Utility of CT Intraluminal Gas Detection in Assessing Gangrenous Appendicitis

[1]Dr Pawar Swathi, [2]Dr A.Rithika reddy, [3]Dr Gosala Rohan Bhradwaj, [4]Dr B Nuthan, [5]Dr G S Kejiriwal

[1,2,3]Junior resident, [4]Senior Resident, [5]Professor
Department of Radio Diagnosis
Maharajah's Institute of Medical Sciences (MIMS)
Nellimarla, Vizianagaram, Andhra Pradesh, India.

Abstract-

Introduction: This manuscript investigates the presence of intraluminal gas in acute, nonperforated appendicitis on CT scans as a marker for diagnosing gangrenous appendicitis.

Methods: This retrospective observational case-control study was conducted over two years at a tertiary institution. It included patients diagnosed with acute appendicitis via CT who underwent surgery within 48 hours. Exclusions were patients under 16, those with more than 48 hours between CT and surgery, and those with CT evidence of perforated appendicitis. Three radiologists independently assessed the CT images for intraluminal gas. The findings were then correlated with surgical and histopathology reports to distinguish between nongangrenous and gangrenous appendicitis. The sensitivity, specificity, and predictive values of CT-detected intraluminal gas for gangrenous appendicitis were calculated.

Results: The study included 93 patients with nonperforated acute appendicitis who had surgery within 48 hours. Intraluminal gas was identified in 26 patients (28%), of which 54% had gangrenous appendicitis. Among the 67 patients without intraluminal gas, 33% had gangrenous appendicitis. The specificity of intraluminal gas for gangrenous appendicitis was 79%, with a negative predictive value of 86% and a likelihood ratio of 1.85.

Conclusion: In established acute appendicitis cases, the presence of intraluminal gas on CT is a moderately specific indicator of gangrenous complications. Reporting this finding can help prioritize and manage patients more effectively, leading to timelier surgical intervention and improved outcomes.

INTRODUCTION:

Acute appendicitis is a leading cause of acute abdominal pain, making appendectomies the most common emergency procedure in Australia [1]. While the diagnosis of acute appendicitis is primarily clinical, CT scans are crucial in reducing unnecessary surgeries by identifying other causes of abdominal pain that mimic appendicitis. Appendicitis can present in various ways, with overlapping symptoms between uncomplicated and complicated cases such as perforation and abscess formation [2]. Therefore, imaging is essential in distinguishing between simple and complicated cases [3], impacting patient management, prognosis, and hospital stay duration.

Many studies have explored CT signs differentiating perforated from nonperforated appendicitis, but few have focused on distinguishing simple phlegmonous appendicitis from gangrenous appendicitis in nonperforated cases [4]. This distinction is critical as these types of nonperforated appendicitis have different prognoses and require time-sensitive treatment. Gangrenous appendicitis occurs in about 17% of acute appendicitis cases [5] and is linked to higher complication rates, such as intra-abdominal abscesses and perforation, if surgery is delayed. Traditionally, the presence of intraluminal air in the appendix was considered a sign to exclude appendicitis, suggesting a patent, nonobstructed, and noninflamed appendix [6]. However, recent evidence shows that intraluminal gas on CT is common in appendicitis, appearing in 19–27% of cases [7, 8]. One theory suggests that intraluminal air is absent in an acutely inflamed appendix due to gas displacement by fluid and increased pressure. As inflammation progresses to gangrene, intraluminal air develops similarly to pneumatosis intestinalis.

This study aims to evaluate the presence of intraluminal air in the appendix on CT as an indicator of gangrenous appendicitis in cases of acute nonperforated appendicitis.

2. MATERIALS AND METHODS

Data Collection: Data were collected from the picture archiving and communication system (PACS) of Maharajah's Institute of Medical Sciences (MIMS), Nellimarla using keywords like "appendix," "appendiceal inflammation," and "appendicitis." The study included consecutive patients from 2022 and 2023 who had a CT scan prior to

appendectomy for acute appendicitis. Extracted data included patient age, sex, CT scan time, CT images, surgery time, operation reports, and surgical histopathology reports.

Exclusion Criteria: Patients were excluded if they did not have surgery within 48 hours of the CT scan, were younger than 18 years old, or had appendiceal perforation evident on the initial CT. Pediatric cases were excluded due to their low number in this adult institution and the preference for alternative imaging modalities in children [4, 9].

Retrospective Image Review: Three radiologists, including two registrars and one consultant with four years of experience, independently reviewed the CT images. They assessed for appendiceal gas and signs of perforation, such as increased appendiceal diameter, wall thickness, wall enhancement, appendicolith, and periappendiceal fat stranding or collections [11]. Cases showing CT evidence of perforation were excluded. Perforation indicators included a defect in the appendiceal wall, surrounding phlegmon or abscess, extraluminal air, and extraluminal appendicolith [10]. Reviewers were aware of patient age and sex but blinded to the original CT report and subsequent surgical and histopathology reports. Disagreements were resolved by group discussion and reviewing the original CT report.

Reference Standards: The reference standards were the surgical records and histopathology reports. A definitive diagnosis of appendicitis required histopathologic evidence of transmural inflammation, ulceration, or thrombosis [12]. Gangrenous appendicitis was defined macroscopically by a friable appendix with green, purple, or black discoloration, or microscopically by transmural inflammation with necrosis. Appendiceal perforation was confirmed by surgical observation of perforation not caused by handling or histopathologic evidence of a wall defect due to transmural necrosis.

Statistical Analysis: A statistical calculator was used to determine the sensitivity, specificity, likelihood ratios, and predictive values of CT intraluminal gas for diagnosing nonperforated gangrenous appendicitis. With gangrenous appendicitis estimated to occur in 17% of acute appendicitis cases [5], we aimed for a minimum of 100 total studies to ensure at least 17 cases of gangrenous and 83 cases of nongangrenous appendicitis. This sample size was calculated to demonstrate a medium-to-large effect with 80% power and an alpha value of 0.05, sufficient for testing our hypothesis.

3. Results

Demographic Information: The PACS database search identified 305 patients. Of these, 135 had CT-diagnosed appendicitis and underwent appendectomy within 48 hours. Exclusions included three patients younger than 18 years, six patients with negative appendectomies (four non-inflamed appendixes, one case of leukemia with appendiceal involvement, and one appendiceal adenocarcinoma), and 31 cases of perforated appendicitis evident on CT. The final study group consisted of 93 patients with a mean age of 49.0 ± 14.7 years (range 19-95). The group included 38 women (mean age 52.6 ± 16.9 years, range 20-95) and 55 men (mean age 46.6 ± 12.3 years, range 19-71).

Retrospective Review: There were 57 cases of surgically or pathologically confirmed simple (nongangrenous) acute appendicitis and 36 cases of nonperforated gangrenous appendicitis. Gangrenous appendicitis had a prevalence of 39% (36/93) in the study group. Intraluminal air in the appendix on CT was present in 26 patients (28%) and absent in 67 patients (72%).

Of the 26 patients with intraluminal air detected on CT, 14 (54%) had histological or surgical evidence of gangrenous appendicitis, while 12 (46%) did not. Among the 67 patients without intraluminal air, 22 (33%) had evidence of gangrenous appendicitis, and 45 (67%) did not (Table 1).

Figures 1–3 show cases of CT-evident acute appendicitis with intraluminal gas, all confirmed as gangrenous appendicitis within 24 hours surgically and histologically. Figure 4 shows a false-positive case with low-grade fat stranding and intraluminal gas, confirmed as uncomplicated suppurative appendicitis within 24 hours surgically and histologically.

4. Statistical Analysis

Intraluminal air on CT was found to be a marker for gangrenous appendicitis in nonperforated cases, with a specificity of 79% (95% CI, 66–89%), a positive likelihood ratio of 1.85 (95% CI, 1.0–3.5), and a negative predictive value of 86% (95% CI, 82–89%) (Table 2). The accuracy of using CT findings of intraluminal gas to correctly classify appendicitis is 72%.

5. Discussion

Gangrenous appendicitis leads to higher complication rates such as perforation, abscess, and feculent peritonitis, resulting in longer hospital stays, higher morbidity and mortality, increased open surgery rates, and more hospital readmissions [1]. CT imaging has become essential in diagnosing appendicitis, reducing negative appendectomies, and identifying complications like perforation [13, 14]. While many studies differentiate between perforated and non-perforated appendicitis using CT, there is limited data on CT markers distinguishing acute suppurative from gangrenous appendicitis. Identifying such markers could prompt more urgent surgeries, improving patient outcomes.

Intraluminal gas in the appendix on CT is often seen in normal appendices [6, 7] and in some acute appendicitis cases [7, 8]. Acute appendicitis diagnosis typically relies on other CT signs such as increased appendiceal diameter, wall thickening, altered enhancement, appendicolith, and periappendiceal fat stranding or collection. Intraluminal air is often absent in acute appendicitis due to luminal obstruction leading to fluid collection and gas displacement. Gangrenous transformation, marked by necrosis, can cause new gas formation, visible on CT.

Our study included 93 patients with non-perforated acute appendicitis who had CT scans before appendectomy between 2018 and 2019. Intraluminal gas was absent in 67 patients (72%), with only 33% (22/67) showing gangrenous appendicitis. Among the 26 patients with intraluminal gas, 54% (14/26) had gangrenous appendicitis.

Intraluminal gas on CT had a specificity of 79%, a negative predictive value of 86%, and a likelihood ratio of 1.85 for gangrenous appendicitis. This means that the presence of gas is suggestive of suppurative appendicitis. The marker had a lower sensitivity (39%) and positive predictive value (27%).

Patients with intraluminal gas on CT are 1.85 times more likely to have gangrenous appendicitis, with a 72% accuracy in classification. Although intraluminal gas alone has limited sensitivity, when combined with other appendicitis features, it is useful for predicting complicated appendicitis.

Our study had limitations, including variability in surgical and histopathological reports and possible discrepancies between CT findings and surgical/histopathology reports due to delays in surgery. Also, non-contrast CT scans, which may affect reporting accuracy, were not excluded.

Appendicitis remains a clinical diagnosis, with CT used mainly for atypical presentations or suspected complications. The higher prevalence of gangrenous appendicitis (39%) in our study compared to others (17%) may reflect this. Although our sample size was smaller than planned, the study remains adequately powered due to the higher prevalence in our cohort.

Future research could involve a large prospective multicenter study to standardize criteria for reporting appendicitis and gangrenous changes. Further studies might also explore gas patterns and locations to understand their relationship with complications, potentially improving triage for urgent appendectomies.

Table 1: Cases of appendicitis with or without CT-detected intraluminal gas, correlated with the final histopathological report of absence or presence of gangrenous appendicitis.

INTRALUMINAL GAS ON CT	**GANGRENOUS APPENDICITIS**	**NON GANGRENOUS APPENDICITIS**
PRESENT	14	12
ABSENT	22	45

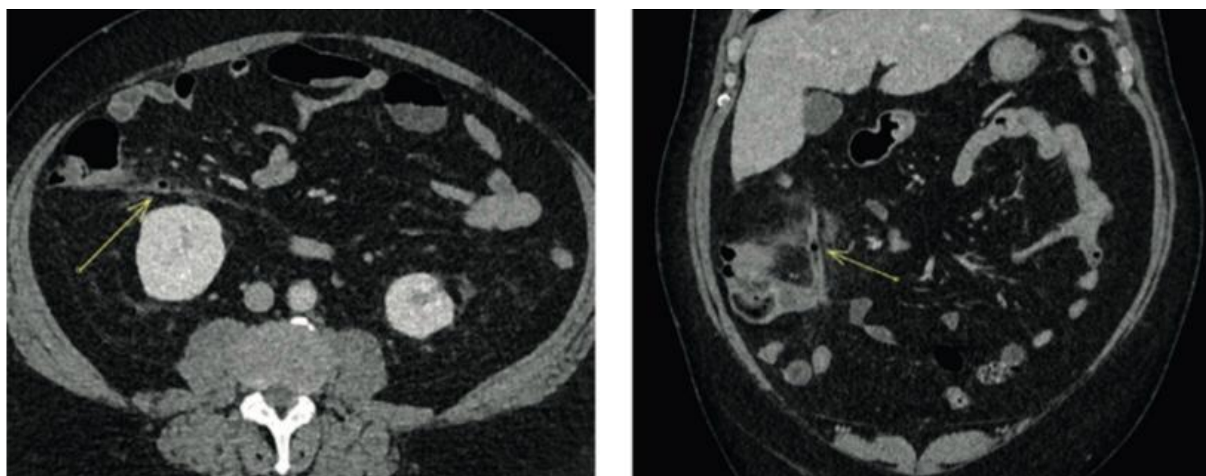

Figure 1: A 64-year-old man with axial (a) and coronal (b) CT abdomen in the portal venous phase showing periappendiceal fat stranding and appendiceal wall hyperenhancement, confirming the clinical suspicion of acute appendicitis. There is a focus of intraluminal gas in the body of the appendix (arrow). Gangrenous appendicitis was confirmed intraoperatively and on subsequent histopathology.

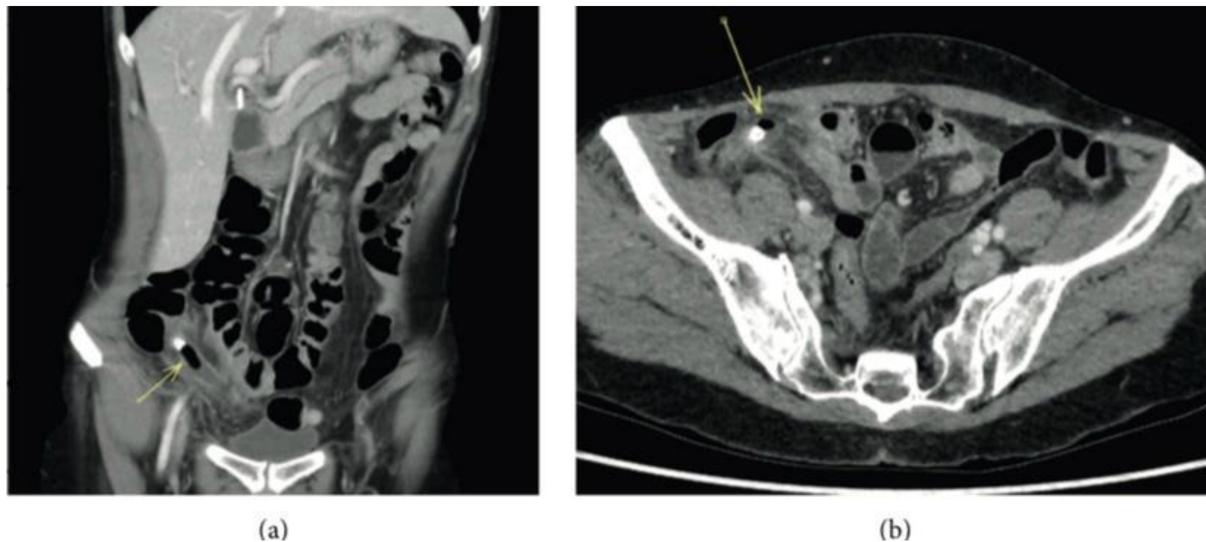

Figure 2: A 58-year-old woman with clinical suspicion of acute appendicitis. Coronal (a) and axial (b) CT abdomen in the portal venous phase shows a distended appendix with periappendiceal fat stranding. There is intraluminal gas adjacent to the appendicolith towards the tip. Gangrenous appendicitis was confirmed on subsequent histopathology report and intraoperatively.

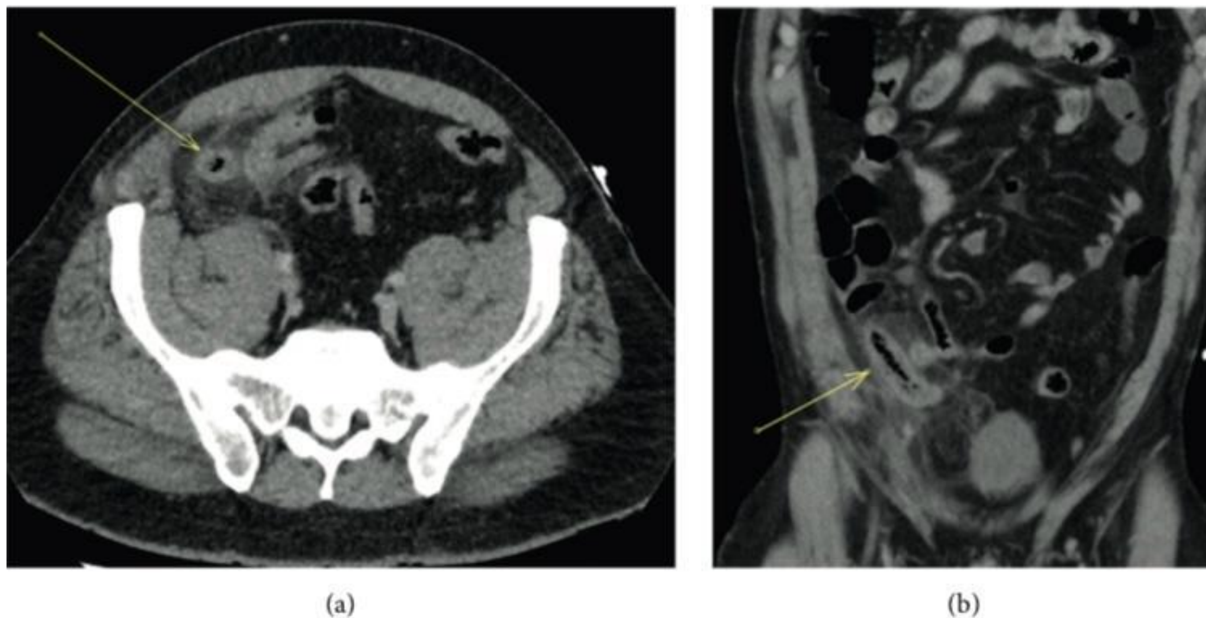

Figure 3: A 45-year-old man with appendiceal intraluminal gas (arrow) on noncontrast CT in axial (a) and coronal (b) projections. Histological and surgical evidence of gangrenous appendicitis. Note the distended appendix with a thickened wall and surrounding fat stranding.

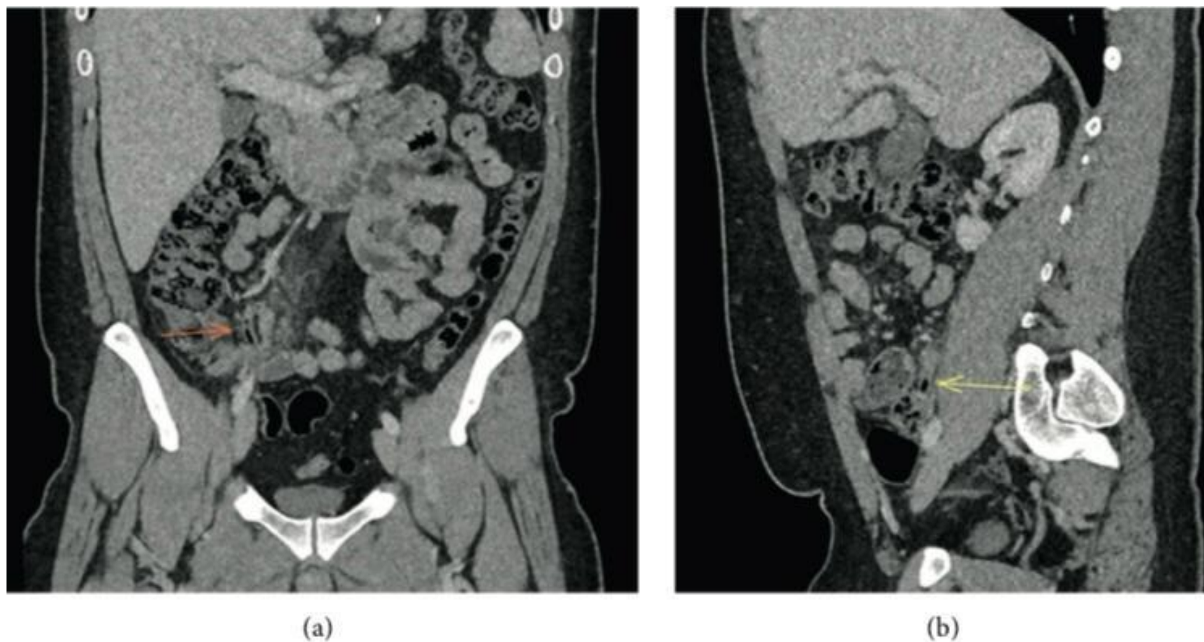

Figure 4: A 33-year-old man with appendiceal intraluminal gas on CT (arrow). Coronal (a) and sagittal (b) CT abdomen in the portal venous phase. The appendix diameter is still within normal limits, but there is low-grade surrounding fat stranding. There is a false-positive case, with histological/surgical reports confirming uncomplicated suppurative acute appendicitis, without gangrenous complication.

Table 2: Statistical analysis of intraluminal gas in predicting gangrenous appendicitis.

STATISTICS	VALUE	95% CONFIDENCE INTERVAL
SPECIFICITY	78.95%	66.1-88.6%
SENSITIVITY	38.89%	23.1 – 56.5%
NEGATIVE LIKELIHOOD RATIO	0.77	0.6-1.0%
POSITIVE LIKELIHOOD RATIO	1.85	1.0-3.5
NEGATIVE PREDICTIVE VALUE	86.32%	82.5 – 89.4%
POSITIVE PREDICTIVE VALUE	27.45%	16.5 – 42.0%

6. CONCLUSION

The presence of intraluminal air as a marker for gangrenous appendicitis is not widely recognized in the radiology community. This study aims to highlight the importance of this CT feature in diagnosing acute appendicitis. Our research shows that intraluminal gas has a moderately high specificity (79%) but low sensitivity for indicating gangrenous appendicitis in nonperforated cases. When intraluminal gas is detected, the likelihood of the appendix being gangrenous is 1.9 times higher, with moderate overall accuracy.

Importantly, when combined with other CT indicators of acute appendicitis—such as increased appendiceal diameter, wall enhancement, and adjacent fat stranding—intraluminal air becomes a valuable predictor for gangrenous appendicitis before it progresses to perforation. Therefore, radiologists should report this finding to ensure timely surgical intervention and improve patient outcomes.

Acknowledgements:

The authors are grateful to physicians, administrative staff at Maharajah's Institute of Medical Sciences (MIMS), Nellimarla for allowing us to undertake this research.

REFERENCES:

1. Arthur, T., Gartrell, R., Manoharan, B., et al. "Emergency appendicectomy in Australia: findings from a multicentre, prospective study." *ANZ Journal of Surgery*, vol. 87, no. 9, 2017, pp. 656–660.

2. Rasmussen, O. O., and Hoffmann, J. "Assessment of the reliability of the symptoms and signs of acute appendicitis." *Journal of the Royal College of Surgeons of Edinburgh*, vol. 36, no. 6, 1991, pp. 372–377.
3. Australian Commission on Safety and Quality in Health Care. *Australian Atlas of Healthcare Variation 2017: 4.5 Appendicectomy*, Sydney, NSW, 2017, pp. 293–304, https://www.safetyandquality.gov.au/sites/default/files/migrated/4.5-Appendicectomy.pdf.
4. Ariza, D. P., Chamorro, E. M., Zornoza, J. C., et al. "Intraluminal Gas in Non-perforated Acute Appendicitis: A CT Sign of Gangrenous Appendicitis." European Congress of Radiology-ECR, 2012.
5. Emil, S., Gaied, F., Lo, A., et al. "Gangrenous appendicitis in children: a prospective evaluation of definition, bacteriology, histopathology, and outcomes." *Journal of Surgical Research*, vol. 177, no. 1, 2012, pp. 123–126.
6. Rettenbacher, T., Hollerweger, A., Macheiner, P., et al. "Presence or absence of gas in the appendix: additional criteria to rule out or confirm acute appendicitis-evaluation with US." *Radiology*, vol. 214, no. 1, 2000, pp. 183–187.
7. Cabarrus, M., Sun, Y.-L., Courtier, J. L., Stengel, J. W., Coakley, F. V., and Webb, E. M. "The prevalence and patterns of intraluminal air in acute appendicitis at CT." *Emergency Radiology*, vol. 20, no. 1, 2013, pp. 51–56.
8. Kim, H. C., Yang, D. M., Kim, S. W., and Park, S. J. "Reassessment of CT images to improve diagnostic accuracy in patients with suspected acute appendicitis and an equivocal preoperative CT interpretation." *European Radiology*, vol. 22, no. 6, 2012, pp. 1178–1185.
9. Van Rijn, R. R. "Imaging pediatric appendicitis: time to put the discussion to bed?" *Radiology*, vol. 286, no. 3, 2018, pp. 1030–1032.
10. Horrow, M. M., White, D. S., and Horrow, J. C. "Differentiation of perforated from nonperforated appendicitis at CT." *Radiology*, vol. 227, no. 1, 2003, pp. 46–51.
11. Kim, H. Y., Park, J. H., Lee, Y. J., Lee, S. S., Jeon, J.-J., and Lee, K. H. "Systematic review and meta-analysis of CT features for differentiating complicated and uncomplicated appendicitis." *Radiology*, vol. 287, no. 1, 2018, pp. 104–115.
12. Bhangu, A., Søreide, K., Di Saverio, S., Assarsson, J. H., and Drake, F. T. "Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management." *The Lancet*, vol. 386, no. 10000, 2015, pp. 1278–1287.
13. Akbulut, S., Koc, C., Sahin, T. T., et al. "An investigation into the factors predicting acute appendicitis and perforated appendicitis." *Ulus Travma Acil Cerrahi Derg*, vol. 27, no. 3, 2021, pp. 315–324.
14. Raja, A. S., Wright, C., Sodickson, A. D., et al. "Negative appendectomy rate in the era of CT: an 18-year perspective." *Radiology*, vol. 256, no. 2, 2010, pp. 460–465.