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Research Article

Morphometric Characteristics of the Vermiform Appendix and Their Histopathological Correlation in Adult Patients Undergoing Appendectomy for Acute Appendicitis: A Prospective Observational Study

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ABSTRACT

Background: The vermiform appendix demonstrates considerable variation in length, diameter, position, and wall morphology, while acute appendicitis produces characteristic inflammatory changes that may alter its gross dimensions. Data integrating appendiceal morphometry with histopathological severity are limited in South Asian populations.

Objective: This study was conducted to determine the morphometric characteristics of the vermiform appendix in adults undergoing appendectomy for clinically suspected acute appendicitis and to evaluate their relationship with histopathological findings.

Methods: This prospective observational study was conducted at multiple tertiary-care teaching hospital in Pakistan over 12 months. Adult patients undergoing appendectomy for clinically suspected acute appendicitis were consecutively enrolled. Following removal, appendix length, external diameter at the base, middle and tip, and anatomical position were recorded using a standardized proforma. Representative tissue sections were fixed in 10% buffered formalin, processed routinely, stained with hematoxylin and eosin, and examined microscopically. Histopathological severity was categorized according to the predominant inflammatory pattern.

Results: Among 180 patients, the mean age was 29.4±10.8 years and 109 (60.6%) were males. Mean appendiceal length was 7.2±2.0 cm and mean maximum external diameter was 10.1±2.4 mm. Retrocecal position was most frequent (43.9%). Acute suppurative appendicitis was the commonest histological diagnosis (51.1%). Increasing appendiceal diameter was significantly associated with increasing histopathological severity ($p<0.001$), whereas length showed no significant association ($p=0.29$).

Conclusion: Appendiceal diameter showed a stronger relationship with inflammatory severity than appendiceal length. Simple gross morphometry combined with routine histopathology provided useful anatomical and pathological information using inexpensive methods suitable for resource-limited settings.

Keywords: Vermiform Appendix, Appendiceal Morphometry, Acute Appendicitis, Histopathology, Appendiceal Diameter, Appendiceal Length, Anatomical Variation, Appendectomy.

INTRODUCTION

The vermiform appendix is a narrow blind-ending diverticulum arising from the posteromedial aspect of the caecum near the convergence of the taeniae coli and demonstrates substantial variation in its size, position, and relationship with adjacent structures.[1] The appendix commonly occupies retrocecal, pelvic, subcecal, preileal, or postileal positions, and these variations may

influence clinical presentation, operative exposure, and the risk of complications during appendectomy.[2]

Morphometric characteristics of the appendix have also demonstrated considerable interindividual variation, with reported differences in length and external diameter according to age, sex, geographical population, and the methods used for measurement.[3] A large systematic review and meta-analysis involving more than 114,000 subjects reported a pooled mean appendiceal length of approximately 80 mm and demonstrated significant variation in appendiceal location and diameter.[4] Cadaveric studies from South Asia have similarly demonstrated wide variation in appendiceal length, external diameter, mesoappendix development, and relationship with the ileocecal junction.[5]

The microscopic architecture of the appendix consists of mucosa, submucosa, muscularis externa, and serosa, with prominent lymphoid aggregates in the mucosa and submucosa that distinguish it from most other colonic structures.[6] The abundance of lymphoid tissue has contributed to increasing recognition of the appendix as an immunologically active component of the gastrointestinal tract rather than merely a vestigial structure.[7] Histomorphometric studies have demonstrated relationships among luminal diameter, wall thickness, and lymphoid follicle size, suggesting that microscopic alterations may influence luminal narrowing and potentially contribute to obstruction.[8]

Acute appendicitis remains one of the most frequent causes of acute abdominal pain requiring emergency surgery, although its underlying pathogenesis is multifactorial and is not completely explained by luminal obstruction alone.[9] The inflammatory process may progress from mucosal inflammation to transmural neutrophilic infiltration, suppuration, gangrene, and perforation, producing corresponding changes in the gross appearance and thickness of the appendiceal wall.[10] Histopathologically, neutrophilic infiltration extending into the muscularis propria is a central criterion for establishing acute appendicitis, while mucosal ulceration, edema, vascular congestion, hemorrhage, and serosal fibrin deposition may accompany more advanced disease.[11]

Histopathological examination remains important because clinical and operative assessments do not always accurately establish the final diagnosis and may fail to identify unusual or incidental pathology.[12] Pakistani studies have demonstrated considerable variation in histopathological findings among appendectomy specimens, including acute appendicitis, suppurative inflammation, lymphoid hyperplasia, parasitic infestation, granulomatous inflammation, and occasional neoplasia.[13]

Despite the frequency of appendectomy in Pakistan, relatively limited local literature has examined the gross morphometry of the appendix together with its histopathological inflammatory severity in the same prospective cohort. Such information is useful for anatomy teaching, surgical anatomy, pathology reporting, and understanding population-specific anatomical variation. Therefore, the present study was conducted to determine the morphometric characteristics of the vermiform appendix in adult patients undergoing appendectomy for acute appendicitis and to assess the relationship between appendiceal dimensions and histopathological findings.

MATERIALS AND METHODS

This prospective observational study was conducted in the Departments of Anatomy and Pathology in collaboration with the Department of General Surgery at multiple tertiary-care teaching hospitals in Pakistan over a period of 12 months from February 2025 till January 2026. The study was designed as a low-cost hospital-based investigation using routine surgical specimens, standard anatomical measurements, conventional histopathological processing, and hematoxylin and eosin staining without requiring specialized imaging, molecular testing, or immunohistochemistry.

Adult patients aged 18 years or older who underwent appendectomy for clinically suspected acute appendicitis during the study period were consecutively enrolled. Clinical suspicion of acute appendicitis was based on the treating surgeon's assessment, supported where appropriate by symptoms, physical examination, leukocyte count, and ultrasonography or other imaging performed as part of routine clinical care. Patients undergoing incidental appendectomy without clinical suspicion of acute appendicitis, those with previously operated appendices, specimens showing gross destruction that prevented reliable measurement, and cases in

which the appendix was not received intact were excluded.

Ethical approval was obtained from the institutional research ethics committee before commencement of the study. The study was conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants before enrollment. Patient identification numbers were replaced with study codes, and all collected information was kept confidential. No additional expensive investigations or procedures were performed solely for research purposes.

Immediately after appendectomy, each specimen was transferred to the pathology laboratory in a clean container. Before fixation, the appendix was gently straightened without excessive traction. Gross anatomical characteristics were recorded by a trained investigator using a standardized data collection proforma. Appendix length was measured from the appendiceal base at the caecum to the distal tip using a flexible measuring scale and was recorded in centimetres. External diameter was measured using a digital Vernier caliper at three predefined locations: the base, middle third, and tip. The maximum external diameter was subsequently recorded for statistical analysis. Measurements were performed before formalin fixation to minimize dimensional changes associated with tissue processing.

The anatomical position of the appendix was recorded according to the operative findings and categorized as retrocecal/retrocolic, pelvic, subcecal, preileal, or postileal. The presence of a visible appendicolith, perforation, gangrenous discoloration, adhesions, or periappendiceal exudate was also documented when present. The mesoappendix was examined grossly for its attachment and any obvious abnormality.

Following gross examination, the appendix was opened longitudinally along the antimesenteric border when feasible. The mucosal surface was examined for ulceration, congestion, necrosis, fecalith, pus, or other gross abnormalities. Representative tissue samples were obtained from the base, middle portion, and tip, with additional sections taken from visibly abnormal areas. Tissue slices approximately 3–4 mm thick were placed in 10% neutral buffered formalin for adequate fixation.

After fixation, the specimens were processed using routine paraffin-embedding techniques. Sections approximately 3–5 µm thick were prepared using a rotary microtome and stained with hematoxylin and eosin. No special stains or immunohistochemical investigations were required for the primary objectives of the study. The prepared slides were examined by a qualified histopathologist.

Histopathological assessment included evaluation of mucosal ulceration, neutrophilic infiltration, edema, lymphoid hyperplasia, vascular congestion, hemorrhage, suppurative inflammation, necrosis, transmural inflammation, serosal inflammatory exudate, and perforation. Acute appendicitis was diagnosed when neutrophilic infiltration involved the muscularis propria. Cases were categorized according to the most advanced predominant histological lesion as acute appendicitis, acute suppurative appendicitis, gangrenous appendicitis, perforated appendicitis, lymphoid hyperplasia without diagnostic acute appendicitis, or histologically unremarkable appendix.

The principal variables analyzed were appendiceal length and external diameter. The primary outcome was the relationship between appendiceal morphometry and histopathological severity. Secondary variables included anatomical position, age, sex, presence of appendicolith, gross perforation, and gangrenous changes.

Data were entered and analyzed using SPSS version 26.0. Continuous variables were assessed for normality using the Shapiro–Wilk test and were expressed as mean±standard deviation or median with interquartile range, as appropriate. Categorical variables were presented as frequencies and percentages. Independent-samples t-test or Mann–Whitney U test was used for comparison between two groups, while one-way analysis of variance or Kruskal–Wallis test was applied for comparisons involving more than two groups. Pearson or Spearman correlation coefficients were calculated according to data distribution. Chi-square or Fisher's exact test was used to evaluate associations between categorical variables. A p-value <0.05 was considered statistically significant.

Table 1. Variables Recorded during Gross and Histopathological examination

Variable	Assessment/definition

Appendix length	Base to tip, cm
External diameter	Base, middle and tip, mm
Anatomical position	Retrocecal, pelvic, subcecal, preileal or postileal
Appendicolith	Present/absent
Gross complications	Gangrene or perforation
Histopathological diagnosis	Acute, suppurative, gangrenous or perforated appendicitis
Lymphoid hyperplasia	Present/absent

RESULTS

A total of 180 adult patients who underwent appendectomy for clinically suspected acute appendicitis were included in the study. The mean age of the participants was 29.4±10.8 years, with an age range of 18–67 years. Males constituted 109 (60.6%) participants and females 71 (39.4%), giving a male-to-female ratio of approximately 1.5:1. The majority of patients belonged to the 18–30-year age group. The mean age did not differ significantly between male and female participants.

The mean appendiceal length was 7.2±2.0 cm, whereas the mean maximum external diameter was 10.1±2.4 mm. The mean external diameter was greatest at the appendiceal base and progressively decreased toward the tip. The mean basal diameter was 11.2±2.8 mm, the middle diameter was 9.8±2.5 mm, and the tip diameter was 7.4±2.0 mm. Male participants had a slightly greater mean appendiceal length than females, although the difference was not statistically significant. Similarly, no statistically significant sex-based difference was observed in maximum appendiceal diameter.

The most frequently observed anatomical position was retrocecal/retrocolic, which was identified in 79 (43.9%) specimens, followed by the pelvic position in 56 (31.1%). Subcecal, postileal, and preileal positions were identified in 22 (12.2%), 14 (7.8%), and 9 (5.0%) specimens, respectively. Therefore, 75.0% of the appendices were located in either retrocecal/retrocolic or pelvic positions.

A visible appendicolith was identified in 34 (18.9%) specimens. Gross perforation was observed in 7 (3.9%) specimens, while gangrenous discoloration was identified in 21 (11.7%). Periappendiceal fibrinous or purulent exudate was observed in 38 (21.1%) cases. Appendicoliths were more frequently observed in specimens showing advanced inflammatory changes, although the association did not reach statistical significance.

Histopathological examination demonstrated acute suppurative appendicitis in 92 (51.1%) specimens, uncomplicated acute appendicitis in 51 (28.3%), gangrenous appendicitis in 20 (11.1%), and perforated appendicitis in 7 (3.9%). Lymphoid hyperplasia without diagnostic acute appendicitis was identified in 6 (3.3%) cases, while 4 (2.2%) specimens showed no significant pathological abnormality. Overall, histopathological evidence of acute appendicitis was identified in 170 (94.4%) specimens.

The most frequent microscopic findings were mucosal ulceration, neutrophilic infiltration, submucosal edema, vascular congestion, lymphoid follicular hyperplasia, and serosal inflammatory exudate. Neutrophilic infiltration involving the muscularis propria was identified in all specimens classified as acute appendicitis. Gangrenous specimens demonstrated extensive mucosal and transmural necrosis, vascular congestion, and marked inflammatory infiltration. Perforated specimens demonstrated transmural necrosis with disruption of the appendiceal wall and prominent serosal inflammation.

A statistically significant relationship was observed between maximum appendiceal diameter and histopathological severity. The mean maximum diameter increased progressively from 7.1±1.3 mm among histologically unremarkable specimens to 8.2±1.7 mm in lymphoid hyperplasia, 9.4±1.9 mm in uncomplicated acute appendicitis, 10.6±2.2 mm in acute suppurative appendicitis, 12.0±2.1 mm in gangrenous appendicitis, and 13.1±2.5 mm in perforated appendicitis (Kruskal–Wallis $p<0.001$).

In contrast, appendiceal length did not demonstrate a significant relationship with histopathological severity. Mean length ranged from 6.9±1.7 cm among histologically unremarkable specimens to 7.5±2.2 cm in acute suppurative appendicitis and 7.4±2.1 cm in gangrenous appendicitis. The differences between the histopathological groups were not statistically significant ($p=0.29$).

Correlation analysis demonstrated a moderate positive correlation between maximum appendiceal diameter and histopathological

severity score (Spearman's rho=0.46, p<0.001). Appendiceal length showed a weak and statistically non-significant correlation with histopathological severity (rho=0.08, p=0.29). Age showed a weak negative correlation with appendiceal length (rho=-0.18, p=0.02), whereas its association with maximum appendiceal diameter was not statistically significant.

Table 2. Demographic and Gross Morphometric Characteristics of the Study Population

Variable	Overall (n=180)
Age, years, mean±SD	29.4±10.8
Male, n (%)	109 (60.6)
Female, n (%)	71 (39.4)
Appendix length, cm, mean±SD	7.2±2.0
Base diameter, mm, mean±SD	11.2±2.8
Middle diameter, mm, mean±SD	9.8±2.5
Tip diameter, mm, mean±SD	7.4±2.0
Maximum diameter, mm, mean±SD	10.1±2.4
Appendicolith, n (%)	34 (18.9)
Gross perforation, n (%)	7 (3.9)
Gangrenous appearance, n (%)	21 (11.7)

Table 3. Anatomical Position of the Vermiform Appendix

Position	N (%)
Retrocecal/retrocolic	79 (43.9)
Pelvic	56 (31.1)
Subcecal	22 (12.2)
Postileal	14 (7.8)
Preileal	9 (5.0)

Table 4. Relationship between Appendiceal Morphometry and Histopathological Diagnosis

Histopathological diagnosis	n (%)	Length, cm, mean±SD	Maximum diameter, mm, mean±SD
Histologically unremarkable	4 (2.2)	6.9±1.7	7.1±1.3
Lymphoid hyperplasia	6 (3.3)	7.0±1.8	8.2±1.7
Acute appendicitis	51 (28.3)	7.1±1.9	9.4±1.9
Acute suppurative appendicitis	92 (51.1)	7.5±2.2	10.6±2.2
Gangrenous appendicitis	20 (11.1)	7.4±2.1	12.0±2.1
Perforated appendicitis	7 (3.9)	7.3±1.8	13.1±2.5
p-value		**0.29**	**<0.001**

DISCUSSION

The present study demonstrated considerable variation in the gross morphology of the vermiform appendix and showed that external diameter was more closely associated with histopathological severity than appendiceal length. This finding was consistent with previous anatomical literature demonstrating substantial interindividual variation in appendiceal dimensions and anatomical position.[14] A large systematic review and meta-analysis also demonstrated differences in appendiceal length and diameter between populations and reported greater appendiceal diameter in patients with acute appendicitis.[15] The mean appendiceal length in the present study was 7.2 cm, which was within the range reported in previous anatomical studies.[16] Differences between studies may have resulted from population characteristics, age distribution, specimen preparation, and measurement techniques. A study conducted on Bangladeshi specimens reported considerable variation in appendiceal length and demonstrated an inverse relationship between age and appendiceal length.[17] The

weak negative association between age and appendiceal length observed in the present study was therefore comparable with previous observations.

Retrocecal/retrocolic position was the most frequently identified anatomical location, followed by the pelvic position. Previous anatomical studies have similarly demonstrated that retrocecal and pelvic positions constitute a substantial proportion of appendiceal locations.[18] These variations have important clinical implications because appendiceal position may influence the pattern of symptoms, physical examination findings, imaging appearance, and operative approach.[19]

The most significant finding of the study was the progressive increase in appendiceal diameter with increasing histopathological severity. Maximum appendiceal diameter increased from 7.1 mm in histologically unremarkable specimens to 13.1 mm in perforated appendicitis. This finding supported the concept that inflammatory edema, vascular congestion, luminal distension, and accumulation of inflammatory material contribute to enlargement of the appendix during acute inflammation.[20] Previous evidence has also demonstrated that an enlarged appendiceal diameter is strongly associated with acute appendicitis.

The absence of a significant association between appendiceal length and histopathological severity suggested that longitudinal dimensions were relatively stable despite progression of inflammation. In contrast, transverse enlargement appeared to reflect inflammatory changes more directly. This distinction may be relevant when gross specimens are examined by anatomists and pathologists because diameter may provide a more useful macroscopic indicator of disease severity than total length.

Histopathological examination demonstrated acute appendicitis in the majority of specimens. The microscopic findings included neutrophilic infiltration, mucosal ulceration, edema, vascular congestion, and serosal inflammation, while advanced cases showed necrosis and perforation. These findings were consistent with established histopathological criteria for acute appendicitis.[21]

The predominance of suppurative inflammation in the present study was also compatible with findings reported in other appendectomy series, although the exact distribution of histopathological categories has varied among institutions.[22] The identification of lymphoid hyperplasia and histologically unremarkable appendices further demonstrated the importance of microscopic assessment because not all specimens removed for suspected appendicitis showed equivalent inflammatory changes.

Previous studies from Pakistan have also demonstrated that histopathological examination of appendectomy specimens may reveal unexpected diagnoses in addition to routine acute inflammation.[23] Routine histopathology therefore remained useful even when the clinical and operative findings appeared straightforward.

The present study had particular relevance to resource-limited healthcare settings such as Pakistan because the assessment required only routinely available equipment, including a measuring scale, Vernier caliper, formalin, paraffin-processing facilities, and hematoxylin and eosin staining. The study did not require expensive molecular testing, advanced imaging, or immunohistochemical techniques. Consequently, the approach was feasible for anatomy and pathology departments working within limited research budgets.

The study also provided an opportunity for meaningful collaboration between anatomy, pathology, and surgery. Anatomical measurement documented population-specific variation, while histopathological assessment provided objective evidence of the inflammatory process. The combination of both approaches allowed the gross anatomical changes to be interpreted in relation to microscopic disease severity.

CONCLUSION

Appendiceal diameter was significantly associated with histopathological severity, whereas appendiceal length showed no significant relationship. Simple morphometric assessment combined with routine histopathology provides a practical and cost-effective method for evaluating appendectomy specimens, particularly in resource-limited settings.

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