

Morphology and Morphometry of the Vermiform Appendix in Kashmiri Population: A Cross-Sectional Contrast Computed Tomography (CT)-Based Study.

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ABSTRACT

Background

Diagnosis of acute appendicitis on contrast-enhanced computed tomography (CT) relies heavily on a 6 mm appendiceal diameter threshold derived largely from Western populations. Population-specific anatomical reference data for Kashmiri adults are lacking, raising the possibility that this threshold may not translate accurately to this population.

Methods

A cross-sectional, prospective observational study was conducted in the Department of Radiodiagnosis, Government Medical College, Srinagar, over one month (1–31 March 2024). Using consecutive sampling, 100 contrast-enhanced abdominal CT scans of asymptomatic adults (≥ 18 years) imaged for indications unrelated to the appendix were included; individuals with prior appendicitis, right iliac fossa surgery, or CT evidence of appendiceal pathology were excluded. Appendiceal position, length, and width at the base, midpoint, and tip were measured on PACS workstations, with 20% re-measured independently for reliability. Data were analysed in SPSS version 26.0 using descriptive statistics.

Results

Participants had a mean age of 34.6 ± 12.3 years (range 18–65 years) with a near-equal male-to-female ratio (58:42). The appendix was most frequently retrocecal (33%), followed by preileal (22%), postileal (19%), subcecal (13%), paracecal (8%), and pelvic (5%) positions. Mean appendiceal length was 5.4 ± 0.6 cm (range 4.2–6.6 cm). Mean width was 7.2 ± 0.3 mm at the base (range 6.7–7.8 mm), tapering to 6.5 ± 0.5 mm at the midpoint and 6.0 ± 0.8 mm at the tip. A basal width exceeding the conventional 6 mm threshold was observed in 41% of asymptomatic individuals.

Conclusion

Kashmiri adults may possess a naturally larger appendiceal caliber than currently accepted international norms, and rigid application of the 6 mm threshold risks overdiagnosis of appendicitis in this population.

Recommendation

Population-specific reference ranges are recommended for appendiceal diameter, with diagnostic emphasis placed on secondary CT signs of inflammation rather than diameter alone, particularly in borderline cases.

Keywords: Appendix; Normal Anatomy; Computed Tomography; Population Anatomy; Appendicitis Diagnosis; Surgical Reference

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1. INTRODUCTION

The vermiform appendix is a wormlike tubular structure attached to the posteromedial aspect of the caecum. Its attachment, forming the base of the appendix, lies 1–2 cm below the ileocecal junction. The base is constant in position and lies deep to McBurney's point, whereas the tip points in variable directions, giving rise to different appendiceal positions—retrocecal, pelvic, pre-ileal, post-ileal, and subcecal. The appendix also shows considerable variation in length and luminal diameter: length has been reported to range from 2 to 20 cm, and luminal diameter from 5 to 8 mm.

Histologically, the appendix shares the same layers as the rest of the gut tube. The mucosa is lined by simple columnar epithelium with abundant goblet cells and crypts of Lieberkühn, and the submucosa is studded with prominent lymphoid follicles. Unlike the remainder of the large intestine, the appendix possesses a complete outer coat of longitudinal muscle. It is intraperitoneal, suspended by the mesoappendix, which transmits the appendicular artery. Developmentally, the appendix arises from the midgut along with the caecum at the fifth week of intrauterine life; differential growth of the caecum causes it to remain narrow, like a diverticulum, with its attachment shifting to the posteromedial aspect of the caecum. During surgery, the anterior taenia coli is used to trace the appendix [1,2]. Once considered a vestigial organ, the appendix is now recognised as playing an important immunological role [3].

The appendix is implicated in a variety of clinical conditions, including inflammation, neoplasms, diverticulosis, and even endometriosis, making its radiological visualisation important. Contrast-enhanced CT is the gold-standard imaging modality, although magnetic resonance imaging (MRI) and ultrasonography remain valuable, particularly when CT is contraindicated, as in pregnancy. For several decades, appendiceal diameter on CT has been a key diagnostic parameter: a diameter exceeding 6 mm at the base has conventionally been regarded as suggestive of inflammation, a criterion originating from seminal work in the 1980s [4]. Growing evidence suggests that normal appendiceal size may vary with age, body habitus, and possibly ethnicity [5].

In clinical practice in Kashmir, many patients have been observed with appendiceal widths above this threshold in the absence of any other signs of illness. In the absence of local reference data, normal anatomical variation risks being misinterpreted as disease. This study was therefore undertaken to map the appendix in Kashmiri adults and generate a local reference dataset to support more accurate, context-aware diagnosis.

2. OBJECTIVES

The objectives of this study were:

1. To document the different anatomical locations of the vermiform appendix in the study population.
2. To measure the typical length and width of the appendix in asymptomatic adults.
3. To generate reference data for the Kashmiri population.

3. METHODOLOGY

3.1 Study Design

This was a cross-sectional, prospective observational study, in which contrast-enhanced abdominal CT scans acquired consecutively during routine clinical practice were prospectively identified, and appendiceal measurements were subsequently recorded from the stored imaging data.

3.2 Study Setting

The study was conducted in the Department of Radiodiagnosis, in collaboration with the Department of Anatomy, Government Medical College, Srinagar, Jammu and Kashmir, India, a tertiary-care teaching hospital. Data collection extended over a one-month period, from 1 March 2024 to 31 March 2024.

3.3 Participants

The study population comprised adult patients (≥ 18 years) who underwent contrast-enhanced abdominal CT for indications unrelated to the appendix, such as renal colic, blunt abdominal trauma, or oncological staging. Patients were excluded if they had a documented history of appendicitis or appendectomy, prior abdominal surgery involving the right iliac fossa, CT evidence of appendiceal or periappendiceal pathology (wall thickening, fat stranding, appendicolith, or abscess), pregnancy, or non-contrast/motion-degraded studies in which the appendix could not be clearly delineated.

3.4 Variables

The independent variable was the anatomical position of the appendix (retrocecal, pre-ileal, post-ileal, subcecal, paracecal, or pelvic), classified according to its course relative to the caecum and terminal ileum on axial and coronal CT images. The dependent variables were the quantitative appendiceal measurements—total length and width at the base, midpoint, and tip—each measured in millimetres or centimetres using electronic callipers on the PACS workstation. Age and sex were recorded as descriptive covariates.

3.5 Data Sources

CT scans were retrieved from the hospital Picture Archiving and Communication System (Centricity PACS, GE Healthcare) and had been acquired on a 128-slice multidetector CT scanner (GE Revolution EVO) following intravenous contrast administration. Each scan was

reviewed by a radiologist (co-author), who traced the appendix from its origin at the caecum to its tip, classified its anatomical position, and measured its length along its long axis and its outer wall-to-wall width at the base, midpoint, and tip using the electronic measurement tool on the PACS workstation.

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3.6 Bias

Selection bias was minimised by including all consecutive eligible CT scans performed during the study period and by applying explicit, pre-specified eligibility criteria rather than discretionary case selection. Measurement bias arising from single-observer assessment was addressed by having a second, independent observer re-measure appendiceal dimensions in a randomly selected 20% subsample ($n = 20$); measurements showed close agreement between observers, supporting the reliability of the primary dataset. A standardised measurement protocol with fixed anatomical reference points (origin at the caecal wall and the appendiceal tip) was used throughout to reduce inter-observer variability.

3.7 Study Size

The sample size was estimated using the formula $n = Z^2 p(1-p)/d^2$, where $Z = 1.96$ (95% confidence level), $p = 0.40$ (anticipated proportion of asymptomatic individuals with a basal appendiceal width exceeding 6 mm, based on prior literature), and $d = 0.10$ (absolute precision). This yielded a minimum requirement of approximately 93 scans; the sample size was rounded up to 100 to allow for exclusions and to accommodate the anticipated volume of eligible scans within the one-month study period.

3.8 Quantitative Variables

Appendiceal length and width (base, midpoint, tip) were treated as continuous variables and summarised as mean $\pm$ standard deviation (SD) and range. In addition, basal width was dichotomised as ≤ 6 mm or >6 mm, based on the conventional diagnostic cut-off described in the literature⁴, to determine the proportion of asymptomatic individuals exceeding this threshold.

3.9 Statistical Methods

Data were entered into Microsoft Excel and analysed using IBM SPSS Statistics, version 26.0. The Shapiro-Wilk test was used to assess the normality of continuous variables. Normally distributed continuous variables were expressed as mean $\pm$ SD and range; categorical variables, including appendiceal position and the proportion exceeding the 6 mm threshold, were expressed as frequency and percentage. Given the descriptive nature of the study objectives, no formal hypothesis testing was performed.

3.10 Ethical Considerations

Ethical approval was obtained from the Institutional Ethics Committee, Government Medical College, Srinagar (approval number GMC/IEC/2024/187, dated 15 February 2024). As the study involved retrospective analysis of anonymised imaging data acquired during routine clinical care, with no additional intervention or patient contact, the Ethics Committee granted a waiver of individual informed consent. Patient confidentiality was maintained throughout by removing all identifying information from the imaging data prior to analysis and by storing measurement data using coded, non-identifiable study numbers accessible only to the study investigators.

4. OBSERVATIONS AND RESULTS

4.1 Sociodemographic Characteristics

Of the 100 asymptomatic adults included, the mean age was 34.6 ± 12.3 years (range 18–65 years). There was a near-equal sex distribution, with 58 men and 42 women (male-to-female ratio 1.4:1).

4.2 Anatomical Position of the Appendix

The position of the appendix was variable. The retrocecal position was the single most common site, accounting for one-third of cases. A substantial proportion lay anterior or posterior to the terminal ileum (pre-ileal and post-ileal positions). The classic pelvic position was the least common (Table 1).

Table 1 Anatomical Position of the Vermiform Appendix in 100 Adults

Position	n	%
Retrocecal (behind caecum)	33	33.0
Preileal (in front of ileum)	22	22.0
Postileal (behind ileum)	19	19.0
Subcecal (below caecum)	13	13.0
Paracecal (beside caecum)	8	8.0
Pelvic (in pelvis)	5	5.0
Total	100	100.0

Note. N = 100. Percentages are rounded to one decimal place.

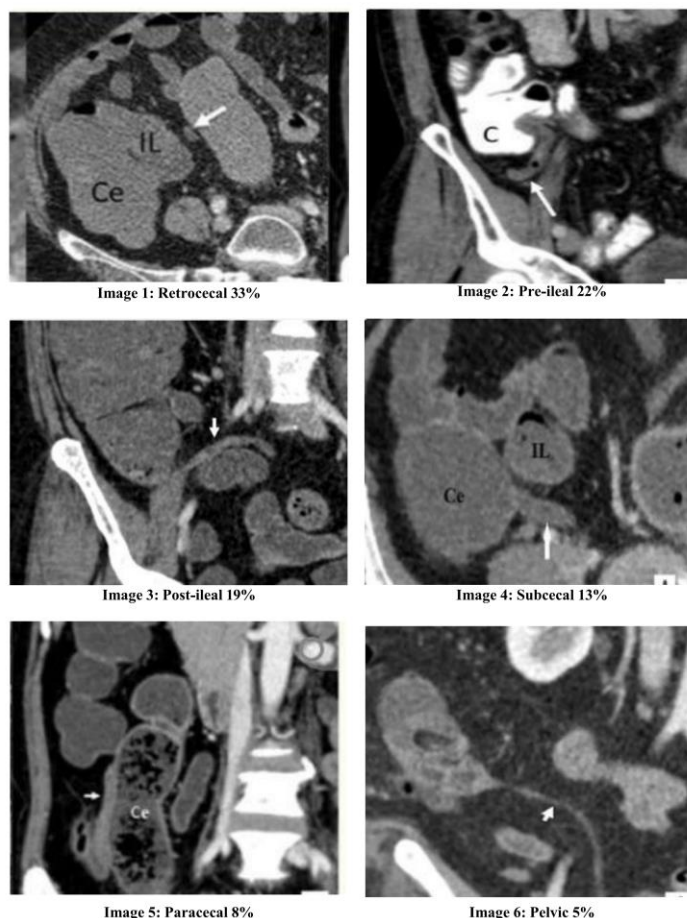


Figure 1. Representative CT Images Showing Different Anatomical Positions of the Appendix (Image 1: Retrocecal, 33%; Image 2: Preileal, 22%; Image 3: Post-ileal, 19%; Image 4: Subcecal, 13%; Image 5: Paracecal, 8%; Image 6: Pelvic, 5%)

4.3 Appendiceal Length and Width

Appendiceal length varied among participants, with a mean of approximately 5.4 cm. Width followed a consistent pattern, being widest at the base and tapering progressively toward the tip. The measurement at the base was of particular clinical relevance (Table 2).

Table 2 Length and Width of the Normal Appendix in 100 Adults

Measurement	Range	Mean $\pm$ SD
Total length (cm)	4.2 – 6.6	5.4 $\pm$ 0.6
Width at base (mm)	6.7 – 7.8	7.2 $\pm$ 0.3
Width at midpoint (mm)	5.5 – 7.6	6.5 $\pm$ 0.5
Width at tip (mm)	4.3 – 7.7	6.0 $\pm$ 0.8

Note. SD = standard deviation. Width was measured as the outer wall-to-wall diameter.

A basal appendiceal width exceeding the conventional 6 mm threshold was observed in 41 of 100 (41%) asymptomatic individuals with no CT or clinical evidence of appendiceal disease.

5. DISCUSSION

The vermiform appendix, long regarded as a vestigial organ, is gaining renewed importance owing to its immunological

role, although it remains implicated in several pathological conditions. Acute appendicitis constitutes a surgical emergency, but its variable anatomical position makes clinical diagnosis challenging [6]. Appendiceal position is determined developmentally: failure of caecal descent results in a subhepatic location, whereas continued growth and rotation of the caecum during early childhood typically carries the appendix into the retrocecal position, the most commonly reported site [7].

The finding that the retrocecal position was the most common, observed in the present study, is consistent with traditional anatomical descriptions. However, the observed rate of 33% is lower than the 60–65% frequently cited in older cadaveric studies [16]. Kachare et al. (2025) [8], in a CT-based abdominal study, reported the post-ileal position as most common (32.9%) and the paracecal position as least common (1.2%). Singh et al. (2023) [9], in a retrospective CT-based study, reported the retrocecal position as most common (25.3%) and the paracecal position as least common (3.1%). Anatomical and imaging studies indicate that appendiceal position varies across geographical and ethnic populations [10-12].

Appendiceal diameter on CT is regarded as a positive indicator of appendiceal health, and an increased diameter has been shown to influence readmission decisions irrespective of clinical findings [13]. A mean basal diameter of 7.2 mm among healthy individuals in the present study prompts reconsideration of the conventional 6 mm standard. This observation is consistent with other studies reporting that a non-inflamed appendix can safely measure 7–8 mm in diameter [14,15]. The appendiceal lumen may be distended by fluid or lymphoid tissue, making it appear larger on imaging without underlying disease [16].

These findings suggest that diagnosing appendicitis based on width alone carries substantial risk in this population, and that reliance on the 6 mm criterion in isolation could lead to unnecessary anxiety and surgical intervention. Diagnosis should instead integrate multiple radiological features. Radiologists are encouraged to prioritise secondary CT signs such as appendiceal wall thickening, periappendiceal fat stranding, or a visible appendicolith, which, combined with clinical presentation and laboratory findings, are considered more reliable indicators of inflammation than diameter alone [17,18].

Appendiceal length is known to be variable, and the range observed in the present study (4.2–6.6 cm) is consistent with earlier reports [19]. Some authors have correlated appendiceal length with ethnicity and body mass [20,21]. Although appendiceal length as an independent risk factor for appendicitis is not firmly established, some evidence suggests that a longer appendix may be more prone to inflammation and perforation [22]. A long, inflamed appendix may also irritate adjacent structures, producing

atypical presentations resembling salpingitis, enteritis, or cholecystitis [23,24].

5.1 Generalizability

As a single-centre study conducted within a defined ethnic and geographic population in the Kashmir valley, these findings are most directly generalisable to adults of similar ethnic background and body habitus presenting to comparable tertiary-care settings. The consecutive sampling approach over a defined one-month period supports representativeness within this institution, but the modest sample size and single-centre design limit extrapolation to paediatric populations, other regions of India, or ethnically distinct populations elsewhere. Multicentre studies across diverse Indian and South Asian populations would be needed to confirm whether the observed reference ranges apply more broadly.

5.2 Recommendation

Based on these findings, it is recommended that radiologists and surgeons in Kashmir and comparable populations treat the 6 mm appendiceal diameter threshold as an adjunctive rather than absolute diagnostic criterion. Secondary radiological signs of inflammation should be given greater diagnostic weight, and population-specific reference ranges, such as those generated in this study, should be incorporated into local reporting practice to reduce the risk of overdiagnosis.

5.3 Limitations

This was a single-centre study involving 100 individuals. While it identifies a clear trend, larger multicentre studies would strengthen the evidence base. Additionally, the study was restricted to adults, and appendiceal dimensions in children were not assessed.

6. Conclusion

This CT-based study of the appendix in the Kashmiri population provides a locally relevant anatomical benchmark. Although appendiceal position is variable, its calibre may naturally exceed currently accepted international standards, indicating that a fixed 6 mm threshold is a poor fit for this population. For surgeons and radiologists working in Kashmir and similar regions, a shift toward flexible, population-sensitive diagnostic criteria is recommended, integrating secondary radiological signs with the overall clinical picture. Adoption of such criteria may improve diagnostic accuracy and reduce unnecessary surgical intervention.

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Conflict of interest

The authors declare no conflict of interest.

List of abbreviations

Abbreviation	Full Form
CT	Computed Tomography
MRI	Magnetic Resonance Imaging
PACS	Picture Archiving and Communication System
SD	Standard Deviation
mm	Millimetre
cm	Centimetre
SPSS	Statistical Package for the Social Sciences
IEC	Institutional Ethics Committee

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Data availability

The datasets generated and/or analysed during the current study are available from the corresponding author upon reasonable request.

Author contributions

Conceptualisation and study design: Javed Ahmad Khan and Naseer Ahmad Khan. Data acquisition and CT image analysis: Naseer Ahmad Khan and Sheikh Aakida Hussain. Data curation and statistical analysis: Baseerat Rashid Kaboo and Reyhana Yousuf. Drafting of the manuscript: Reyhana Yousuf and Sajad Hamid. Critical revision for important intellectual content: Javed Ahmad Khan and Sajad Hamid. All authors reviewed and approved the final version of the manuscript.

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