Topographical anatomy of the vermiform appendix within a select adult and fetal South African population

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SUMMARY

One of the intra-abdominal structures that is considered vestigial, yet highly potent, is the appendix, which can vary in position, length, and diameter due to differences among sexes, population groups, and embryological variations. These variations have been documented in various adult and fetal populations; however, few have investigated these variations within a South African population. The present study therefore aimed to describe the topographical anatomy of the vermiform appendix within a select adult and fetal South African population. The appendicular position, length, outer diameter (at the base, midpoint, and tip), distance of the spino-umbilical line, and the relation to the spino-umbilical line were determined in 20 adult (subset A) and 45 fetal (subset B) embalmed cadavers obtained from the Department of Clinical Anatomy, University of KwaZulu-Natal, South Africa. There was a high incidence of the retrocecal position in subset A, and the pre-ileal position in subset B. The average distance of the spino-umbilical line, length, and diameter in subset A were 216.54 ± 36.51 mm, 75.56 ± 19.45 mm, and 5.99 ± 1.64 mm, respectively. The average length, diameter, and distance of the spino-umbilical in subset B were 21.99 ± 5.38 mm, 1.47 ± 0.36 mm, and 29.02 ± 5.70 mm, respectively. The appendicular base was frequently found along the spino-umbilical line in subset A, and cephalically in subset B. The present study's findings may assist in diagnosing appendicitis and appendectomy within this select adult and fetal South African population.

Key words: Vermiform appendix – Topographical anatomy – Adult – Foetal – South African population

INTRODUCTION

Embryologically, the vermiform appendix arises from the caecal diverticulum (saccular diverticulum) during the sixth week of gestation (Pansky, 1982; Sadler, 2004; Hodge et al., 2023). The vermiform appendix is a hollow, long vesti-

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gial tube which is shaped like a worm and arises from the posterior medial aspect of the caecal wall in the lower (right) abdominal quadrant and two centimeters from the inferior aspect of the ileocecal valve (Pansky, 1982; Sadler, 2004). The appendix's locationon the medial side is beneficial as the appendicular base can be located near the convergence of the taeniae coli during surgery (Hodge et al., 2023). This is beneficial to surgeons in ligation or closure of the appendicular base during appendectomy.

The appendix has no standard or fixed anatomy, as its position varies among various individuals (Ahmed et al., 2007; Parmar et al., 2017). The length of the vermiform appendix ranges between 2.0-20.0 cm (Ahmad et al., 2017; Parmar et al., 2017). Due to the anatomical variations of the appendix such as agenesis, duplicity, and positional changes, careful considerations should be taken prior to any intra-abdominal surgical procedures (Ahmed et al., 2007; Parmar et al., 2017).

The spino-umbilical line is the distance from the umbilicus to the anterior superior iliac spine, and is used as a reference point in identifying the appendix (Mwachaka et al., 2014). Previous studies have attempted to locate McBurney's point, which is theorized to be the location of the appendicular base on the right spino-umbilical line as being either between the lateral and middle third or at precisely at the midpoint of the line (Mwachaka et al., 2014). This landmark is theorized to be the abdominal surface landmark for identifying the appendicular base in preparation for surgical intervention. Furthermore, the appendicular diameter is a crucial factor for the diagnosis of acute appendicitis in children (Mullins et al., 2001; Trout et al., 2014).

This study aimed to describe the surgical anatomy of the vermiform appendix in terms of its length, diameter, and relation to the spino-umbilical line within a select South African population.

MATERIALS AND METHODS

This retrospective study consists of 20 adult (subset A) and 45 fetal (subset B) cadavers obtained from the Department of Clinical Anatomy at the University of KwaZulu-Natal, South Africa. Institutional ethical approval was obtained (BREC/00005966/2023). Embalmed adult and fetal cadaveric specimens of all age groups, both sexes, and White population group with no abnormalities of the abdominal organs or fibrosis; and only appendices that contained an intact abdomen with no signs of surgical intervention were used in this study.

Method of cadaveric preservation

After the cadavers were prepared for embalming, a sagittal incision was made through the skin, superficial fascia, and deep fascia in the upper inner quadrant of the thigh. Blunt dissection and an aneurism needle were used to clean and expose the femoral artery. An incision was made on the femoral artery utilizing the arterial forceps to lift the femoral artery and making a short sagittal incision along the path of the artery. A cannula with two openings was inserted into the femoral artery and secured to avoid leaking. Under low pressure the embalming fluid process commenced. The embalming fluid was filled in the pressure tank, and pressure was applied in the tank by use of the air compressor which was connected to the tank. From the tank, the embalming fluid was carried by a tube in which the end was connected to the cannula. The extremities were supplemented with a hypodermal injection under the skin of the dorsum of the foot and hands. The arteries were ligated, and the incision was stitched back using string. Once the process was completed, the body was washed with disinfectant and covered in calico cloth and polyurethane plastic. Cadavers were moistened 2 to 3 times a week with wetting fluid.

Skin measurements were taken from the umbilicus to the anterior superior iliac spine prior to dissection (Detton and Tank, 2017). All measurements were taken in triplicate using a digital vernier caliper. The appendix was then exposed and assessed/analyzed according to the following parameters:

Spino-umbilical line: The distance from the umbilicus to the right anterior superior iliac spine (i.e., the right spino-umbilical line) was measured using suture material. McBurney's point was taken as the lateral middle third of the right spino-umbilical line.

Table 1. Description of the various positions of the vermiform appendix (adapted from Parmar et al., 2017).

Appendicular position	Description
Paracecal / paracolic	Appendix is located upward and lateral to the cecum and ascending colon.
Retrocecal / Retrocolic	Appendix is located behind the cecum or the ascending colon.
Pre-ileal	Appendix is directed to the spleen and is in front of the terminal ileum (antero- superiorly).
Post-ileal	Appendix is directed to the spleen and is behind the terminal ileum (postero-superiorly).
Subileal / promonteric	Appendix is directed diagonally towards the sacral promontory in a medial direction.
Pelvic	Appendix is directed downward, hanging on the pelvic brim with the appendicular tip projecting into the pelvic cavity.
Subcecal / midinguinal	Appendix is found under the cecum and directed inferiorly towards the midpoint of the inguinal ligament.

Appendicular position: The position of the vermiform appendix was recorded manually on a data sheet and defined as indicated in Table 1.

Mesoappendix: The state of the mesoappendix (i.e., complete, or incomplete) was recorded manually on a data sheet. The incomplete mesoappendix was defined as one that did not reach the appendicular tip. A complete mesoappendix was where the mesoappendix reached the appendicular tip.

Relationship to McBurney's point: McBurney's point was used to determine the location of the appendicular base. The relationship between the appendicular base and McBurney's point was classified as cephalic, caudal, or along the spino-umbilical line.

Appendicular length and diameter: The length of the vermiform appendix was measured from the base to the tip using suture string. It was removed at its attachment point to the cecum and placed in specimen jars containing 10% formalin. The diameter of the appendix was measured along three points viz.: at the base, tip, and at the midpoint of the length. The length was measured and then the midpoint diameter was recorded.

Gestational age: For the fetal cadavers, the foot length was measured using suture material from the midpoint of the heel to the longest toe. The suture material was then measured using a digital vernier caliper. The average length of the foot was then used to determine the gestational age (in weeks) of the fetus by categorizing and comparing it to the model used by Hern (1984), Wyk and Smith (2016) and Selvendran et al. (2021). In the case where both feet were amputated, the circumference of the head was measured to determine the gestational age of the fetus. The circumference of the head was measured using suture string from the supra-orbital ridges (anteriorly) to the external occipital protuberance (posteriorly) above the ear lobes (on both sides laterally). The measurements were recorded manually on a data sheet and an average was calculated to determine the gestational age by comparing it to the data from Kiserud et al. (2017).

Statistical analysis

Descriptive statistics were used to summarize the data. Frequencies and percentages were used for categorical data. Numerical measurements were expressed by means and standard deviations (SD). Demographic factors, such as sex as well as clinical factors such as position, distance of the spino-umbilical line, length, and width was examined using Fisher's exact test, Chi-square test, and T Tests. A significant p-value of 0.05 was set. Stata v17 statistical software was used for the analysis.

RESULTS

A total of sixty-five (n = 65) cadavers were used in this study with two subsets viz., adult (n=20) (subset A), and fetal (n=45) (subset B). The vermiform appendix was present in all the samples of subset A and B. The mesoappendix was incomplete (did not reach the appendicular tip) in all the cadavers included in subset B, whilst the mesoappendix was complete in all the cadavers included in subset A. Subset B was predominantly male (75.56%) as compared to Subset A (65.00%).

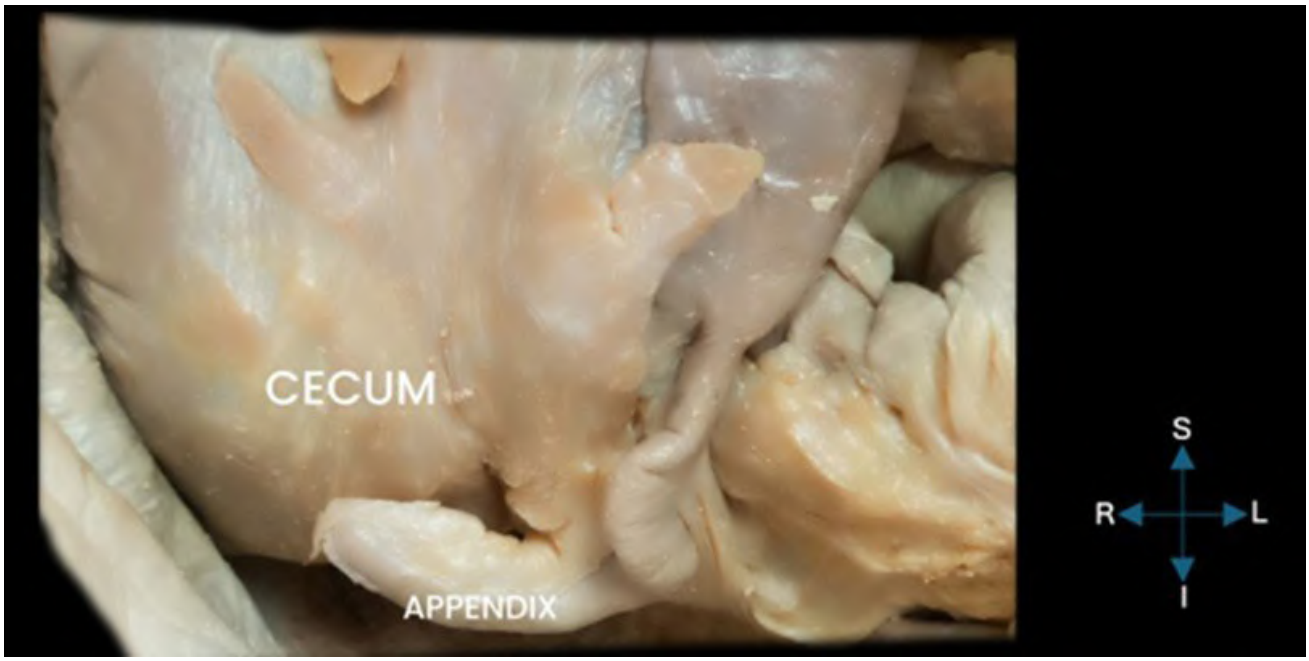

Fig. 1.- Retrocecal position of the appendix (subset A). S: superior; I: inferior; R: right; L: left.

Subset A: The age of the adult cadavers ranged between 55 to 98 years with an average age of 72 ± 10 years. The most frequently occurring position in this subset was the retrocecal position (40.0%) (Fig. 1), followed by the pelvic position (30.0%). Other variations seen in this subset included the post-ileal (15.0%), para-cecal (5.0%), sub-cecal (5.0%), and sub-ileal (5.0%) positions (Fig. 2). The retrocecal position of the appendix was prevalent in females, while the retrocecal and the pelvic positions were prevalent in males in this study as summarized in Table 2. In terms of the length of the appendix, the average length was 75.56 ± 19.45 mm (range: 38.66-109.94 mm) with males having a longer appendix than females (Table 2). The distance of the spino-umbilical line was 216.54 ± 36.51 mm with a range of 140.43-276.92 mm. The appendicular base was predominantly located along (65%) the spino-umbilical line. The outer diameter measurements yielded an average diameter of 5.99 ± 1.64 mm (range: 2.73-0.64 mm), with males having a larger diameter than females (Table 2). There was a statistically significant difference between the outer diameter at the base of the vermiform appendix in males and females (p = 0.04). There was a statistically significant difference between the relation to the spino-umbilical line in males and females (p = 0.02).

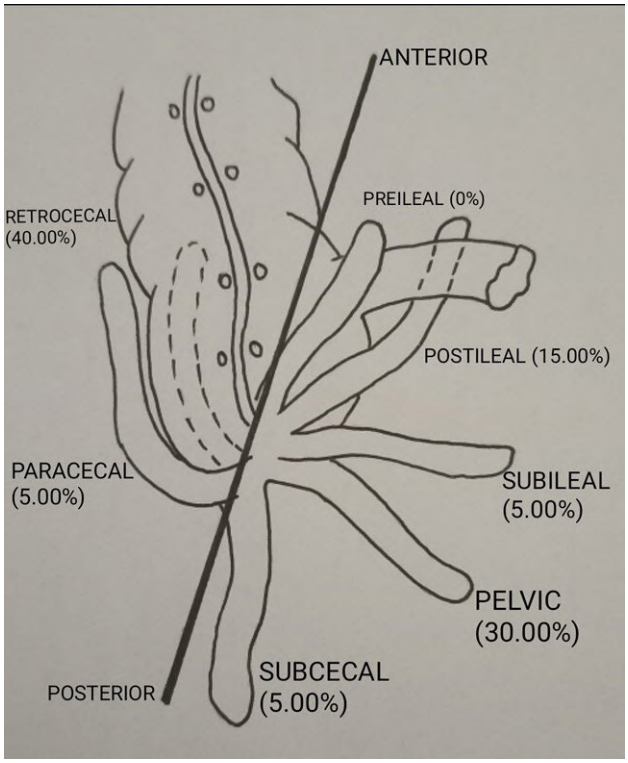

Fig. 2.- Incidence of the various positions of the vermiform appendix in subset A.

Subset B: The age of the fetal cadavers ranged between 14 to 28 weeks and the average age was 21 ± 3 weeks. The most frequently occurring position of the vermiform appendix in the fetal subset of this study was the pre-ileal position (31.11%) (Fig. 3), followed by the post- ileal position (28.89%). Other variations seen in this study include the

Table 2. Morphological and morphometric variables of the vermiform appendix among males and females in subset A.

Parameter	Female (n = 7)	Male (n = 13)	Total (n = 20)	p-value (Observed power)
Position				
Retrocecal	3 (42.86%)	5 (38.46%)	8 (40.00%)	0.40
Pelvic	1 (14.29%)	5 (38.46%)	6 (30.00%)	
Postileal	2 (28.57%)	1 (7.69%)	3 (15.00%)	
Subileal	0 (0.00%)	1 (7.69%)	1 (5.00%)	
Subcecal	1 (14.29%)	0 (0.00%)	1 (5.00%)	
Paracecal	0 (0.00%)	1 (7.69%)	1 (5.00%)	
Distance of the spino-umbilical line				
Average Distance	214.72 ± 24.96 mm	217.52 ± 42.39 mm	216.54 ± 36.51 mm	0.88 (0.05)
Relation to spino-umbilical line				
Cephalic	0 (0.00%)	0 (0.00%)	0 (0.00%)	0.02
Caudal	5 (71.43%)	2 (15.38%)	7 (35.00%)	
Along	2 (28.57%)	11 (84.62%)	13 (65.00%)	
Appendicular length				
Average length	74.39 ± 17.29mm	76.20 ± 21.18 mm	75.56 ± 19.45 mm	0.85 (0.05)
Appendicular Diameter				
Base	5.58 ± 1.70 mm	7.44 ± 1.78 mm	6.79 ± 1.93 mm	0.04
Midpoint	5.30 ± 2.05 mm	6.45 ± 2.33 mm	6.05 ± 2.25 mm	0.29 (0.18)
Tip	4.94 ± 1.66 mm	5.22 ± 1.99 mm	5.12 ± 1.84 mm	0.76 (0.06)
Average	5.28 ± 1.63 mm	6.37 ± 1.57 mm	5.99 ± 1.64 mm	0.16 (0.28)

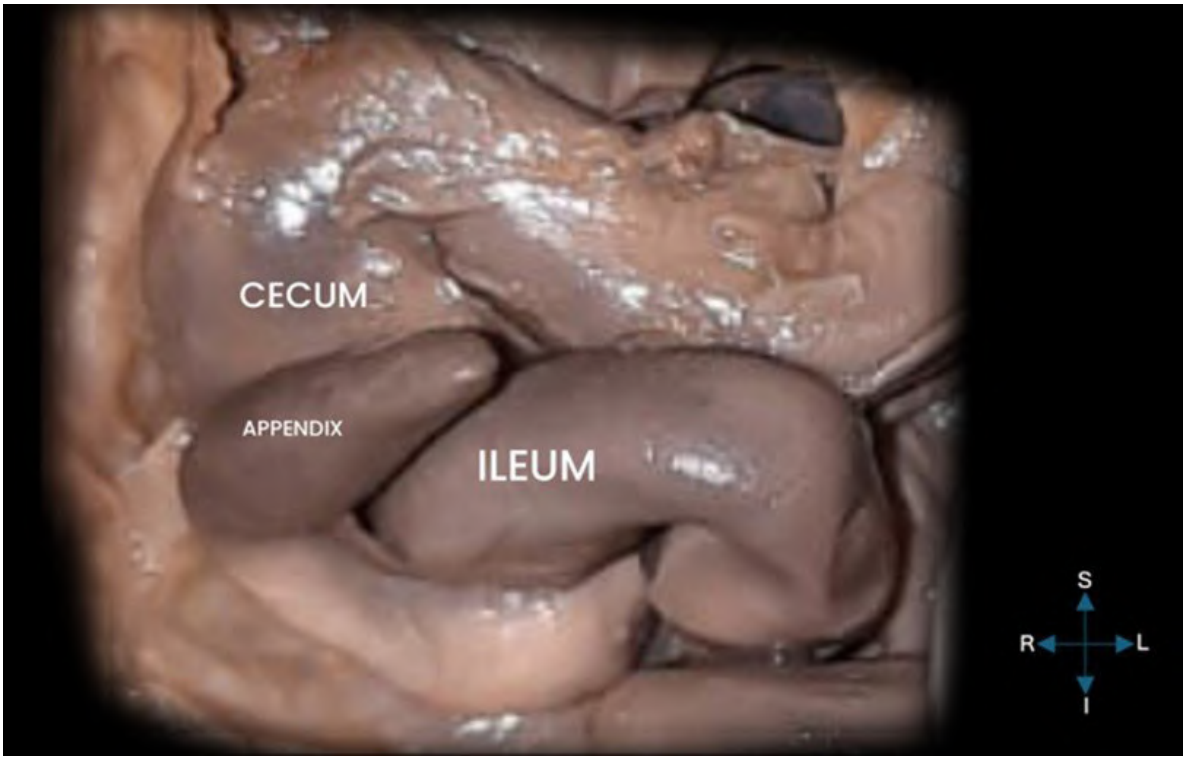

Fig. 3.- Pre-ileal position of the appendix (subset B). S: superior; I: inferior; R: right; L: left.

Table 3. Morphological and morphometric variables of the vermiform appendix among males and females in subset B.

Parameter	Male (n = 34)	Female (n = 11)	Total (n = 45)	p-value (Observed power)
Position				
Retrocecal	2 (5.88%)	1 (9.09%)	3 (6.67%)	0.07
Postileal	10 (29.41%)	3 (27.27%)	13 (28.89%)	
Preileal	13 (38.24%)	1 (9.09%)	14 (31.11%)	
Subileal	0 (0.00%)	0 (0.00%)	0 (0.00%)	
Pelvic	0 (0.00%)	1 (9.09%)	1 (2.22%)	
Subcecal	4 (11.76%)	0 (0.00%)	4 (8.89%)	
Paracecal	5 (14.71%)	5 (45.45%)	10 (22.22%)	
Distance of the spino-umbilical line				
Average Distance	28.27 ± 5.88 mm	31.36 ± 4.56 mm	29.02 ± 5.70 mm	0.12 (0.34)
Relation to spino-umbilical line				
Cephalic	26 (76.47%)	7 (63.64%)	33 (73.33%)	0.45
Caudal	0 (0.00%)	0 (0.00%)	0 (0%)	
Along	8 (23.53%)	4 (36.36%)	12 (26.67%)	
Appendicular length				
Average length	22.60 ± 4.83 mm	20.11 ± 6.73 mm	21.99 ± 5.38 mm	0.19 (0.26)
Appendicular Diameter				
Base	1.54 ± 0.47 mm	1.79 ± 0.59 mm	1.60 ± 0.51 mm	0.16 (0.29)
Midpoint	1.44 ± 0.43 mm	1.61 ± 0.48 mm	1.48 ± 0.44 mm	0.29 (0.18)
Tip	1.33 ± 0.29 mm	1.36 ± 0.41 mm	1.34 ± 0.32 mm	0.75 (0.06)
Average	1.44 ± 0.33 mm	1.59 ± 0.43 mm	1.47 ± 0.36 mm	0.24 (0.22)

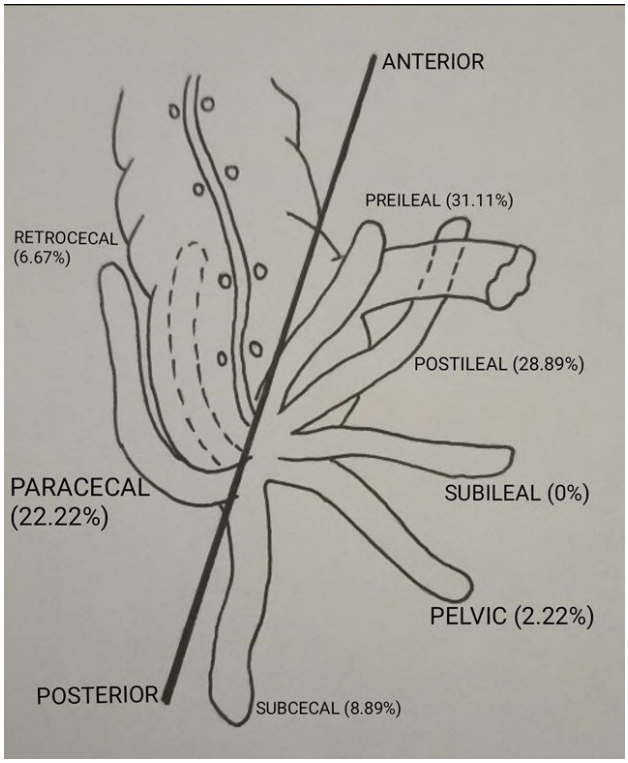

Fig. 4.- Incidence of the various positions of the vermiform appendix in subset B.

paracecal (22.22%), subcecal (8.89%), retro-caecal (6.67%), and pelvic (2.22%) position (Fig. 4). The paracecal position was prevalent in females, while the pre-ileal position was prevalent in males as summarised in Table 3. The length of the spino-umbilical line was measured to be 29.02 ± 5.70 mm (range: 20.21-40.23 mm) with the appendicular base located cephalic (73.33%) to the spino-umbilical line. In terms of the length of the appendix, the average length was 21.99 ± 5.38 mm (range: 11.46mm-32.52 mm) with males having a longer appendix than females (Table 3). Outer diameter measurements yielded an average diameter of 1.47 ± 0.36 mm and notably larger in females than males (Table 3).

There was no statistically significant difference between the position of the vermiform appendix among males and females in subset A (p = 0.40) and B (p = 0.07). There were no statistically significant differences in the length of the appendix between males and females in subset A (p =

0.85) and B (p = 0.19). There was no statistically significant difference between the distance of the spino-umbilical line among males and females in subset A (p = 0.88) and B (p = 0.12).

DISCUSSION

The vermiform appendix is a cylindrical muscular structure attached to the large intestine. It displays numerous variations based on its topography and relation to the spino-umbilical line. This study aimed to investigate the appendicular anatomy in terms of the position of the appendix, length, diameter, and relation to common surgical landmarks.

Appendicular position

This study found six distinct positions of the appendix in adults (subset A) viz.: retrocecal, pelvic, post-ileal, sub-ileal, subcecal, and paracecal. The retrocecal position (40.00%) was identified as the principal location of the appendix in the adult subset of our study. This finding coincides with studies conducted by Mwachaka et al. (2014), de Souza et al. (2015), El-Amin et al. (2015), Abegaz et al. (2016), Patel and Naik (2016), Parmar et al. (2017), Chaudhari and Kanani (2018), Azhagiri et al. (2019), Edibamode et al. (2019), Khatun et al. (2019), and Sumi et al. (2019), in which the retrocecal position was predominantly found in adults.

There is a higher risk of appendicitis in the retrocecal position which can cause a compromised blood supply to the organ (Mwachaka et al., 2014; Ahmad et al., 2017; Parmar et al., 2017). Symptoms that display an upper urinary tract infection can occur when the appendix is in the retrocecal position due to irritation to the ureter (Lamture and Salunke, 2018; Azhagiri et al., 2019).

The pelvic position was found in 30.00% of cases in subset A. This finding contradicts the findings of studies conducted by Rahman et al. (2006), Ahmed et al. (2007), Ashindoitiang and Ibrahim (2012), Ghorbani et al. (2014), and Ahmad et al. (2017), in which the pelvic position was predominant. In the pelvic position, the appendicular tip lies on the psoas muscle which may cause irritation to the muscle when the appendix is inflamed and the hip is flexed (Rahman et al., 2006). The obturator internus muscle can also get stretched when the appendicular tip is in the pelvic position which will result in pain when the thigh is medially rotated and flexed (Chaudhari and Kanani, 2018; Azhagiri et al., 2019). Furthermore, it may cause irritation to the rectum or bladder, causing the need to defecate, urination pain or suprapubic pain (Chaudhari and Kanani, 2018; Azhagiri et al., 2019).

The post-ileal position was found in 15.00% of cases in subset A. Testicular pain and irritation to the ureter can be caused in males when the appendix is in the post-ileal position (Azhagiri et al., 2019). This study reports a 42.86% of cases with the appendix in a retrocecal position in females as opposed to retrocecal (38.46%) and pelvic (38.46%) positions in males. This finding concurs with a study conducted by Khatun et al. (2019), in which a frequent retrocecal position was found in both males and females. Azhagiri et al. (2019), on the other hand, reported frequent retrocecal and pelvic positions in males and females, respectively. Table 4 reports the incidences of the various appendicular positions among various adult populations.

This study also found six distinct positions of the vermiform appendix in fetuses (subset B) viz.: retrocecal, pre-ileal, post-ileal, subcecal, pelvic, and paracecal. The prevalence of the pre-ileal position in this study was 31.11%. This finding contradicts the findings of studies conducted by Nidhi et al. (2016), and Malas et al. (2004) in which the subcecal position was noted to be the predominant position.

This differs from our study where this position was noted in 8.89% of cases in subset B. However, Shaikh and Gurukkal (2018) conducted a similar study on an Indian population as well, and noted the pelvic position of the vermiform appendix to be prevalent. Maisel (1960) conducted a study on a South African population and noted the pelvic position to be prevalent, which contradicted the present study's incidences.

The differences between the incidences of the appendicular position can be attributed to the geographical location, population group, and the length of the appendix.

Table 4. Frequency of the various positions of appendix in adult populations as reported by several authors.

Author (year)	Population	Modality	Sample size	Appendix position						
				Retro-caecal	Post-ileal	Pre-ileal	Sub-ileal	Pelvic	Sub-caecal	Para-caecal
Rahman et al. (2006)	Bangladeshi	Post-mortem	100	22%	-	10%	-	47%	-	-
Ahmed et al. (2007)	-	Surgical	303	20.1%	22.1%	3.00%	-	51.2%	-	3.60%
Ashindoitiang and Ibrahim (2012)	Nigerian	Surgical	80	23.8%	17.5%	5.00%	-	41.3%	12.5%	-
Ghorbani et al. (2014)	Iranian	Autopsy	200	7%	-	1.5%	-	55.8%	19.0%	-
Mwachaka et al. (2014)	Kenyan	Cadaveric	48	27.1%	18.8%	-	18.8%	25.0%	4.2%	2.1%
de Souza et al. (2015)	Brazilian	Cadaveric	377	43.5%	14.3%	2.4%	-	9.3%	24.4%	5.8%
El-Amin et al. (2015)	Sudanese	Cadaveric	60	60.0%	3.30%	1.70%	35.0%	-	-	-
Abegaz et al. (2016)	Ethiopian	Surgical	154	72.7%	-	10.4%	-	11.7%	5.19%	-
Patel and Naik (2016)	Indian	Cadaveric	50	64.0%	4.00%	-	-	30.0%	2.00%	-
Ahmad et al. (2017)	Pakistani	Cadaveric	76	35.95%	8.87%	4.86%	-	41.83%	3.89%	2.84%
Ekanayake et al. (2017)	Sri Lankans	Autopsies	60	34.5%	50.0%	-	-	12.1%	-	3.45%
Parmar et al. (2017)	-	Surgical	100	66.0%	3.00%	1.00%	-	27.0%	2.00%	1.00%
Chaudhari and Kanani (2018)	Indian	Cadaveric	200	55.5%	-	-	-	23.5%	6.5%	5.0%
Azhagiri et al. (2019)	Indian	CT	75	43.0%	8.00%	3.00%	-	33.0%	13.0%	-
Edibamode et al. (2019)	Nigerian	Cadaveric	41	53.7%	9.80%	2.40%	-	26.8%	7.30%	-
Khatun et al. (2019)	Nepalis	Surgical	264	35.98%	23.10%	4.16%	-	25.37%	11.36%	-
Sumi et al. (2019)	Bangladeshi	Cadaveric	70	62.9%	4.30%	-	-	31.4%	1.40%	-
Present study	South African	Cadaveric	20	40.0%	15.0%	-	5.00%	30.0%	5.00%	5.00%

CT: computed tomography

Length of the vermiform appendix

Previous literature attributes the differences in the length of the vermiform appendix to population group, genetics, nutrition and age of fetuses included in these studies. The average length of the vermiform appendix in the presented study corresponds to other population studies conducted by Ahmad et al. (2017), and Khatun et al. (2019). Table 5 shows the length of the vermiform appendix reported by various authors in adult populations.

In subset A, the length of the appendix ranges between 38.66 mm to 109.94 mm with males being longer that females. This is similar to the length range reported by Khatun et al. (2019) and Mwachaka et al. (2014) among the Nepal and Kenyan population, respectively. Also, the sex differences correspond to the studies conducted by Ghorbani et al. (2014) and Vieira et al. (2019). Table 6 shows the length of the vermiform appendix in males and females reported by various authors in adult populations.

Table 5. Average length of appendix reported by several authors in adult populations.

Author (year)	Population	Modality	Sample size	Average length (mm)
Ashindoitiang and Ibrahim (2012)	Nigerian	Surgical	80	115
Mwachaka et al. (2014)	Kenyan	Cadaveric	48	76.5 (±23.6)
Willekens et al. (2014)	-	Imaging (CT)	186	81.11 (±28.44)
de Souza et al. (2015)	Brazilian	Cadaveric	377	114
Ekanayake et al. (2017)	Sri Lankan	Autopsy	60	82
Khatun et al. (2019)	Nepalis	Surgical	264	86.7 (±24.4)
Aragao et al. (2023)	-	Fresh cadavers	50	97.4 (±26)
Present study	South African	Cadaveric	20	75.56 (±19.45)

CT: computed tomography

Table 6. Length of appendix in males and females by several authors in adult populations.

Author (year)	Population	Modality	Sample size	Average length (mm)
Setty and Katikireddi (2013)	Indian	Cadaveric	40 (adult)	Male: 65.2 Female: 62.8
Ghorbani et al. (2014)	Iranian	Autopsy	200	Male: 91.2 Female: 80.3
Ahmad et al. (2017)	Pakistani	Cadaveric	76	Male: 71.5 Female: 61.3
Chaudhari and Kanani (2018)	Indian	Cadaveric	200	Male: 55 Female:51
Khatun et al. (2019)	Nepalis	Surgical	264	Male: 87.4 (±24.1) Female: 85.5 (±24.8)
Salih et al. (2020)	-	Cadaveric	50	Male: 78.9 Female: 70.2
Present study	South African	Cadaveric	20	Male: 76.20 (±21.18) Female: 74.39 (±17.29)

In subset B, the mean length of the vermiform appendix obtained was slightly smaller than the that reported in the study of Shaikh and Gurukkal (2018). However, wider ranges and larger appendicular lengths were reported by Setty and Katikireddi (2013) and Nidhi et al. (2016). The present study also noted that appendicular length was longer in males than females which correspond to previous literature (Mohammad et al., 2013; Setty and Katikireddi, 2013; Nidhi et al., 2016; and Shaikh and Gurukkal, 2018).

Distance of the spino-umbilical line

In this study, the average distance of the spino-umbilical line was 216.54 ± 36.51 mm in subset A. This finding contradicts a study conducted in Kenya by Mwachaka et al. (2014), in which the average distance of the spino-umbilical line was 158.3 ± 17.9 mm. The average distance of the spino-umbilical line was 29.02 ± 5.70 mm in subset B.

Diameter of the vermiform appendix

The average diameter of the vermiform appendix in this study was 5.99 ± 1.64 mm (range: 2.73-10.64 mm). The findings of the outer diameter at the base, midpoint, and tip of the vermiform appendix in subset A contradict a study conducted by Aragao et al. (2023), which could be attributed to the geographical location. The findings of the average diameter of the vermiform appendix in male and female fetuses in the present study contradicts a study conducted by Mohammad et al. (2013), which can be attributed to the age of the fetuses. An appendicular diameter larger than six millimeters is a sign for acute appendicitis in children (Mullins et al., 2001; Trout et al., 2014).

Table 7. State of mesoappendix by various authors.

Author (year)	Population	Modality	Sample size	Complete mesoappendix (%)
Ashindoitiang and Ibrahim (2012)	Nigerian	Surgical	80	45%
Ghorbani et al. (2014)	Iranian	Autopsy	200	79.5%
Ahmad et al. (2017)	Pakistani	Cadaveric	76	76.16%
Ekanayake et al. (2017)	Sri Lankan	Autopsy	60	51.7%
Chaudhari and Kanani (2018)	Indian	Cadaveric	200	74.0%
Swathipriyadarshini et al. (2022)	-	Cadaveric	60	76.0%
Aragao et al. (2023)	-	Fresh cadavers	50	92%
Present study	South African	Cadaveric	20	100.00%

Table 8. Relation of appendix to spino-umbilical line as reported by various authors in adult populations.

Author (year)	Population	Modality	Sample size	Relation to spino-umbilical line		
				Cephalic	Caudal	Along/At
Naraynsingh et al. (2002)	-	Imaging (CT)	32	67%	32%	-
Oto et al. (2006)	-	Imaging (3D MDCT)	142	51%	43%	6%
Mwachaka et al. (2014)	Kenyan	Cadaveric	48	29.2%	18.8%	52.1%
Ahmad et al. (2017)	Pakistani	Cadaveric	76	24.9%	17.6%	57.5%
Present study	South African	Cadaveric	20	0.00%	35.00%	65.00%

CT: computed tomography; MDCT: multi-detector computed tomography

The outer diameter decreased from the base to the midpoint and to the tip of the vermiform appendix in subset A and B. This coincides with the findings of a study conducted by Salih et al. (2020) in which the diameter of the vermiform appendix decreased from the base to the tip. According to Salih et al. (2020), the diameter of the vermiform appendix at the base, midpoint, and tip was larger in males than in females. This coincides with the findings of this study as the diameter of the vermiform appendix at the base, midpoint, and tip was larger in males than in females in subset A. However, in subset B the diameter at the base, midpoint, and tip was larger in females than in males.

Mesoappendix

The mesoappendix reached the tip of the appendix (i.e. complete) in all the cadavers (100.00%) in subset A. No population study in literature has ever reported such. Table 7 shows the percentage of the mesoappendix reaching the appendicular tip reported by various authors in adult populations.

The mesoappendix was incomplete in all cadavers (100%) in subset B. A study by Nidhi et al. (2016) reported that the mesoappendix did not extend to the tip of the vermiform appendix in fetuses. In a study conducted by Shaikh and Gurukkal (2018), the mesoappendix was complete in 35.5% of fetuses, which were between the ages of 11 to 40 weeks. However, according to the literature the highest incomplete mesoappendix frequency is below the age of 10 years. This can be attributed to the embryological process. There are consequences when the mesoappendix fails to reach the end of the appendix, such as loss of vascularization of the appendix, which results in the appendix being susceptible to perforation and gangrene during appendicitis or any inflammatory situation, and the chances of appendicitis can be increased (Vieira et al., 2019).

Relation to the spino-umbilical line

According to Oto et al. (2006), McBurney's point is the location of the appendicular base. This study reported that the appendicular base was found at

McBurney's point in 65.0% of cases in subset A. In subset B, the appendiceal base was found at McBurney's point in 26.67% of the sample. Thus, revealing that the appendicular base is not always found at McBurney's point. Studies conducted by Naraynsingh et al. (2002) and Oto et al. (2006) indicate that the base is not always found at McBurney's point.

In a study conducted on 60 fetuses by Mohammad et al. (2013), the appendiceal orifice was found at McBurney's point in 24% of cases. This study also reported that the appendicular base was located cephalic to the spino-umbilical line in 73.33% of the sample in subset B. In a study by Naraynsingh et al. (2002) and Oto et al. (2006), the appendicular base was found predominately cephalic to the spino-umbilical line in an adult population. Contrary to this, the appendicular base was found caudal to the spino-umbilical line in 35.0% of cases in subset A. Table 8 shows the relation of the vermiform appendix to the spino-umbilical line reported by various authors in an adult population.

CONCLUSION

This study reported on the topographical anatomy of the appendix within a select adult and fetal South African population. Knowledge of the variations in the topography of the vermiform appendix in fetuses and adults are important to clinicians, as it will ensure thorough preparation and may assist in operating on infants, fetuses, and adults. Pre-operative scans (such as ultrasonography, and computed tomography scans) should be carefully conducted to ensure that the vermiform appendix is identified correctly to prevent any mishaps. For future research on the vermiform appendix, a separate post-mortem study should be conducted to determine the luminal thickness and the diameter of the luminal space in adults and fetuses.

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Ethical responsibility

The authors state that every effort was made to follow all local and international ethical guidelines and laws that pertain to the use of human cadaveric donors in anatomical research.

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