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The size of intestines in Vietnamese adults

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SUMMARY

The length of the small intestine of the Westerner is about 5-9 m long, whereas data on the intestinal length of Vietnamese patients is lacking in the literature. This study aims to determine the size of intestines in Vietnamese and the difference between fixed cadavers, autopsies and in operative patients. There were 130 subjects examined in this study: intestine from 40 formalin fixed cadavers, 30 autopsies and 60 living patients. The cohort included 91 males and 39 females, with ages ranging from 18 to 75 years-old and origin from various social levels. Subjects were excluded from this study if there was current or prior GI disease, GI surgery, or any other abdominal surgery. The length of the duodenum was 24.3 ± 1.2 cm in formalin fixed cadavers and 25.60 ± 1.4 cm in autopsies. The length of the small intestine was 382.5 ± 45.5 cm in preserved cadavers, 442.3 ± 62.5 cm in autopsies and 556.2 ± 74.4 cm in operative patients. The length of the large intestine was measured to be 132.5 ± 17.6 cm in preserved subjects, 149.3 ± 12.1 cm in autopsies and 156.3 ± 14.5 cm in operative patients. The greatest diameter was the jejunum in autopsies, or 4.1 ± 0.37 cm, and the smallest diameter was the ileum in autopsies, or 2.5 ± 0.30 cm. In Vietnamese, the length of the intestine in surgical patients was the longest; in the formalin-preserved group was the shortest, and in autopsies group was in the average range. The length of the Vietnamese small intestine was shorter than that of the European and American subjects. Surgeons need to be aware of variations in intestine length so that resection resulting in small bowel syndrome can be anticipated or avoided.

Key words: Duodenum – Jejunum – Ileum – Intestine – Small Intestine – Colon

Abbreviations:

Centimeter(s) (cm)
Device-Assisted Enteroscopy (DAE)
Gastrointestinal (GI)
Large Intestine (LI)
Meter(s) (m)
Small Bowel Syndrome (SBS)
Small Intestine (SI)
Standard Deviation (SD)

INTRODUCTION

Despite the critical importance of surgical approaches to intestinal resection, there is little definitive information available on length of the human gastrointestinal (GI) tract (Minko et al., 2014; Hounnou et al., 2002). ''Short bowel syndrome'' (SBS, or short gut) is a malabsorption disorder that is the consequence of an intestinal resection large enough to induce a lack of functional intestine (Hounnou, et al., 2002; Dupont and

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Goutail-Flaud, 1990; Pironi, 2016, Pironi et al., 2016). The primary symptom is diarrhea, which can result in dehydration, malnutrition, other nutritional disorders, and weight loss (NIDDK 2015). Other symptoms may include bloating, heartburn, fatigue, lactose intolerance, anemia, hyperkeratosis, easy bruising, muscle spasms, poor blood clotting, bone pain, and foul-smelling stool (NIDDK 2015). Still further, SBS is the leading cause of intestinal failure in early life (Goulet et al., 2019). Thus, if a large intestinal resection is needed, then preoperative assessment of intestinal length would be useful for the prediction and urgent management of postoperative malabsorption disorders to achieve the optimal patient outcome.

Nevertheless, the subject of intestinal length remains highly controversial in the literature. Even today, 19 years after intestinal transplant was accepted as clinical practice in the surgical field, no study has yet analyzed the full length of donor or recipient intestine (Mazariegos et al., 2010; Nayyar et al., 2010; Gondolesi et al., 2012). All medical students know that the length of the small intestine (SI) is approximately 6.7 m from what textbooks have taught them (Underhill, 1955; Jatal et al., 2015; Moore et al., 2019). In contrast, every surgeon understands from experience that there is great variation in intestinal length. In previous studies, intestinal length varied dramatically depending upon the measurement technique used (Hirsch et al., 1956; Sadahiro et al., 1991; Sadahiro et al., 1992; Saunders et al., 1995; Treves, 1885; Reiquam et al., 1965; Gondolesi et al., 2012; Hounnou et al., 2002) with the length of the SI ranging from 7.7 m to 9.7 m in post-mortem patients, and from 2.4 m to 3.7 m in vivo. Adding more confusion, other studies documented that intestinal length may be correlated with gender, age, weight, height, or race (Hounnou et al., 2002; Gondolesi et al., 2012). In recent years, the development of endoscopic techniques such as double-balloon, single-balloon and rotational enteroscopy have enabled access to the jejunum and ileum by pleating the SI onto a plastic over-tube. These technologies have generated a renewed interest in SI length estimates, as length (in cm) is the primary indicator for location within the bowel. In addition, total SI length likely impacts success in attempts to visualize the entire SI (i.e., total enteroscopy) by device-assisted enteroscopy (DAE).

An extensive literature survey revealed that there are no studies of intestinal length in Vietnamese. The present work addresses this gap in the literature by examining the SI and colon lengths and diameters in living patients vs. fresh/autopsy patients vs. fixed cadavers, and by comparing results to those of other subject populations found in prior investigations.

MATERIALS AND METHODS

Anatomical Donors and Patients

This study was conducted on 130 Vietnamese adults divided into three Groups: A, B and C. The entire study cohort included 91 males and 39 females; with ages ranging from 18 to 75 years-old and origin from various social levels. Subjects were excluded from this study if there was current or prior GI disease, GI surgery, or any other abdominal surgery.

Group A *was composed of 40 formalin-fixed cadavers that had been prepared for use in the formal course of human gross anatomy in the Department of Anatomy at the University of Medicine and Pharmacy at Ho Chi Minh City, Vietnam. The age range of subjects in this group was 38 to 91 years with the average age of 65.1-years-old. All guidelines were followed regarding the use and care of cadaveric materials, as well as all regulations set forth by the Vietnamese Anatomical Education Program.*

The embalming procedure is a 2-phase procedure beginning within the first 24 hours after death. The first step of the first phase of the embalming procedure is an injection of an 18 L mixture composed of 37% Formalin (2 L), 1 M Phenol (1 L), Glycerin 1 L, 90% Alcohol (2 L) and water (12 L). Three days following injection, cadavers are placed into 300 L of solution composed of 37% Formalin (2 L), 1 M Phenol (3 L) and water (295 L). The specimens remain submerged in the vat for a minimum of 4 months.

Group B *was composed of 30 fresh cadavers in autopsies performed at Binh Dan Hospital (Ho Chi Minh City, Vietnam). The age range of subjects in this group was 38 to 91 years with the average age of 65.1-years-old.*

Group C *was composed of 60 cases on patients undergoing abdominal surgery at Binh Dan Hospital. These patients were advised to fast the night before surgery and underwent colon cleansing. Endotracheal anesthesia was used, and muscle relaxants were administered on a case-by-case basis.*

Measurement of Intestinal Length and Diameter

A literature survey revealed different measurement methods by investigators in prior studies. Some authors had patients swallow a polyethylene or rubber tube. Some authors used measurement tapes; applying the tape directly on the free border of the SI. These methods were determined unsuitable for the present work, especially in a surgical setting.

In this research study, sterilized, non-elastic suturing threads were used to measure along the mesenteric and free borders of the SI, and the length and diameter of the colon. Then, the threads were taken out and measured using a measuring tape. This method allowed an easy way

to accommodate the many folds of the SI, and the threads could be easily sterilized to use for patients on the operating table. Because intestines are distensible viscera, there would be some degree of error just like in prior studies. In order to reduce these errors in the present study, non-elastic suturing threads were used and only one investigator was allowed to take all the measurements on all the subjects.

The standard anatomical landmarks were used for establishing the different segments of the small and large intestines. Briefly, the SI consists of the duodenum, jejunum and ileum, and extends from the pylorus to the ileoceal junction where the ileum joins the cecum (i.e., the first part of the LI). The duodenum begins at the pylorus on the right side and ends at the duodenojejunal flexure on the left side at the level of the L2 vertebra, 2 - 3 cm to the left of the midsagittal plane. It had four parts: (1) superior, running anterolateral to the body of the L1 vertebra; (2) descending, along the right sides of the L1-L3 vertebrae; (3) inferior, crossing the L3 vertebra; (4) ascending; beginning at the left side of the L3 vertebra and coursing superiorly to the superior border of the L2 vertebra. The jejunum begins at the duodenojejunal flexure and assumes an intraperitoneal course of about 2.8 m (mostly in the left upper quadrant of the abdomen); the remaining 4.2 m is the ileum. Still further in fresh (autopsy or surgical specimens), the jejunum is deeper red in color with a thick and heavy wall, whereas the ileum is paler pink in color with a light and thin wall. The vasa recta were also used as another distinguishing feature in fixed, autopsy or surgical specimens, because the vasa recta are long in the jejunum, and short in the ileum.

The LI is composed of the cecum; appendix; ascending, transverse, descending and sigmoid colon; the rectum and anal canal. In its entirety the LI can be distinguished by the presence of omental appendices; teniae coli, haustra, of much greater caliber than the SI. The cecum, although enveloped by the peritoneum, has no mesentery and represents a blind pouch within 2.5 cm of the inguinal ligament. The ascending colon courses superiorly from the cecum along the right paracolic cutter to the hepatic flexure (near the right hepatic lobe), where the transverse colon then extends to the splenic flexure. The descending colon begins at the splenic flexure and courses inferiorly next to the left paracolic gutter to the left iliac fossa, where the sigmoid colon begins. The sigmoid colon is characterized by an S-shaped loop extending through the iliac fossa to the S3 vertebra. Still further, the termination of teniae coli at this location indicates the rectosigmoid junction. The rectum continues inferiorly with the anal canal.

All measurements were saved and evaluated using MicroSoft® Excel 2007. Results were expressed as mean length (or diameter) in centimeters (cm) ± cm standard deviation (SD). Data were analyzed using percentage analysis with SD. The results were compiled from the 3 groups separately, and then the groups compared. Lastly, the results were compared to those of other authors.

In the formalin-fixed cadavers (Fig. 1) and autopsies, measurements for length were taken along both the mesenteric and free borders of the SI. In patients undergoing surgery, only the free border measurements were taken (Fig. 2A).

Large intestine (LI) measurements for length were done along the free teniae coli from the cecum to the end of the sigmoid colon (equal to the level of the 3rd sacral vertebra).

Measurements for the rectal part of the colon were obtained only on cadavers using a tube that was positioned from the anus up to just anterior to the 3rd sacral vertebra.

To measure the diameter of the intestine, the flat diameter was measured at seven pre-determined locations (Fig. 2B). At the duodenum, the diameter was measured in the middle of each of the part (i.e., the descending portion and the transverse portion). At the jejunum and ileum, two locations were chosen: (1) at 15 cm from the duodenojejunal flexure (defined as d15) and (2) at 15 cm backward from the ileocecal junction (defined as d'15 representing the smallest diameter of the SI). For

Fig 1. Measurement of intestine in formalin fixed-cadavers. In this research study, sterilized, non-elastic suturing threads were used to measure along the mesenteric and free borders of the SI, and the length and diameter of the colon. Then, the threads were taken out and measured using a measuring tape.

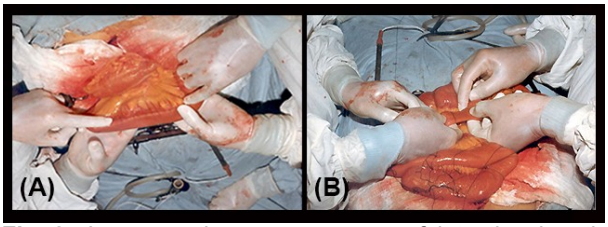

Fig 2. Intraoperative measurement of intestine length and diameter. (**A**) Measurements of length were taken along the mesenteric and free borders of the small intestine. (**B**) This is an example of measuring the flattened diameter at one of several locations in the intestine.

Table 1. Length and diameter of Duodenum

Mean Length of Duodenum cm ± cm (SD)		**Mean Diameters of Duodenum** cm ± cm (SD)			
		Descending portion		*Transverse portion*	
Formalin Cadavers	Fresh* Cadavers	Formalin Cadavers	Fresh* Cadavers	Formalin Cadavers	Fresh* Cadavers
24.30 ± 1.20	25.60 ± 1.40	3.45 ± 0.62	3.48 ± 0.30	2.72 ± 0.20	2.95 ± 0.17

Fresh cadavers are autopsy specimens.

Table 2. Length of small intestine: Jejunum and Ileum

Mean Length of Small Intestine cm ± cm (SD)					
Formalin Cadavers		**Fresh* Cadavers**		**Intraoperative Patients**	
Mesenteric Border	Free Border	Mesenteric Border	Free Border	Mesenteric Border	Free Border
261.4 ± 25.8	382.5 ± 45.5	386.5 ± 81.3	442.3 ± 62.5	Not determined.	556.2 ± 74.4

Fresh cadavers are autopsy specimens.

Table 3. Studies of diameter of Small Intestine

Mean Flattened Diameter of Small Intestine cm ± cm (SD)			
Proximal Portion of Jejunum (d15)		*Distal Portion of Ileum* (d'15)	
Formalin Cadavers	Fresh Cadavers	Formalin Cadavers	Fresh Cadavers
3.3 ± 0.39	4.1 ± 0.37	1.97 ± 0.50	2.5 ± 0.30

the LI, the diameters were measured at the middle of each of the parts (i.e., ascending colon, transverse colon and descending colon).

RESULTS

Duodenum

The length of the duodenum was 24.3 ± 1.2 cm in formalin preserved cadavers and 25.60 ± 1.4 cm in autopsies. The flattened diameter of the descending and transverse regions of the duodenum were 3.45 ± 0.62 cm and 3.0 ± 0.30 cm in fixed cadavers, and 2.72 ± 0.20 cm and 2.95 ± 0.17 cm in fresh cadavers, respectively. These results are summarized in Table 1.

Jejunum and ileum

Length. The length of SI from both mesenteric and free borders was measured. In formalin-fixed cadavers, the mean length was determined to be 261.4 ± 25.8 cm and 382.5 ± 45.5 cm, at the mesenteric and free borders, respectively. In fresh cadavers at the time of autopsy, the mean length at the mesenteric border was 386.5 ± 81.3 cm, and the mean length at the free border was 442.3 ± 62.5 cm. Secondary to time limitations with intraoperative patients, only the length at the free border was measured. The mean length of SI at the free border in intraoperative patients was determined to be 556.2 ± 74.4 cm. These results are shown in Table 2.

Diameter. The flattened diameter of the SI was measured at 15 cm from the duodenojejunal flexure (defined as d15; the proximal portion of jejunum) and at 15 cm backward from the ileocecal junction (defined as d'15; the distal portion of the ilium). Secondary to medical ethics, surgeries on patients could not be prolonged for measurements and only the diameter of the middle of the SI could be measured instead of measuring the positions d15 and d'15. Therefore, the mean diameter of SI in intraoperative patients was not calculated. The mean diameter of the proximal portion of the jejunum was determined to be 3.3 cm ± 0.39 cm in formalin-fixed cadavers and 4.1 ± 0.37 cm in fresh cadavers. The mean diameter of the distal portion of the ileum was 1.0 ± 0.50 cm in formalin-fixed cadavers and 2.5 ± 0.30 cm in fresh cadavers. These results are shown in Table 3.

Colon

Length of Colon. Measurement of colonic length was based on the free teniae coli. Two portion of colon were measured. The first portion was determined from the cecum to the end of the sigmoid colon (equal to the level of the 3rd sacral vertebra). A non-stretchable suturing thread was used to measure along the free teniae coli. The second portion was the length of the rectum. Measurements of the rectum were taken using a tube that was positioned from the anus up to just anterior to the 3rd sacral vertebra. The total length of the colon was the sum of lengths of these two portions. The length of the rectum was not measured on intraoperative patients. Thus, the total colonic length was the length of the first portion plus 10 cm (the mean length of the rectum measured on cadavers). These measurements were determined to

Table 4. Length and diameter of Duodenum

	Cecum		Ascending Colon		Transverse Colon		Descending Colon		Sigmoid Colon	
	A	B	A	B	A	B	A	B	A	B
Mean Diameter (cm)	5.25	6.2	4.68	5.3	3.37	4.8	2.59	3.1	2.98	3.6
Range (cm)	3.4-8.4	3.1-8.8	2.7-8.2	3.2-7.8	1.6-5.7	2.4-6.3	1.4-4.2	2.3-4.9	1.6-4.1	2.3-5.7

be 132.5 ± 17.6 cm, 149.3 ± 12.1 cm, and 156.3 ± 14.5 cm in formalin fixed cadavers, fresh cadavers and patients, respectively.

Diameter of the Colon. The diameter of colon was only measured at formalin-fixed cadavers and fresh cadavers in autopsies. Due to the time limitation of the operation, the colonic diameters were not calibrated in intraoperative patients. These results are summarized in Table 4.

Meckel's Diverticulum

In one of the 130 cases examined, Meckel's Diverticulosis (ileal diverticulum) was observed in a female, formalin-fixed cadaver (Fig. 3).

DISCUSSION

Clinical disorders induced by large intestinal resection depend on the size and level of the resection. SBS in adults and children is usually caused by surgery done for Crohn's disease, Volvulus, tumors of the SI; trauma to the SI, necrotizing enterocolitis; bypass surgery (i.e., bariatric surgery) to treat obesity, or surgery to remove diseases of the SI (NIDDK, 2015). Further, some children are also born with an abnormally short SI (i.e., congenital short bowel). Diarrhea and serious nutritional complications can result due to a lack of absorption of fats, proteins and vitamins, and hydrolytic disturbances caused by lack of water reabsorption (Underhill, 1955; Hounnou et al., 2002, Dupont and Goutail-Flaud, 1990; Pironi, 2016, Pironi et al., 2016). Generally, a large or subtotal resection of SI leaving approximately 75 cm or less of residual SI causes SBS (Hounnou et al., 2002; Dupont and Goutail-Flaud, 1990). Optimal patient management includes multidisciplinary nutritional treatment, long-term parenteral nutrition, as well as surgical procedures for intestinal lengthening such as serial transverse enteroplasty (STEP) (Bianchi, 1980; Hounnou et al., 2002; Chang et al., 2006; Jones et al., 2013) and intestinal transplantation.

The extent of post-resection problems depends not only upon the size of the resected segment, but also on the length of the remaining intestine. Thus, it is reasonable to suggest that an intestinal resection of a given size induces more serious post-surgical complications if the intestine was short preoperatively (Haunnou et al., 2002). Therefore, anatomical knowledge and preoperative assessment of intestinal length is essential to predict the consequences of intestinal resection and to rapidly address post-operative management of patients for optimal outcomes.

Intestinal length varies between studies and whether the measurement is taken in vivo or post mortem (Haunnou et al. 2002). In the initial study done in 1924, patients swallowed a ballasted rub-

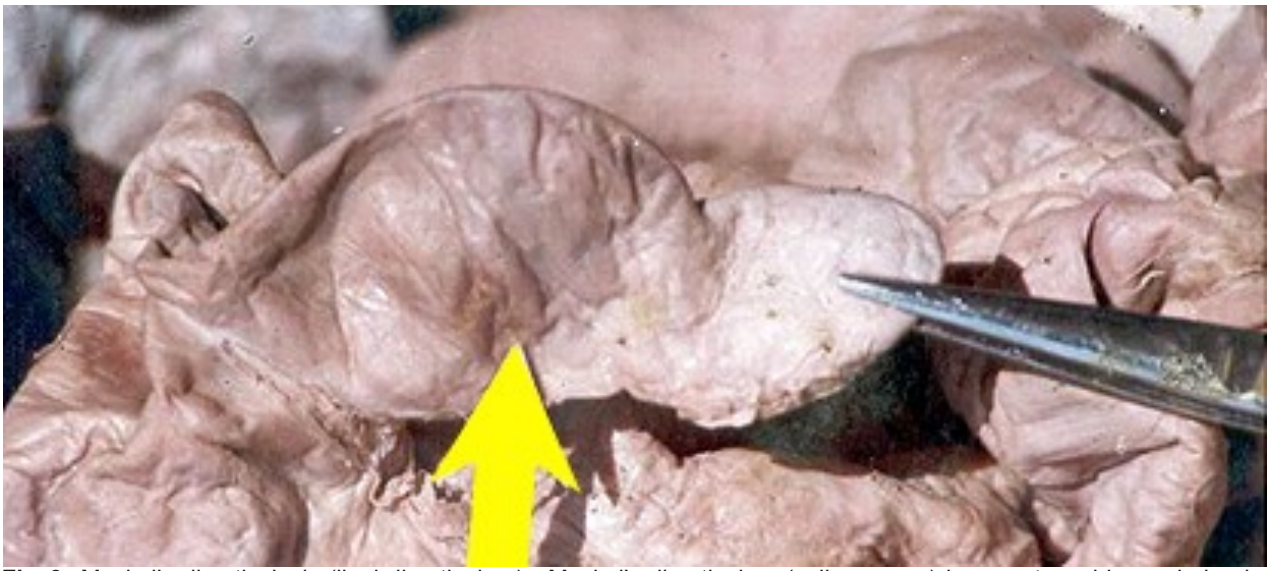

Fig 3. Meckel's diverticulosis (ileal diverticulum). Meckel's diverticulum (yellow arrow) is an outpouching or bulge in the lower part of the small intestine. The bulge is congenital (present at birth) and is a remnant of the umbilical cord.

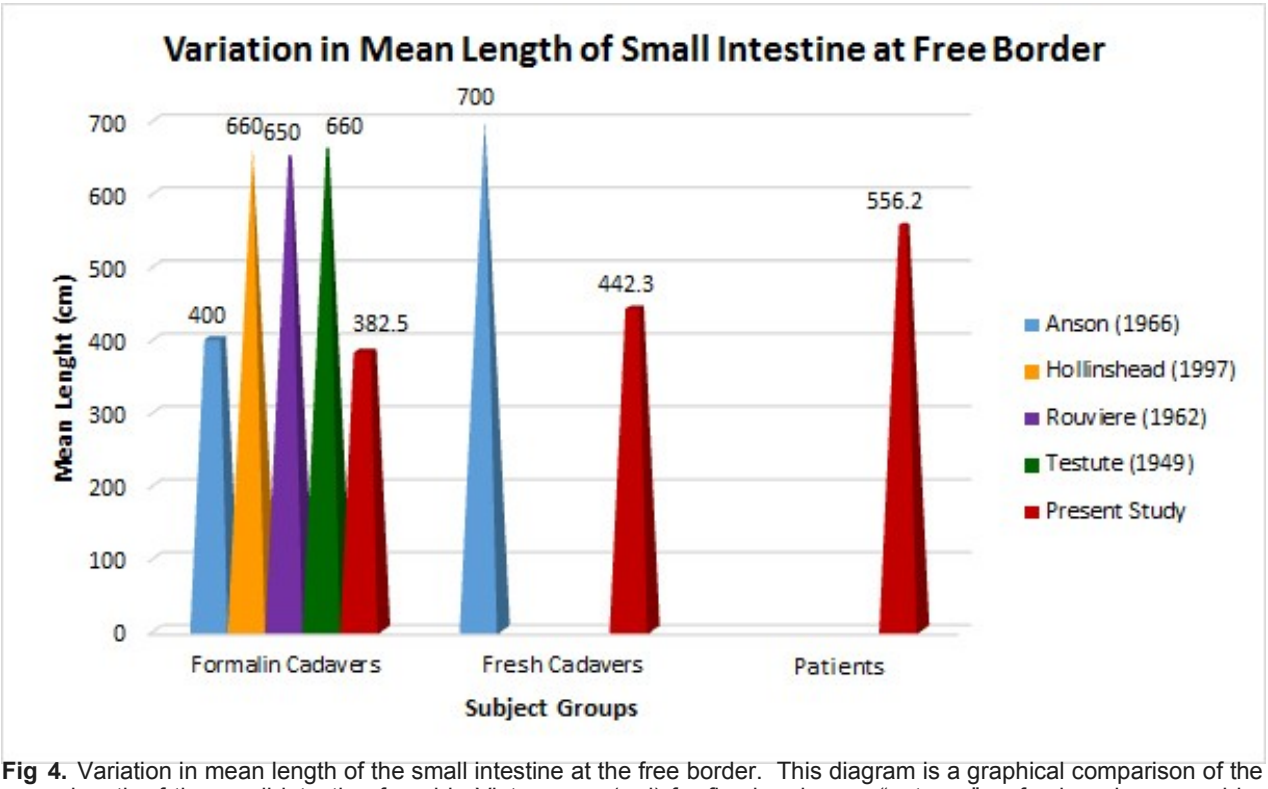

Fig 4. Variation in mean length of the small intestine at the free border. This diagram is a graphical comparison of the mean length of the small intestine found in Vietnamese (red) for fixed cadavers, "autopsy" or fresh cadavers and intraoperative patients in the current investigation with the results of other studies.

ber tube determining a mouth-to-anus digestive tract length of 200 - 270 cm (Van der Reis and Schembra, 1996). However, secondary to intestinal telescoping (i.e., the protrusion of a bowel segment into another), this technique underestimated length, and measurements were not reproducible. Hirsch et al. (1956) used a "finer" polyvinyl tube, but the results also showed significant variation, and length seemed to be affected by mechanical factors, diet, sympatholytic or sympathomimetic drugs and fever (Hirsch et al., 1956). Still further, other studies measuring in vivo colon length also showed method- dependent variation with measurements of 109 cm using a polyvinyl tube (Hirsch et al., 1956), 114 cm with surgical laparotomy (Sadahiro et al., 1995) and 129 cm with barium enema radiography (Sadahiro et al., 1991). The present work is different and more reproducible in that (1) a single population (i.e., Vietnamese) of patients in one location was examined; (2) sterilized, non-elastic suturing threads and one manipulator (i.e., operator) ensure the accommodation of SI folds (in vivo and in vitro), less mechanical manipulation (i.e., as with tubing) and less operator induced errors; (3) measurements in fixed and fresh (autopsy) cadavers and living patients along both the mesenteric and free borders allow for the comparison of fixation vs. fresh vs. pharmacological influences on intestinal length.

When surgeries were performed on Vietnamese patients, the size of the SI was found not to be as long as 7 meters described in Western anatomy textbooks. At Binh Dan hospital, there was a case that required a resection of a 1.5 m portion of the SI due to volvulus-induced necrosis. The remaining part was estimated to be only about 1 m in length. Via surgeries on Vietnamese patients, it was an unexpected discovery that there was no intestine which actually reached the length of 7 m.

In SI, the length measured at the free border was significantly greater than that of the mesenteric border. Overall, the data indicated that the average intestinal length in Vietnamese was lesser than that in the Westerner (Fig. 4). In comparison among the three groups of samples, the shortest length of SI was observed in the formalin fixed cadaver group while the longest was in operative patients (Fig. 4; Table 1 and Table 2). The length of SI in autopsies was the intermediate value. Still further, the mean length at the free border was shortest in Vietnamese in comparison to other studies (Anson, 1966; Hollinshead, 1977; Rouviere, 1962; Testut and Latarjet, 1949), and with the present work and that of Anson (1966) differing from others with shorter mean length of 260-278 cm. The reason for this difference is not clear. However, overall these results are reasonable because of anesthetics used during surgery relax smooth muscles, and therefore operative patients should have the greatest SI length.

The average diameter of descending and transverse regions of the duodenum in Vietnamese was relatively smaller than that of the Westerner (Table 1 and Table 2). The mean diameters of the jeju-

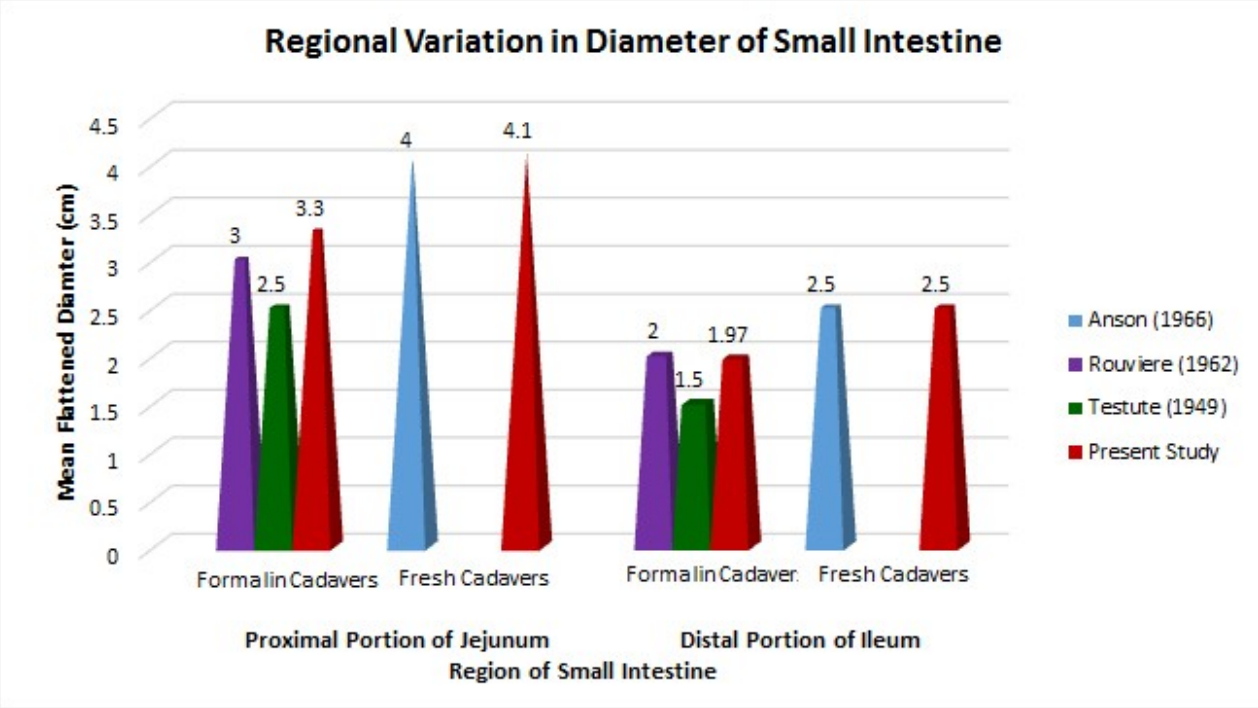

Fig 5. Regional variation in diameter of small intestine. This diagram is a graphical comparison of the mean diameter of the proximal jejunum and distal ileum found in Vietnamese cadaveric specimens (red) in the current investigation with the results of other studies.

num and the ileum in this study were within the range of results from other investigators (Fig. 5; Table 3).

The mean length of the colon in this study was within the range of results from other researchers (Fig. 6). Regional variation in colic mean diameter in the present study was found to be smallest in formalin-fixed cadavers (Table 4); with the descending colon being the shortest (1.59 cm), followed by sigmoid colon (2.98 cm), and then ascending colon (4.68 cm) and cecum (5.25 cm), respectively. In contrast, the descending colon (shortest: 3.1 cm) and sigmoid colon (3.6 cm) had similar diameters in fresh cadavers, with the as-

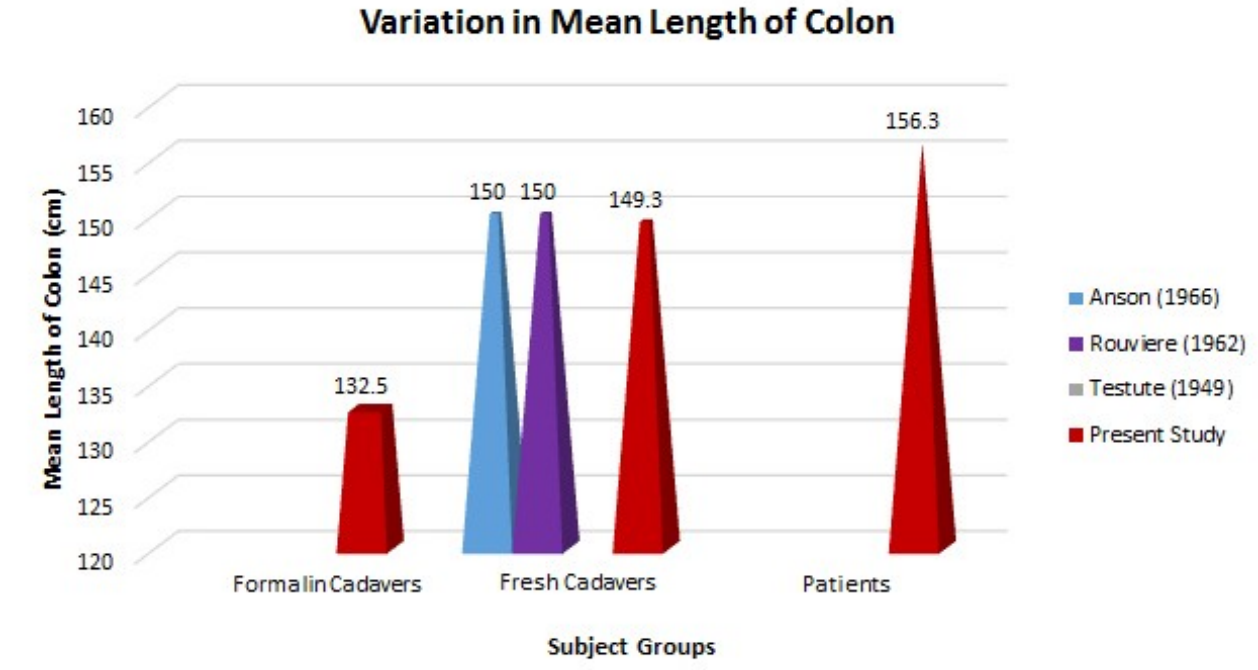

Fig 6. Variation in mean length of colon. This diagram is a graphical comparison of the mean length of the colon found in Vietnamese (red) for fixed cadavers, "autopsy" or fresh cadavers and intraoperative patients in the current investigation with the results of other studies.

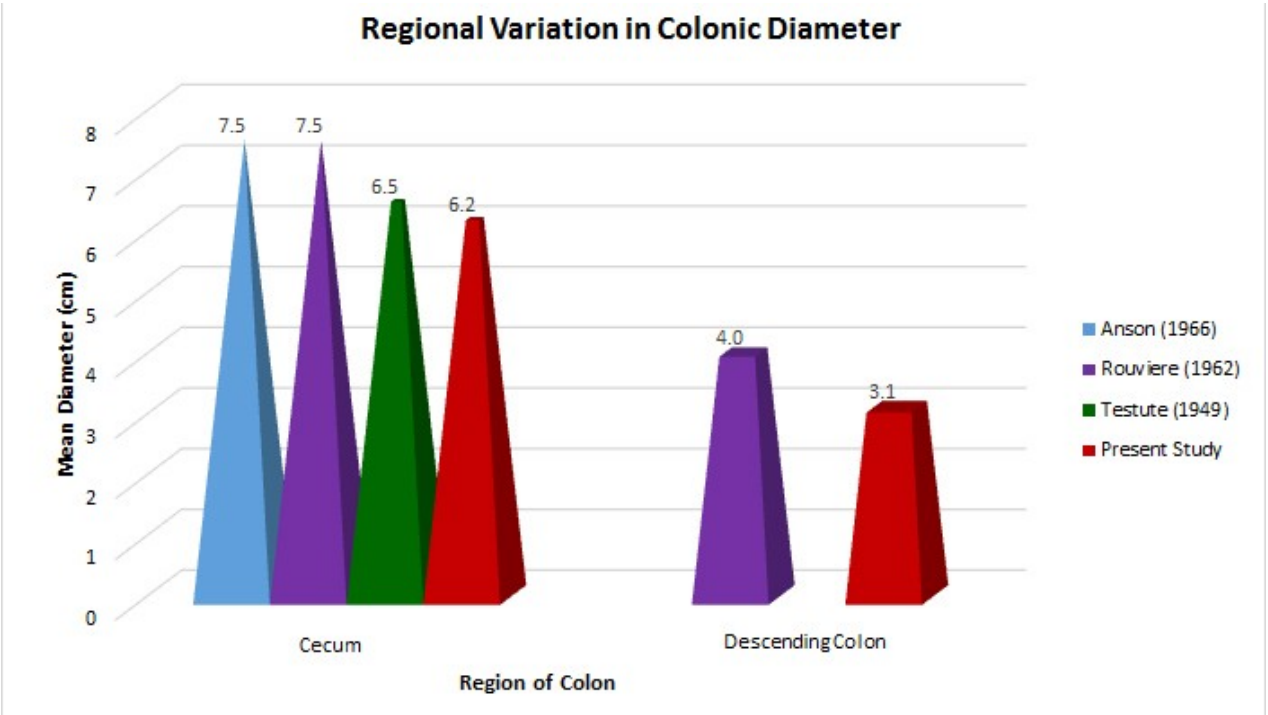

Fig 7. Regional variation in colonic diameter. This diagram is a graphical comparison of the mean diameter of the cecum and descending colon in Vietnamese cadaveric specimens (red) in the current investigation with the results of other studies.

cending colon (5.3 cm) being the next largest diameter and then the cecum (6.2 cm). In caparison to work done by other investigators available in the literature (Anson, 1966; Rouviere, 1961; Testut and Latarjet, 1949), the cecum of Vietnamese people has a similar length in fresh cadavers, and a shorter diameter (Fig. 7). The diameter of the descending colon was also of lesser length than documented in prior studies (Rouviere, 1962).

Meckel's diverticulum was named after Johann F. Meckel, a German anatomist, who described the structure in 1809 (Meckel, 1809). It is the most common congenital malformation of the GI tract (present in 2-4% of population) due to persistence of the congenital vitello-intestinal duct (Sagar et al., 2006; Dumper et al., 2006). Males are disproportionately affected compared to females with a ratio of 4:1 (Bennett et al., 2004; Stallion and Shuck, 2019). Bleeding from Meckel's diverticulum due to ectopic gastric mucosa is the most common clinical presentation, especially in younger subjects, but it is rare in the adult population. The complications in adults include: obstruction, intussusception, ulceration, hemorrhage, and, rarely, vesicodiverticular fistulae and tumors (Dumper et al., 2006). Due to the rarity of cases in adults, it is still misdiagnosed preoperatively. It is not known whether this is a rare finding or not in Vietnamese, as compared to other countries. In this aspect, further work is needed.

In the present work, the length of the intestine in operative patients was the greatest, and in formalin preserved cadavers was the least. In autopsies, the length of the intestine was found to be in the average range that Western authors have taken and described in anatomical textbooks. Results show that the length of the flap intestine varies greatly between one person and the other, while the fixed intestine length is less variable. Surgeons need to be aware of this so that resection of a length of SI resulting in SBS can be anticipated or avoided.

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NOTES ON CONTIBUTORS

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