invasive procedures. Nonetheless, documenting such variants in the radiology report is essential, as they may influence future diagnostic pathways or interventions. Communication between radiologists, cardiologists, and surgeons ensures that these findings are considered in the clinical context.

Malignant coronary anomalies, such as those with interarterial courses, are clinically important because of their potential for sudden cardiac death. While such outcomes were not directly reported in our adult studies reviewed, previous literature suggests that up to 30-50% of left main anomalies may present with sudden death as the first symptom. Early diagnosis enables prophylactic interventions such as reimplantation or re-roofing. Malignant anomalies were a minority in our data; for example, 14 of 136 anomalies in a 2022 Turkish series were RCA anomalies originating from the left sinus with interarterial courses, and warranted further evaluation. Others, such as retroaortic circumflex arteries, were treated conservatively. For malignant variants, individualized management is advised, with surgical intervention considered when there is evidence of ischemia, malignant course anatomy, or high-risk patient profile. Follow-up with functional testing or imaging may be warranted even in patients managed conservatively.8

When comparing the 2019 study to newer ones, there was no stark contradictions; instead, a high degree of agreement was observed. The slight differences (such as the Iranian study's lower anomaly percentage) can be explained as above.[4,5] One could also speculate about genetic or ethnic factors: for example, could Turkish populations have a marginally higher incidence of certain variants than another population? Some older studies hinted at geographic variation (one cited range was 0.3% to 5.6% in literature,) but given the consistency among Türkiye, Greece, and Switzerland in our table, any ethnic effect seems small if present at all.[3,4,6] It is more likely that methodological factors and sample criteria explain variations in reported rates. The systematic review by Fuenzalida et al.[12] essentially pooled global data and found an average prevalence around 1% for coronary origin anomalies. That average includes many studies that might not have counted things like high take-off or separate conus branches, whereas studies that specifically looked for any tiny anomaly using CT found closer to 2-3%. Therefore, we can conclude that the true prevalence in the general population probably lies in the 1-2% range, and that the Turkish study at 2.5% is at the higher end but still credible given its thorough CT-based detection.

Recent advancements and long-term outcomes are being emphasized in the context of analyzing abnormalities and expanding management. Large registries and trackers, such as the American Heart Association, now provide guidance on which abnormalities require surgery, which can be monitored, and how to counsel patients throughout their lifetime, including athletes. Increased CT-based detection allows for better case allocation and follow-up. Benign abnormalities do not appear to have a significant impact on survival or patient risk, as evidenced by similar atherosclerosis rates in affected and normal arteries. Early diagnosis of malignant abnormalities improves patient outcomes and prognosis by ensuring timely administration.

In summary, the discussion confirms that the original 2019 study's message-that coronary artery variants occur in roughly 2% of people and can be reliably detected by MDCT-holds true in the context of the latest research. If anything, the subsequent literature has reinforced the utility of MDCT, expanded the sample sizes, and provided outcome-oriented data. There is now strong multi-center evidence that MDCT angiography should be considered the preferred diagnostic modality when a coronary anomaly is suspected or when non-invasive imaging is needed to delineate an anomalous course seen on another test. The comparative analysis also alleviates any concern that the 2.5% figure

was an outlier; on the contrary, it fits the pattern seen in similar patient groups globally.

Conclusion

Coronary artery origin variations, though rare, represent an important category of cardiac anatomical anomalies with implications for clinical practice. Based on recent large-scale studies and reviews from the past decade, the prevalence of such anomalies detected with modern imaging ranges between 1% and 3% in adults, most often close to 2%.This updated literature perspective validates the findings of the 2019 Turkish MDCT study, which reported a 2.5% prevalence of origin variations, placing the study's findings in line with international data. Small differences in prevalence between studies are more likely due to variations in methodology, patient selection, or anomaly definitions than to true population differences.[3-8]

In terms of the types of anomalies, the distribution has remained consistent: the most frequently encountered variants are benign ones such as high take-off coronary ostia, separate LAD and LCx origins, and coronaries arising from the opposite aortic sinus. These constitute the majority of cases and typically do not cause symptoms, but their recognition can prevent diagnostic errors and guide procedural planning. Rarer anomalies, like a single coronary artery or an anomalous origin from the pulmonary artery, are found in only ~0.05-0.1% or fewer individuals, yet are of high clinical significance when present.

Multi-detector CT angiography has proven to be a reliable and often preferred modality for evaluating suspected coronary anomalies. Evidence consistently shows that MDCT can identify virtually all clinically important anomalies of origin with excellent spatial resolution, as reflected by the high diagnostic success reported across multiple studies. This is a noteworthy advancement from prior eras when diagnostic cardiac catheterization was required; CT now offers a noninvasive alternative that not only identifies the anomalous origin but also vividly depicts its course relative to other cardiac structures. As the role of CT expands in both the assessment of chest pain and preventive screening, the incidental discovery of coronary variants is expected to rise, further refining prevalence estimates and clinical awareness.

In summary, coronary artery origin anomalies are uncommon but present across populations at a consistent low rate. While most are benign and pose little clinical risk, a subset carries significant danger, making early and accurate detection essential.[3-8] Continued research, including pooled registries and meta-analyses, is warranted to better understand the long-term outcomes associated with each anomaly type and to guide management decisions. For clinicians and radiologists, staying alert to these anomalies and applying appropriate imaging strategies can ensure recognition and enable timely intervention when necessary.

Ethics

Ethics Committee Approval: The study was conducted with approval from the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (decision no: 2024-10/07, date: 03.07.2024).

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

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Authorship Contributions

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References

1. Gentile F, Castiglione V, De Caterina R. Coronary artery anomalies. Circulation. 2021;144:983-96.
2. Angelini P, Velasco JA, Flamm S. Coronary anomalies: incidence, pathophysiology, and clinical relevance. Circulation. 2002;105:2449-54.
3. Graidis C, Dimitriadis D, Karasavvidis V, et al. Prevalence and characteristics of coronary artery anomalies in an adult population undergoing multidetector-row computed tomography for the evaluation of coronary artery disease. BMC Cardiovasc Disord. 2015;15:112.
4. Güven F, Kantarcı M. Koroner arter çıkış varyasyonlarının çok kesitli bilgisayarlı tomografi ÇKBT ile değerlendirilmesi. Genel Tıp Derg. 2019;29:201-5.
5. Andishmand A, Montazerghaem H, Pedarzadeh A, et al. Prevalence and characteristics of coronary artery anomalies (CAAS) in 3016 symptomatic adult participants undergoing coronary computed tomography angiography (CCTA): a single-center retrospective study in Iran. J Cardiovasc Thorac Res. 2023;15:218-22.
6. Gräni C, Benz DC, Schmied C, et al. Prevalence and characteristics of coronary artery anomalies detected by coronary computed tomography angiography in 5634 consecutive patients in a single centre in Switzerland. Swiss Med Wkly. 2016;146:w14294.
7. Al-Umairi RS, Al-Kindi F, Al-Tai S. Prevalence and spectrum of coronary anomalies detected on coronary computed tomography angiography: a single centre experience in oman. Sultan Qaboos Univ Med J. 2019;19:e108-13.
8. Şahin T, Ilgar M. Investigation of the frequency of coronary artery anomalies in MDCT coronary angiography and comparison of atherosclerotic involvement between anomaly types. Tomography. 2022;8:1631-41.
9. Yamanaka O, Hobbs RE. Coronary artery anomalies in 126,595 patients undergoing coronary arteriography. Cathet Cardiovasc Diagn. 1990;21:28-40.
10. Shabestari AA, Akhlaghpoor S, Tayebivaljozi R, Fattahi Masrour F. Prevalence of congenital coronary artery anomalies and variants in 2697 consecutive patients using 64-detector row coronary CTAngiography. Iran J Radiol. 2012;9:111-21.
11. Gilan İY, Esen K, Balcı Y, Öztürk AH. Prevalence of anomalies and variants of coronary arteries: a single center study by coronary CT angiography. Clin Imaging. 2025;119:110389.
12. Fuenzalida JJV, Becerra-Rodriguez ES, Quivira Muñoz AS, et al. Anatomical variants of the origin of the coronary arteries: a systematic review and meta-analysis of prevalence. Diagnostics (Basel). 2024;14:1458.

RESEARCH ARTICLE

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Type 2 Dynamic Curves: A Diagnostic Dilemma

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Abstract

Objectives: Type 2 dynamic contrast-enhancement curves on breast magnetic resonance imaging (MRI) represent an intermediate kinetic pattern that often creates diagnostic uncertainty due to considerable overlap between benign and malignant lesions. This study aimed to analyze the histopathological outcomes of breast lesions demonstrating a Type 2 curve and to assess whether combining kinetic and morphological features improves diagnostic accuracy.

Methods: A retrospective review was performed on 644 dynamic contrast-enhanced breast MRI examinations conducted between January 2022 and January 2023. 32 lesions in 27 patients that exhibited a Type 2 kinetic curve and had available histopathological data were included. All lesions were reassessed by two experienced radiologists, curve types were verified using region of interest analysis, and lesions were categorized according to Breast Imaging Reporting and Data System (BI-RADS) morphology. Sensitivity and specificity values were calculated for the Type 2 curve alone and in combination with BI-RADS categories.

Results: Among the 32 lesions, 72.7% were malignant and 27.3% were benign. The most common benign lesion was sclerosing adenosis, while invasive ductal carcinoma was the most frequent malignant diagnosis. When evaluated alone, the Type 2 kinetic pattern demonstrated limited sensitivity (33.1%) and moderate specificity (72.7%) for predicting malignancy. However, diagnostic performance increased markedly when morphological assessment was incorporated. BI-RADS 4 lesions showed a malignancy rate of 68.8%, and all BI-RADS 5 lesions were malignant, yielding a positive predictive value of 100%. Combining dynamic curves with BI-RADS morphology produced significantly higher sensitivity and specificity compared with relying on kinetic patterns alone.

Conclusion: A substantial proportion of breast lesions demonstrating a Type 2 dynamic curve were malignant, indicating that this intermediate kinetic pattern should be interpreted with caution. Because Type 2 curves may also occur in benign lesions, they should not be used in isolation for diagnostic decision-making. Larger, preferably prospective studies are needed to clarify the clinical significance of Type 2 curves in breast MRI.

Keywords: BI-RADS-2 lesions, Type 2 kinetic pattern, benign, malign lesion

Introduction

Breast magnetic resonance imaging (MRI) is a non-invasive imaging modality with high sensitivity for detecting breast cancer.[1] It is used in patients with dense breast tissue when mammography is insufficient, for evaluating multifocal or multicentric masses, for preoperative surgical planning, for monitoring response to neoadjuvant chemotherapy, for assessing malignancy in the contralateral breast, and for postoperative follow-up.[1] In addition to providing morphological information about lesions, breast MRI also allows the evaluation of perfusion and enhancement characteristics through kinetic (time-signal intensity) curves obtained via dynamic contrast-enhanced imaging.[2] In this technique, an intravenous gadolinium-based contrast agent is administered to assess the lesion's enhancement and washout characteristics, thereby aiding in differentiating cancerous from normal breast tissue.[2]

The obtained dynamic contrast-enhancement curves can be categorized into three types: Type 1 (persistent), Type 2 (plateau), and Type 3 (wash-out).[3] In the literature, Type 1 curves are generally associated with benign masses, whereas Type 3 curves are more suggestive of malignancy.[3] However, Type 2 curves show substantial overlap between benign and malignant pathologies.[2,4]

Therefore, to determine the diagnostic value of Type 2 dynamic curves on breast MRI, this study examined the histopathological results of lesions demonstrating such curves.

Methods

Patient and Data Selection

Dynamic contrast-enhanced breast MRI examinations performed on 644 patients between January 2022 and January 2023 were retrospectively reviewed. Among these, 45 lesions in 38 patients demonstrated a Type 2 curve. Seven patients and eight lesions were excluded because of prior radiotherapy, prior surgery or biopsy, poor image quality, or unavailable histopathological data. Ultimately, 27 patients and 32 lesions were included in the study.

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Imaging and Evaluation

All lesions were re-evaluated by two experienced radiologists. Curve types were confirmed using region of interest -based analysis of dynamic contrast images. Lesions were classified according to Breast Imaging Reporting and Data System (BI-RADS) MRI criteria.[3] Histopathological data were obtained retrospectively from the hospital information system.

Imaging Protocol

A 1.5-Tesla MRI scanner with a 4-channel dedicated breast coil was used. Standard T2-weighted and 3D T1-weighted sequences were acquired. Gadolinium-based contrast material (0.1 mmol/kg) was administered intravenously, followed by dynamic post-contrast imaging and morphological assessment according to established breast MRI protocols.[1,5]

Statistical Analysis

Statistical analysis was performed using Statistical Package for the Social Sciences software version 20.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and percentages, while continuous variables were presented as means ± standard deviations. Receiver operating characteristic analysis and chi-square tests were applied. A p value 0.05 was considered statistically significant.

The study was conducted with approval from the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (decision no: 2023-01/01, date: 03.01.2023).

Results

The mean age of the 27 patients included in the study was 49.9±10.1 years (range: 43-85 years). All 32 lesions demonstrated a Type 2 curve. Of these lesions, 9 (27.3%) were benign and 23 (72.7%) were malignant. The most common benign and malignant diagnoses were sclerosing adenosis (25%) and invasive ductal carcinoma (43.8%), respectively (Table 1).

When the morphological BI-RADS categories of lesions demonstrating a Type 2 kinetic curve were evaluated (Table 2), 6 lesions were classified as BI-RADS 3 (18.8%), 16 as BI-RADS 4 (50.0%), and 10 as BI-RADS 5 (31.2%). All 6 lesions in the BI-RADS 3 category were consistent with benign pathology. Among the 16 BI-RADS 4 lesions, 11 (68.8%) were malignant and 5 (31.2%) were benign. All 10 lesions categorized as BI-RADS 5 were concordant with malignant findings on histopathology.

When the dynamic contrast-enhancement curve type was compared with the histopathological results, the sensitivity of a Type 2 curve for predicting malignancy was 33.1%, and specificity was 72.7%. Evaluation based solely on the kinetic curve pattern was limited in its ability to detect malignant lesions. However, diagnostic performance increased markedly when a Type 2 curve was combined with morphological assessment findings. In particular, when the lesion's BI-RADS category was considered, the sensitivity and specificity increased significantly (Table 3). Similarly, when only BI-RADS 5 lesions with a Type 2 curve were classified as malignant, no false-positive results were observed in our study; the positive predictive value was 100%, because all such lesions were truly malignant.

Table 1. Histopathological findings of lesions demonstrating Type 2 dynamic curves (n=32)

Histopathological diagnosis	n (%)
Sclerosing adenosis	8 (25%)
Fibroadenoma	1 (3.1%)
Intraductal papilloma	0 (0.0%)
Benign (total)	**9 (27.3%)**
Ductal carcinoma in situ	5 (15.6%)
Invasive ductal carcinoma	14 (43.8%)
Invasive lobular carcinoma	4 (12.5%)
Malignant (total)	**23 (72.7%)**
Total	**32 (100%)**

Table 2. Distribution by BI-RADS category (n=32)

BI-RADS category	Lesion count	(%)	Malignant (n)	Malignancy rate (%)
BI-RADS 3	6	18.8	0	0.0
BI-RADS 4	16	50.0	11	68.8
BI-RADS 5	10	31.2	10	100.0
Total	**32**	**100**	**21**	**65.6**

BI-RADS: Breast Imaging Reporting and Data System

Table 3. Diagnostic performance with addition of morphologic features in lesions showing Type 2 dynamic curve

Evaluation method	Sensitivity (%)	95% CI	Specificity (%)	95% CI
Type 2 curve only	35.2	15.4-54.2	69.5	35.9-97.5
Type 2 curve + BI-RADS 3	37.3	19.2-59.0	72.9	50.7-100
Type 2 curve + BI-RADS 4	89.5	79.8-100	91.6	68.4-100
Type 2 curve + BI-RADS 5	100	85.5-100	100	68.2-100

Confidence intervals were calculated using the Wilson method. Sensitivity and specificity calculations were performed on 23 malignant and 9 benign lesions, respectively
BI-RADS: Breast Imaging Reporting and Data System, CI: Confidence interval

Discussion

Type 2 curves obtained on dynamic contrast-enhanced breast MRI are considered an intermediate enhancement pattern between benign and malignant lesions, often causing diagnostic uncertainty.[3] In our study, 68.6% of lesions with a Type 2 dynamic curve were malignant on histopathology, which is higher than the rates reported in previous studies.[4,5]

Several studies have reported that the sensitivity of a Type 2 curve for detecting malignancy ranges from 30% to 45%, while specificity ranges from approximately 70% to 80%.[4,5] Our sensitivity (38.1%) and specificity (75.0%) values are consistent with these findings.

Schnall et al.[2] demonstrated that lesions with a Type 3 wash-out curve had a fivefold higher risk of malignancy compared with Type 1 curves;

76% of Type 3 lesions were malignant. Similar conclusions have been reported in other large series, reinforcing the strong association between Type 3 curves and malignancy.[5,6] However, the diagnostic significance of Type 2 curves remains controversial.

In our study, most Type 2 curve lesions exhibited suspicious morphological features and higher BI-RADS categories, warranting biopsy. All BI-RADS 5 lesions were malignant, and approximately 70% of BI-RADS 4 lesions were malignant, consistent with previous reports.[3,7] Conversely, most BI-RADS 3 lesions were benign, but one invasive carcinoma was identified, emphasizing that malignancy cannot be completely excluded even in probably benign lesions.[4]

Among benign lesions with a Type 2 curve, sclerosing adenosis was the most frequent pathology, a finding consistent with prior literature.[8] Sclerosing adenosis is known to mimic malignancy on MRI, particularly on dynamic contrast-enhanced sequences.[8] Fibroadenomas were the second most common benign lesions and were also reported to demonstrate atypical enhancement patterns in some cases.[6]

One of the most important findings of this study is that combining kinetic curve analysis with morphological assessment significantly improves diagnostic accuracy. Reliance on kinetic curve patterns alone may lead to misinterpretation; therefore, lesion morphology, BI-RADS category, and clinical context must be considered.[3,6] Lesions with suspicious morphology (BI-RADS 4 or 5) should undergo biopsy regardless of the presence of a Type 2 curve.

Study Limitations

This was a single-center, retrospective study with a relatively small sample size (n=35 lesions). Histopathological outcomes were evaluated on a lesion-by-lesion basis; thus, the number of lesions exceeded the number of patients because some patients had more than one lesion. Due to the retrospective design, selection bias may have been present in the collected data. Because the study focused exclusively on lesions exhibiting a Type 2 kinetic curve, most malignant lesions in the general population, which typically demonstrate a Type 3 curve, were not considered in this investigation. Nevertheless, the aim of this study was to examine in detail the small subset of malignant lesions that present with a Type 2 curve. Finally, the interpretation of dynamic curve patterns may be somewhat subjective. Although two experienced radiologists evaluated the lesions by consensus, minor interobserver variations remain possible (Figure 1).

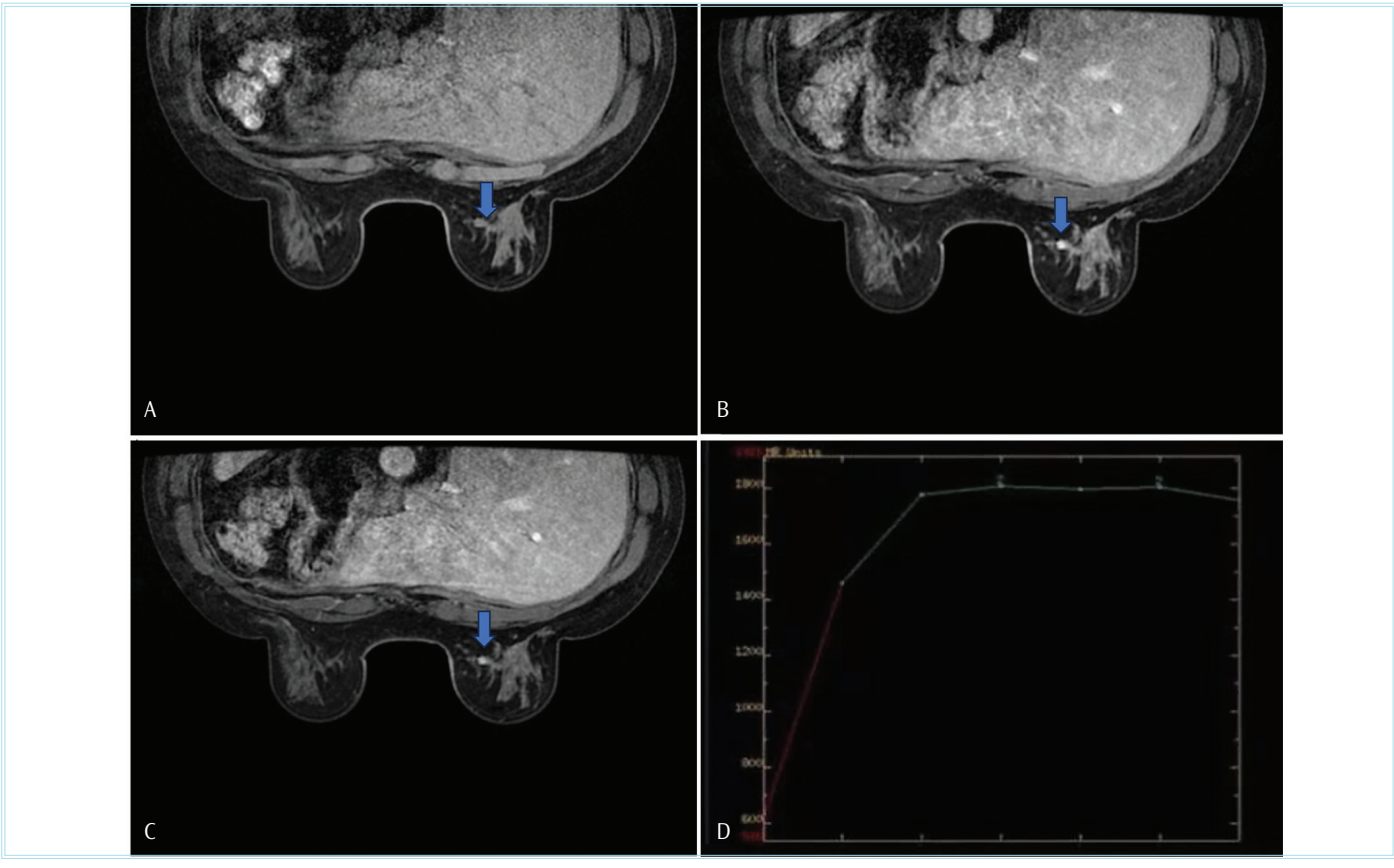

Figure 1. Example of a malignant lesion demonstrating a Type 2 contrast-enhancement kinetic curve

In the dynamic breast MRI assessment, the lesion measuring approximately 10 mm and located in the lower inner quadrant of the right breast (A, B, C) exhibits a smooth and persistent enhancement pattern, without evidence of washout. The contrast-enhancement remains stable over time, corresponding to a Type 2 (plateau) kinetic curve, as illustrated in panel (D). Histopathological analysis subsequently confirmed the lesion to be invasive breast carcinoma

MRI: Magnetic resonance imaging

Conclusion

A considerable proportion of breast lesions demonstrating a Type 2 dynamic contrast enhancement curve were malignant. Although Type 2 curves may also be seen in benign lesions, they should not be regarded as reassuring findings. Morphological features and BI-RADS categorization remain essential for accurate diagnosis, and biopsy should not be delayed when clinically indicated. The combination of kinetic and morphological MRI assessments enhances diagnostic performance. Larger prospective studies are needed to further clarify the clinical significance of Type 2 enhancement curves.

Ethics

Ethics Committee Approval: The study was conducted with approval from the Erzincan Binali Yıldırım University Non-Interventional Clinical Research Ethics Committee (decision no: 2023-01/01, date: 03.01.2023).

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: H.K.Ö., O.T., Concept: H.K.Ö., O.T., Design: H.K.Ö., O.T., Data Collection or Processing: H.K.Ö., O.T., Analysis or Interpretation: O.T., Literature Search: H.K.Ö., O.T., Writing: H.K.Ö.

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References

1. Kuhl C. The current status of breast MR imaging. Part I. Choice of technique, image interpretation, diagnostic accuracy, and transfer to clinical practice. Radiology. 2007;244:356-78.
2. Schnall MD, Blume J, Bluemke DA, et al. Diagnostic architectural and dynamic features at breast MR imaging: multicenter study. Radiology. 2006;238:42-53.
3. Mann RM, Kuhl CK, Kinkel K, Boetes C. Breast MRI: guidelines from the European Society of Breast Imaging. Eur Radiol. 2008;18:1307-18.
4. Jansen SA, Newstead GM, Abe H, Shimauchi A, Schmidt RA, Karczmar GS. Pure ductal carcinoma in situ: kinetic and morphologic MR characteristics compared with mammographic appearance and nuclear grade. Radiology. 2007;245:684-91.
5. Kuhl CK, Mielcareck P, Klaschik S, et al. Dynamic breast MR imaging: are signal intensity time course data useful for differential diagnosis of enhancing lesions? Radiology. 1999;211:101-10.
6. Durur-Subasi I, Karaman A, Demirci E, Sipal S, Akcay M. The benign mimickers of carcinoma on breast MRI. JMMS. 2022;9:96-101.
7. Williams TC, DeMartini WB, Partridge SC, Peacock S, Lehman CD. Breast MR imaging: computer-aided evaluation program for discriminating benign from malignant lesions. Radiology. 2007;244:94-103.
8. Oztekin PS, Tuncbilek I, Kosar P, Gültekin S, Oztürk FK. Nodular sclerosing adenosis mimicking malignancy in the breast: magnetic resonance imaging findings. Breast J. 2011;17:95-7.

RESEARCH ARTICLE

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Underlying Malignancy in Patients Initially Diagnosed with Organizing Pneumonia on CT-Guided Lung Biopsy: When Should Repeat Biopsy be Considered?

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Abstract

Objectives: Organizing pneumonia (OP) is a non-specific clinicopathological entity that may mimic pulmonary malignancy and can coexist with primary or metastatic lung cancer. This study aimed to evaluate the clinical and radiological characteristics of patients initially diagnosed with OP on computed tomography (CT)-guided lung biopsy who were subsequently found to have underlying malignancy on repeat biopsy.

Methods: This retrospective study included 151 patients who underwent CT-guided lung biopsy for suspected primary or metastatic lung cancer. The study group comprised twelve patients (7.9%) whose initial biopsy results were reported as OP. Patients with persistent clinical or radiological suspicion of malignancy underwent repeat biopsy. Clinical risk factors and thoracic CT features associated with malignancy were evaluated and correlated with final pathological outcomes.

Results: Among the 12 patients diagnosed with OP on initial biopsy, 6 underwent repeat biopsy due to ongoing suspicion of malignancy. Underlying malignancy was confirmed in 5 of these patients (41.6% of the study group): three cases of primary lung cancer and two cases of metastatic malignancy. Key indicators prompting repeat biopsy included lesion progression, lack of response to treatment, history of malignancy, and technically inadequate initial biopsy. No progression was observed in patients managed with clinical and radiological follow-up alone.

Conclusion: OP and malignancy may coexist and share overlapping imaging features. In patients with OP who demonstrate lesion progression, treatment resistance, or persistent clinical or radiological suspicion of malignancy, repeat biopsy should be strongly considered to avoid delayed cancer diagnosis.

Keywords: Organizing pneumonia, lung cancer, CT-guided lung biopsy

Introduction

Cryptogenic organizing pneumonia (OP), formerly called bronchiolitis obliterans OP, is a clinicopathological pulmonary diagnosis secondary to alveolar wall damage from various causes. OP shows no sex predilection and is more common in the fifth and sixth decades of life.[1]

OP can present with dry cough, dyspnea, malaise, fever, weight loss, and flu-like symptoms. However, none of these symptoms is specific to OP. Due to non-specific clinical features, OP can be confused with various diseases such as infections and cancer. This situation may lead to delays in the diagnosis and treatment of the underlying disease and to mismanagement.[2] In organizing pneumonia, thoracic computed tomography (CT) shows imaging features such as peripheral consolidations, perilobular opacities, ground-glass opacities, inverted-halo sign, and mass-like appearance, but none of these findings are specific.[3,4] OP may be associated with primary or metastatic lung cancer or develop secondarily from existing lung cancer in patients.[5-8]

OP has been associated with many non-specific clinical and radiological features. OP and lung cancer can co-occur in the same patient. Due to these characteristics, lung biopsy results obtained under CT guidance should be interpreted carefully. Because biopsy samples may be taken from an area of OP accompanying lung cancer, this can give misleading results.[9]

The aim of this study is to examine specific clinical and radiological features of patients diagnosed with OP on initial biopsy whose repeat biopsy also revealed malignancy, and to identify predictors of malignancy among patients with OP.

Methods

This retrospective study Binali Yıldırım University Mengücek Gazi Training and Research Hospital was approved by the institutional review board (date: 04/09/2025; decission no: 2025-15/05). The requirement for informed consent was waived by the institutional ethics committee

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due to the retrospective nature of the study. In this retrospective study, 151 patients who underwent CT-guided lung biopsy for suspected lung cancer or metastatic disease were evaluated. Twelve of 151 patients (7.94%) whose biopsy results were reported as OP formed our study group. Patients whose biopsy results were reported as suspicious, or whose initial biopsy did not indicate OP were excluded from the study. Among the 12 patients whose biopsy results were reported as OP, those who continued to have clinical or radiological suspicion of malignancy underwent a second biopsy. The Patient selection flow diagram is shown in Figure 1.

Concordance and discordance between histopathological and radiological findings were determined according to a previously conducted study. Concordance is defined as the agreement between pre-biopsy imaging features and a histopathological result not reported as malignant.[10]

Discrepancy is defined as a mismatch between pre-biopsy imaging features and a histopathological result reported as non-malignant. Absence of infection, a new or growing lesion, lesion size greater than 1 cm, a history of cancer, and a mass lesion are clinical features that raise suspicion of malignancy.

On thoracic CT, heterogeneous contrast enhancement, invasion of surrounding tissues, upper-lobe lesions, lesions with irregular borders, multiple lesions, spiculated contours, and solid lesions are radiological features that raise suspicion for malignancy. The presence of at least one of the defined clinical features and at least two accompanying radiological features was considered an indication for repeat biopsy. The patients' ages, gender, average lesion size, and thoracic CT images were evaluated.

A total of 15 imaging features were evaluated on thoracic CT scans: crazy-paving pattern; adjacent bronchiectasis; ground-glass opacities; inverted halo sign; multiple similar lesions; adjacent pleural effusion; adjacent atelectasis; peripheral location; background pulmonary fibrosis; preservation of the subpleural region; microlobulation; halo sign; intralesional calcification; trapped lung; and spiculation.[11,12]

Statistical Analysis

Descriptive statistics were used to summarize clinical, imaging, and pathological variables. Continuous variables were reported as mean ± standard deviation or median with interquartile range, as appropriate. Categorical variables were presented as frequencies and percentages. Due to the limited sample size, inferential statistical analyses were not performed.

Results

A total of 151 patients underwent CT-guided biopsy. OP was detected in 12 of these patients. Our study group consisted of these 12 patients (7 women and 5 men). Two of the 12 patients had a history of malignancy. Five of the 12 lesions (41.6%) had spiculated contours. Of the 12 lesions, one (8.3%) had ground-glass opacity, four (33.3%) were of mixed type, and seven (58.3%) were solid. Six of these 12 patients, who still had clinical or radiological suspicion of malignancy, underwent repeat biopsy. Four of these six patients underwent repeat CT-guided lung biopsy, one underwent a wedge resection, and one underwent a bronchoscopy-guided biopsy to obtain pathological samples. The six patients who did not undergo repeat biopsy were followed clinically for a mean of 4 months from the date of the first biopsy. No progression of lesions was observed during these 4 months. Of the 6 patients who underwent repeat biopsies because of persistent radiological and clinical suspicion of malignancy, 1 had lung metastases from pancreatic cancer, 1 had lung metastases from colon cancer, and 3 had primary lung cancer. In the remaining patient, the pathology report indicated OP (Table 1, 2).

Discussion

Since malignancy and OP can coexist in the same patient, distinguishing isolated OP from OP associated with malignancy.[5,6,13] The clinical and radiological features of OP are non-specific and can mimic malignancy. In this study, among 151 patients who underwent CT-guided lung biopsy, pathology reports for 12 patients indicated OP.

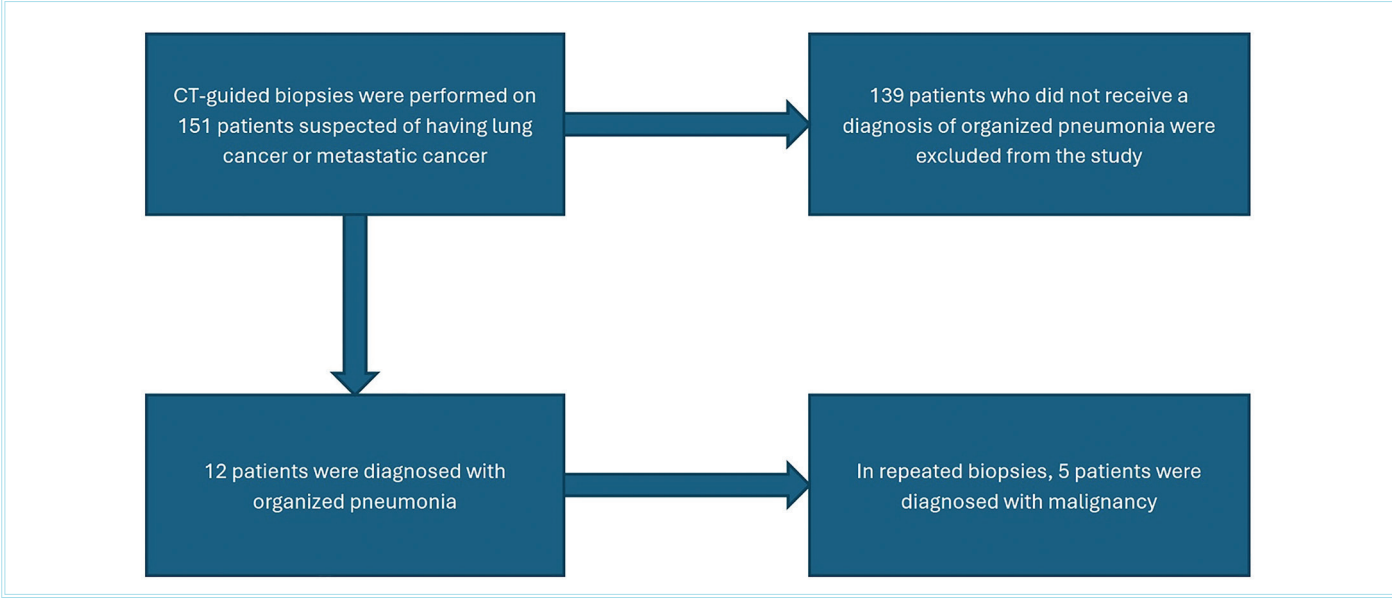

Figure 1. Patient selection flow diagram
CT: Computed tomography

Due to continued clinical and radiological suspicion of malignancy, repeat biopsies were performed in 6 of the 12 patients; underlying malignancy was confirmed in 5 of these 6 patients (5/12, 41.6%). A detailed examination of these five patients with OP revealed several features suggestive of an underlying malignancy.

Table 1. Demographic and imaging characteristics of 12 patients diagnosed with organizing pneumonia after CT-guided lung biopsy

	Diagnosed malignancy (n=5)	Proven organized pneumonia (n=7)
Male	2 (40%)	3 (42.9%)
Female	3 (60%)	4 (57.1%)
Density (%)		
Ground glass Mixed	0 (0%) 2 (40%)	1 (14.2%) 2 (28.5%)
Solid	3 (60%)	4 (57.1%)
Reversed Halo sign	0 (0%)	0 (0%)
Multiple similar lesion	2 (40%)	3 (42.9%)
Crazy paving pattern	0 (0%)	0 (0%)
Adjacent bronchiectasis	1 (20%)	2 (28.5%)
Adjacent pleural effusion	1 (20%)	2 (28.5%)
Adjacent atelectasis	2 (40%)	3 (42.9%)
Peripheral location	3 (60%)	4 (57.1%)
Lung fibrosis	0 (0%)	1 (14.2%)
Calsicification in lesion	0 (0%)	1 (14.2%)
Spiculated contour	3 (60%)	2 (28.5%)
Subpleural sparing	0 (0%)	2 (28.5%)
Microlobulation	1 (20%)	1 (14.2%)
Trapped lung	1 (20%)	1 (14.2%)
Halo sign	0 (0%)	1 (14.2%)

CT: Computed tomography

In the first patient, a follow-up thoracic CT scan performed three months later showed an increase in lesion size, leading to a wedge resection and a diagnosis of malignancy with accompanying OP. This demonstrates that a second biopsy should be considered if there is an increase in lesion size on subsequent imaging.

In the second patient, thoracic CT scans obtained immediately before and during the biopsy showed a large area of consolidation suggestive of underlying malignancy. Since no regression was observed in the lesion on a thoracic CT scan performed 14 days after treatment initiation, the CT-guided biopsy was repeated, confirming a concomitant malignancy. This indicates that a second biopsy should be considered in patients who do not respond to treatment.

The third and fourth patients had known diagnoses of pancreatic and colon adenocarcinoma, respectively. Two months later, a follow-up thoracic CT scan showed lesion progression in both patients, leading to repeat biopsies that demonstrated metastatic disease accompanied by OP in the lungs. This demonstrates that metastatic disease should be considered in the differential diagnosis when lesion progression occurs in patients with a known history of cancer.

In the fifth patient, the first biopsy could not be performed adequately because of hemorrhage. Therefore, a second biopsy was performed 21 days later, and concomitant malignancy was diagnosed. This shows us that if a biopsy cannot be obtained under appropriate conditions, repeated biopsies may be considered in patients with clinical and radiological suspicion of malignancy.

Evaluation of patients' thoracic CT images at diagnosis revealed no findings indicative of malignancy. Given the many similarities between OPand malignancy or metastatic lung disease, this finding is not surprising.[6,13-15] Compared with the previous study, our findings are similar.[9]

Table 2. Additional characteristics of 5 patients diagnosed with malignancy on repeat biopsy

Patient no	First biopsy	Cancer histopathology	Diagnosing method	Previous malignancy	Consistency	Clinical follow-up
1	-	Squamous cell carcinoma of the lung	Wedge resection	No	Consistent	A thoracic CT scan performed 3 months later showed an increase in lesion size, and wedge resection confirmed the diagnosis of associated malignancy.
2	-	Lung adenocarcinoma	CT-guided repeat lung biopsy	No	Consistent	A thoracic CT scan taken 14 days after treatment showed no regression, prompting a repeat biopsy and confirming the diagnosis of accompanying malignancy.
3	-	Pancreatic cancer with lung metastasis	CT-guided repeat lung biopsy	Yes	Inconsistent	A follow-up thoracic CT scan taken 2 months later showed progression of the lesion, so a repeat biopsy was performed.
4	-	Colon adenocarcinoma with lung metastasis	CT-guided repeat lung biopsy	Yes	Consistent	A follow-up thoracic CT scan taken 2 months later showed progression of the lesion, so a repeat biopsy was performed.
5	Restriction due to bleeding around the lesion during the procedure	Squamous cell carcinoma of the lung	Bronchoscopy	No	Inconsistent	A second biopsy was performed 21 days after the first, and an accompanying malignancy was diagnosed.

CT: Computed tomography

Study Limitations

Due to the retrospective nature of our study, the follow-up periods of the patients and the time between biopsy and control imaging varied, and the small number of patients in our study group prevented us from performing statistical analysis; these are considered limitations of our study. More comprehensive research is needed to standardize the follow-up of patients with organized pneumonia.

Conclusion

OP and malignancy can coexist and share similar clinical and radiological features. In patients diagnosed with organized pneumonia who do not respond to treatment, who do not show regression on follow-up imaging, who show progression, repeat biopsy should be considered if malignancy is suspected on clinical and radiological grounds.

Ethics

Ethics Committee Approval: This retrospective study Binali Yıldırım University Mengücek Gazi Training and Research Hospital was approved by the institutional review board (date: 04/09/2025; decission no: 2025-15/05).

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

Footnotes

Authorship Contributions

Concept: M.F.Ö., Desing: M.F.Ö., K.B.M., Data Collection or Processing: T.B.A., Analysis or Interpretation: M.F.Ö., K.B.M., Literature Search: K.B.M., T.B.A., Writing: M.F.Ö., K.B.M., T.B.A.

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

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References

1. Chaudhary K, Kaur P, Poudel B, Schroeder K, Khatri V. A case report of squamous cell carcinoma misdiagnosed as cryptogenic organizing pneumonia. Cureus. 2023;15:e42574.
2. Cherian SV, Patel D, Machnicki S, et al. Algorithmic approach to the diagnosis of organizing pneumonia: a correlation of clinical, radiologic, and pathologic features. Chest. 2022;162:156-78.
3. Zare Mehrjardi M, Kahkouee S, Pourabdollah M. Radio-pathological correlation of organizing pneumonia (OP): a pictorial review. Br J Radiol. 2017;90:20160723.
4. Torrealba JR, Fisher S, Kanne JP, et al. Pathology-radiology correlation of common and uncommon computed tomographic patterns of organizing pneumonia. Hum Pathol. 2018;71:30-40.
5. Romero S, Barroso E, Rodriguez-Paniagua M, Aranda FI. Organizing pneumonia adjacent to lung cancer: frequency and clinico-pathologic features. Lung Cancer. 2002;35:195-201.
6. Ichikawa T, Hattori A, Suzuki K, et al. Clinicopathological characteristics of lung cancer mimicking organizing pneumonia on computed tomography-a novel radiological entity of pulmonary malignancy. Jpn J Clin Oncol. 2016;46:681-6.
7. Long NM, Plodkowski AJ, Schor-Bardach R, et al. Computed tomographic appearance of organizing pneumonia in an oncologic patient population. J Comput Assist Tomogr. 2017;41:437-41.
8. Mao R, Zhang L, Hou J, Zou Y, Zhu L, Chen Z. Organizing pneumonia secondary to lung cancer of unknown primary site. Respir Med Case Rep. 2019;28:100892.
9. Kim C, Liberman Y, Borisovsky G, et al. Incidence of malignancy in lung lesions initially classified as organizing pneumonia on CT-guided biopsies. Abdom Radiol (NY). 2025:1-9.
10. Camacho A, Chung AD, Rigiroli F, et al. concordance assessment of pathology results with imaging findings after image-guided biopsy. J Vasc Interv Radiol. 2022;33:159-68.e1.
11. Baque-Juston M, Pellegrin A, Leroy S, Marquette CH, Padovani B. Organizing pneumonia: what is it? A conceptual approach and pictorial review. Diagn Interv Imaging. 2014;95:771-7.
12. Roberton BJ, Hansell DM. Organizing pneumonia: a kaleidoscope of concepts and morphologies. Eur Radiol. 2011;21:2244-54.
13. Maldonado F, Daniels CE, Hoffman EA, Yi ES, Ryu JH. Focal organizing pneumonia on surgical lung biopsy: causes, clinicoradiologic features, and outcomes. Chest. 2007;132:1579-83.
14. Huo JP, Liu C, Jin BB, et al. Ryptogenic organizing pneumonia masquerading as lung carcinoma: a case report and review of the literature. Exp Ther Med. 2018;15:39-46.
15. Melloni G, Cremona G, Bandiera A, et al. Localized organizing pneumonia: report of 21 cases. Ann Thorac Surg. 2007;83:1946-51.

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