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A MORPHOMETRIC STUDY OF BRANCHING PATTERN OF INFERIOR MESENTERIC ARTERY

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ABSTRACT

Inferior Mesenteric Artery (IMA) is a major anterior branch of the abdominal aorta that supplies arterial blood to the organs of the hind gut. Knowledge of the arterial supply of the gut is essential for anatomists and surgeons for the safety and survival of patients in standard operative procedures. The study was conducted at Department of Anatomy, Gandhi Medical College, Musheerabad, Secunderabad, Telangana, India. The material consisted of seventy five adult cadavers (40 - 70 years) and 25 fetuses (28 – 38 weeks). This paper is aimed to study the morphology and the branching pattern of the inferior mesenteric artery and emphasize the anatomical variations. The most common branching pattern of inferior mesenteric artery was into LCA in 74 (98.66%) cases and common sigmoid trunk which gave off 3 - 4 sigmoid arteries. Absence of LCA was observed in one single case of adult cadavers and one in fetuses and sigmoid vessels were found to be arising from IMA, giving origin to two small branches and continued as superior rectal artery (SRA). In 70% of the cases the sigmoid arteries presented normal branching pattern. The sigmoid arteries were 3-4 in number. However, the anatomical arcade in the present study is unaffected, unaltered by anomalous arterial pattern of IMA.

KEY WORDS: **abdominal aorta, inferior mesenteric artery, sigmoid arteries, superior rectal artery.**

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INTRODUCTION

The mesenteric vascular supply is a combination of rich collateral networks and commonly encountered variant anatomy. The effect of normal and variant anatomy has implications on pathology, treatment choices, and planning interventions. A review of anatomic variants will assist in understanding the implications of abnormal anatomy on treatment of diseases associated with the mesentery. The unpaired ventral branches of the descending aorta vascularize the gut tube and its derivatives. The Coeliac trunk (CT), Superior mesenteric artery (SMA) and Inferior mesenteric artery (IMA) are the three main arteries of abdominal aorta serving as the derivatives of foregut, midgut and hindgut respectively. The arterial supply of the abdomen is unique for each individual, much the same way as a fingerprint[1]. By convention, the boundaries of the foregut, midgut, and the hind gut correspond to the territories of the arteries that supply the abdominal gut tube[2]. The conventional description and illustration of the arterial blood supply to the intestinal tract, especially to the descending colon, sigmoid flexure in most standard textbooks of anatomy and surgery are too incomplete, inaccurate and misleading to be relied upon in the intestinal surgery. Surgical procedure for diseases of colon continues to be one of the most common operative procedures performed by the surgeons. Inferior Mesenteric Artery is a major anterior branch of the abdominal aorta that supplies arterial blood to the organs of the hind gut. It is the smallest of the three anterior branches of the abdominal aorta. The inferior mesenteric artery, often abbreviated as IMA, is the third main branch of the abdominal aorta. It originates in an anterior lateral orientation to the left just above the aortic bifurcation arising at level of L3 vertebral level, typically between the L2 and L4 vertebral bodies[3]. Then it travels in a retroperitoneal plane towards the sigmoid colon. The IMA is responsible for supplying blood flow to the large intestine from the left (or splenic) flexure to the upper part of the rectum. These include the distal one third of the transverse colon, descending colon, sigmoid colon, as well as the upper rectum.

There are three major branches that arise from the IMA. These branches include[4]:
1. Left colic artery
2. Sigmoid arteries
3. Superior rectal artery

All these arterial branches further divide into arcades which then supply the colon at regular intervals.

IMA originates from the front of the abdominal aorta, near its left margin just below the third part of the duodenum at the level of 3rd lumbar vertebra. It runs downwards arching slightly to the left, and as it crosses the left common iliac, its name arbitrarily changes to the superior rectal (or hemorrhoidal) artery.

Left Colic Artery

The left colic artery (LCA) is the first branch of the IMA supplies the distal 1/3 of the transverse colon and the descending colon. After arising from its parent artery, it travels anteriorly to the psoas major muscle, left ureter and left internal spermatic vessels, before dividing into ascending and descending branches. The ascending branch crosses the left kidney anteriorly, before entering the mesentery of the transverse colon, moving superiorly. It supplies the distal 1/3 of the transverse colon, and the upper aspect of the descending colon. The descending branch moves inferiorly to supply the lower part of the descending colon. It anastomosis with the superior sigmoid artery.

Sigmoid Arteries

The sigmoid arteries supply the descending colon and the sigmoid colon. There are typically 2 - 4 branches, with the uppermost branch termed the superior sigmoid artery. They run inferiorly, obliquely and to the left, crossing over the psoas major**,** left ureter and left internal spermatic vessels**.**

Superior Rectal Artery

The superior rectal artery is a continuation of the IMA, supplying the rectum. It descends into the pelvis, crossing the left common iliac artery and vein. At the S3 vertebral level, the artery divides into two terminal branches – one supplying each side of the rectum. Within the walls of the rectum, smaller divisions of these branches eventually communicate with the middle and inferior rectal arteries**.** The ascending branch of LCA collateralizes to the middle colic artery, distal transverse colon, and splenic flexure (Griffith's point)[5]. This collateralization is important, as this area is at high risk for watershed ischemia in the setting of dehydration or mesenteric occlusive disease. In the presence of stenotic or occlusive disease of IMA or superior mesenteric artery (SMA), the presence of collateral channels between either artery is critical for maintaining the integrity of vascular supply to the affected region. Patency and continuity of these collateral channels, namely, colic marginal artery and meandering mesenteric artery, are highly variable. Moreover, knowledge of the pattern of collateral supply also constitutes a critical point of consideration during colic resections in cases of cancer management. The descending left colic artery branch collateralizes to the sigmoid arteries. These are comprised of two or three sigmoid artery branches within the mesocolon. The uppermost sigmoid artery collateralizes to the left colic artery whereas, the lowermost collateralizes to the superior rectal artery (SRA). The SRA descends into the pelvis dividing into right and left branches. The SRA collateralizes with both the middle rectal (branch of the internal iliac artery) and the inferior rectal artery (branch of the internal pudendal artery). Proximally, its territory of distribution overlaps (forms a watershed) with the middle colic artery, and therefore the SRA. The SMA and IMA anastomose via the marginal artery of the colon (artery of Drummond) and via Riolan arcade (also called "meandering artery", an arterial connection between the left colic artery and the medial colic artery). Pattern of branching however is reported to deviate from this

classical description[1, 6-9]. Detailed knowledge of the anatomical variations of the visceral branches of the abdominal aorta is of extreme clinical importance, particularly, when performing laparoscopic abdominal surgery. Further, colonic vascular supply has some weak areas which have been reported to be highly predisposed to ischemic colitis[10-12]. Notable examples are Griffths' point at the left colic flexure [13-14] and the Sudeck's point at the rectosigmoid region[6, 14-15]. The knowledge of the anomalous arterial branching patterns is essential from the view point of surgical and radiological anatomy. So the present study was conducted to identify the variations in the branching pattern of IMA in light of its morphology and development. Knowledge of the arterial supply of the gut is essential for anatomists and surgeons for the safety and survival of patients in standard operative procedures. Therefore, the present study was undertaken to emphasize inferior mesenteric artery, its branching pattern and its surgical significance. The enlightenment and proper knowledge of IMA and its branching pattern as mentioned above will provide the surgeon with proper guidelines in ligating the IMA and its branches during surgical resections in conditions like colorectal malignancies at proper levels to prevent postoperative gangrenous changes in the leftover viable large gut. A thorough knowledge of the anatomy of the celiac, superior mesenteric, and inferior mesenteric arteries and their variants are necessary to accomplish a successful, uncomplicated abdominal operation. Hence, we thought that it is worthwhile to undertake an anatomical study of blood supply of the hid gut in the local available material, the normal and abnormal pattern of the mesenteric vessels and their branches, with articular reference to their surgical significance. Therefore, this paper is aimed to study the morphology and branching pattern of the IMA.

The objectives of the study include

- To trace the origin of IMA and identify their branches
- The measure the length of the main artery
- To study the course of IMA
- To observe the anatomical variations of IMA

MATERIALS AND METHODS

The material for the present study consisted of seventy five human cadavers with age ranging between 40 to 70 years (52 male and 23 female cadavers) and 25 fetuses within the range of 28 – 38 weeks. Dead and unclaimed fetuses were obtained mainly from the maternity wing of Gandhi Hospital, Musheerabad, Secunderabad, Telangana, India. The fetal ages varied from premature to full term, still born and neonatal deaths. On receipt of the fetuses from the Hospital, their R length and embalming done by injecting 40% commercial formalin about 20cc by local infiltration and also by injecting into the umbilical vein. The following day, the abdomen was opened by a large incision across the lower part of the abdomen around and below umbilicus. The abdominal cavity of the fetus thus opened was washed with tap water to clean away the meconium and the cavity was cleaned with a cotton swab to keep the viscera dry for proper dissection. The dissection was conducted as per Cunningham's manual of practical anatomy[16]. The peritoneum and the visceras were separated carefully and cleaned from the field of view. Permission was taken from the authorities of Osmania Medical College, Koti, Hyderabad and Mediciti Medical College, Hyderabad, where we have done dissection over the cadavers to explore the origin of IMA from abdominal aorta. All the observations were made over 75 cadavers in the dissection halls of the three Medical Institutions including parent institution i.e., Gandhi Medical College, Secunderabad. The whole dissection is carried out meticulously to locate the abdominal aorta which lies in the deeper plane from which the inferior mesenteric artery takes origin above the level of its bifurcation. After locating the abdominal aorta along with the origin of IMA, we have neatly explored the branching pattern of IMA in all fetuses.

RESULTS

In all the cadavers of the present study, IMA and its branches that originated from abdominal aorta were traced and identified. Origin of IMA, distance (cm) of IMA from the point of origin from aorta to its bifurcation point, angle of origin of IMA from abdominal aorta were measured and tabulated. The inferior mesenteric artery was observed to give off the left colic (superior left colic) and sigmoid arteries (inferior left colic) and later continued as the superior rectal artery.

Vertebral level of origin, length and diameter

In all the 75 cadavers and 25 fetuses studied, IMA was found to spring from abdominal aorta (Table 1) a few cm proximal to the bifurcation of aorta (Table 2). The origin and course of IMA has great surgical significance. In the present study IMA showed normal pattern in 56 (75%) cases. The abdominal aorta gave off IMA at the level of the 3rd lumbar vertebra (L3). IMA took origin from the aorta 2 – 5.2cm proximal to its bifurcation (Table 2).

Table 1
Origin of Inferior Mesenteric Artery from aorta in adult cadavers and fetuses

Origin	Adult		Fetus	
	Aorta	Other	Aorta	Other
Number of cadavers	75	0	25	0
Percentage (%)	100	0	100	0

Table 2
Distance from origin of aorta to the bifurcation of inferior mesenteric artery

Number of cadavers	Mean (cm)	Median (cm)	SD	Min (cm)	Max (cm)
75	3.68	3.73	0.804	2.0	5.2

Table 3
Branches given by inferior mesenteric artery

Branch	Adult		Fetus	
	Number	Percentage (%)	Number	Percentage (%)
LCA	74	98.66	24	96
Sigmoid	75	100	25	100
Superior Renal Artery	75	100	25	100

Branches of IMA

In most of our cadavers studied IMA gave off three branches (Table 3). The most common branching pattern of inferior mesenteric artery was into LCA in 74 (98.66%) cases and common sigmoid trunk which gave off 3 - 4 sigmoid arteries. There was only one single case out of 75 adult cadavers and one case out of 25 fetuses in which LCA was absent (Table 3, Fig 1A) and sigmoid vessels were found to be arising from IMA (Fig 1B) giving origin to two small branches and continued as superior rectal artery (SRA).

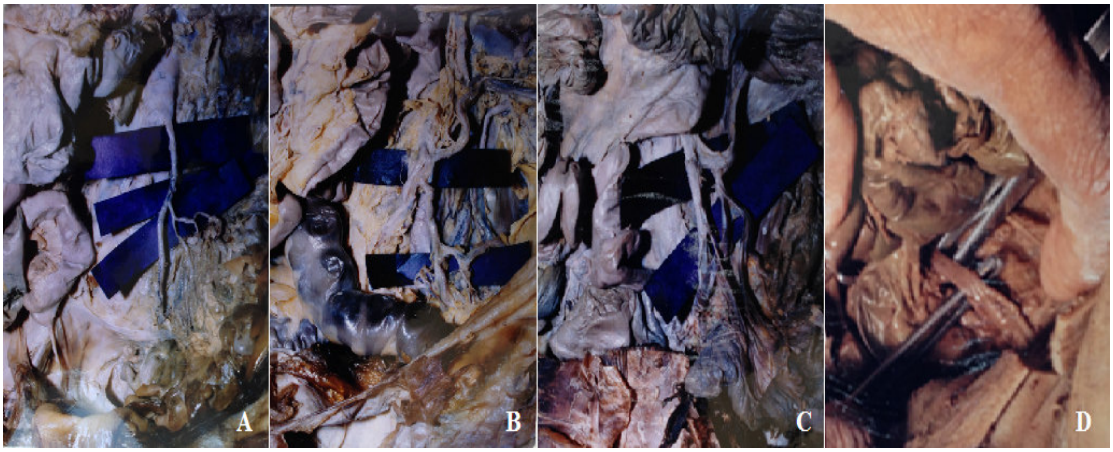

Figure 1
A- absence of LCA; B- sigmoid vessels arising from IMA; 1st sigmoid vessel arising from LCA; 1 sigmoid vessel and continuation as SRA.

In 70% of the cases the sigmoid arteries presented normal branching pattern. In about 30% of the cases 1st sigmoid has taken origin from LCA (Fig 1C) which formed a loop of anastomosis with the ascending branch of LCA. In about 70% of the cases 1st sigmoid has taken origin from IMA. In 74 cadavers the colic angle was between 75^{o} - 85^{o}. The diameter of IMA was measured to be 4mm. The main trunk of IMA was found to spring from abdominal aorta at the level of L3 and made an acute angle at about 3 – 4cm above the aortic bifurcation. The sigmoid arteries were 3-4 in number. They crossed in front of psoas major ureter and testicular vessels. The first sigmoid artery anastomosed with the descending branch of the left colic artery. This pattern was observed in 80% of our cadavers studied. In 53 (70%) cases of the present study the sigmoid arteries presented normal branching pattern. Variations of the sigmoid arteries were in the mode of origin and number of sigmoid arteries. In 20% of the cases LCA was found arising from IMA and one sigmoid vessel arising from IMA which later

continued as superior rectal artery (Fig 1D). Similar presentation was observed in the fetus (Fig 2A) specimen studied. In few of the cases 1st sigmoid seemed to be arising from IMA distinctly and rest four sigmoid arteries were seen to take origin from IMA in the form of cluster (Fig 2B). The number of sigmoid arteries were found to be variable between 3 - 4. It was interesting to note that in one cadaver, in addition to absence of LCA, only one sigmoid has taken origin from IMA and which in turn has given origin to 2-3 small branches. In one foetal specimen in addition to absence of LCA, two sigmoid vessels were found to spring from IMA (Fig. 2C). In 35 (46.67%) cadavers 3 – 4 sigmoid arteries were found to arise from IMA (Fig 2D).

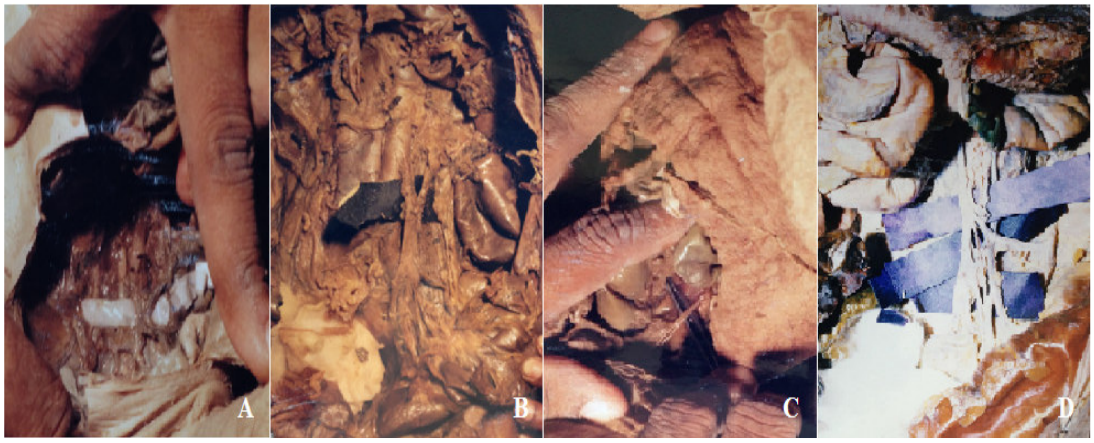

Figure 2

A- LCA and one sigmoid vessel arising from IMA and continued as SRA; B- ascending branch of LCA from IMA and 4 sigmoid vessels arising from IMA in form of cluster; C- absence of LCA and 2 sigmoid vessels arising from IMA in fetus; D- 3-4 sigmoid vessels arising from IMA.

In fetal specimen LCA was observed to spring from IMA and IMA continued as SRA. In the cadavers studied the SRA was found to be direct continuation of the IMA. It descends between the layers of the pelvic mesocolon and crosses the left common iliac vessels. It divides into two branches which supply the rectum and anastomose with the middle rectal arteries. In all the 75 specimens the superior rectal artery showed the above mentioned pattern.

Distance of IMA from bifurcation of aorta

The distance of IMA from the bifurcation of aorta reported in various other studies is enumerated in Table 4. In the present study, the length of IMA was observed to be within the range of 2 – 5.2cm.

Table 4

Distance of inferior mesenteric artery from the origin of aorta to its bifurcation observed in the past studies and present study

Author	Number	Mean (cm)	Range (cm)
Griffith, 1956[13]	100	…..	2.5 – 5
Michels et al., 1965[6]	127	…..	3 – 5
George, 1935[17]	92	…..	2.7 – 8.2
Decker and du Plesis, 1986[18]	…..	…..	3 – 8
Simeon et al., 2013[19]		3.65	2–7
Rekha and Charushila, 2015[20]	50	3.62	2 - 5
Present study	75	…..	2.2 – 5

DISCUSSION

The knowledge of normal and abnormal branching pattern of inferior mesenteric artery is vital for surgical gastroenterologists who do lot of surgical interventions in abnormal situations of large bowel like polyposis, diverticulosis and malignancies involving different components of hind gut like colon, rectum and anal canal. Hence, they need proper knowledge and enlightenment of branching pattern of inferior mesenteric artery which is the main vessel of hind gut and the anastomotic pattern of arcades existing between inferior mesenteric artery and superior mesenteric artery which helps the potentiation of collateral blood flow throughout the musculature of whole hid gut. The variation in the number and branching pattern of the arteries of the gut may be correlated with their embryologic development. After the formation of longitudinal anastomotic channels, numerous ventral splanchnic branches disappear and only three trunks persist as the celiac trunk, the superior mesenteric artery and the inferior mesenteric artery[21]. Any deviation from the normal pattern of fusion of these channels can lead to the existence of anomalous branching pattern of these major vessels. Superior and

inferior mesenteric arteries are known to show variations in their branching pattern. In a study by Simeon, Philip, Johnstone and Hassan[19] on fifty seven formalin embedded cadavers, the inferior mesenteric artery branched into left colic artery and a common sigmoid trunk in twenty three cases, while the classical branching pattern was observed in only seven cases. Variations of the left colic artery are however, extremely rare. According to Poynter [22], this artery has not been extensively studied and the literature is not very extensive. Generally IMA is very stable, arises directly from abdominal aorta[23] and not subject to much variation. We examined the anatomy of these arteries in 75 adult cadavers and 25 fetuses. The most frequent and common pattern of branching of the inferior mesenteric artery observed was a left colic and a sigmoid artery arising from a common trunk with a second sigmoid artery from the inferior mesenteric artery. Some variations, however, deserve a special mention. The embryologic basis, frequency in the literature, and clinical relevance of these variants are discussed. Anatomical variations of the inferior mesenteric artery are extremely uncommon, since the inferior mesenteric artery is regularly diverged at the level of the third lumbar vertebra. Greenberg[24] (1950) in their study in 74 autopsy specimens found IMA spring from abdominal aorta (AA) at an angle of 70 - 90^{o} at L3 level. In all the 75 (100%) cadavers of the present study IMA was observed to arise from the abdominal aorta and in 74 (98.66%) cases the colic angle was between 75^{o} – 85^{o}. IMA originated from L3 level vertebra with slight variation observed in colic angle (75^{o} – 85^{o}). According to Lee Mc Gregor's[18] surgical anatomy the superior mesenteric artery arises at 20 – 30^{o} angle from abdominal aorta. The acute angle of its origin explains why this artery is most commonly occluded by an aortic embolus. The diameter of SMA is 8 – 10mm. Here, this finding can be correlated with the angle of origin of IMA from AA at higher angles (75 – 85^{o}) and due to lesser diameter of IMA compared to SMA this vessel is less likely to be occluded by embolic phenomenon unlike SMA. Kahn and Abrams (1964) analyzed IMA patterns in 142 cases by angiographic study and reported IMA to be present in all of them. Sierocinski[25] studied arterial supply of descending colon in 100 cadavers; IMA was constant in all of them and common trunk was not noted. Lippert and Pabst[26] had mentioned the frequency of the variation in which the IMA originated from SMA to be < 0.1%. A rare origin of IMA from superior mesenteric artery (SMA) was observed by Kitamura, Nishiguchi, Sakai and Kumamoto[27]. Armstrong, Hunt, Price and Resnik[28] reported the angiographic demonstration of a common origin of the IMA and renal artery. Benton and Cotter[29] reported an extremely rare variation of double IMA, which arose from the abdominal aorta.

Branches of IMA

In the present study cadavers, IMA gave three branches LCA in 74 (98.66%) cadavers, sigmoid and superior rectal artery (100%). According to a study, the inferior mesenteric artery most commonly divides into LCA and common sigmoid trunk[19]. Decker and du Plesis[18] and Rekha and Chrushila[20] reported absence of LCA in 6% and 1.34% of the cases respectively. The absence of the left colic branch has been reported by Sonneland, Anson, Beaton[30]. Griffiths[13] noted absence of LCA in 6 cases and in all these cases the first sigmoid artery only was well developed reached up to splenic flexure to anastomose with the middle coliac artery. Similar findings were observed in the present study with the absence of LCA in two cases, one (1.33%) out of 75 in adult cadavers and one (4%) out of 25 in the fetuses studied. In such cases 1st sigmoid may anastomose with middle colic to fulfill the role of LCA. In about 8 (32%) of the cases in the present study 1st sigmoid has taken origin from LCA which formed a loop of anastomoses with ascending branch of LCA. In 61% of the cases observed by Michels, Siddharth, Kornblith, and Parke[6] anastomotic arc connecting with rami of the ascending branch of left colic was observed.

Distance of IMA from bifurcation of aorta

The distance of IMA from bifurcation of aorta found in various other studies is enumerated in Table 4. Michels, Siddharth, Kornblith and Parke[6] reported the mean length of IMA (3.65 ± 1.03cm) within the range of 2 – 7 cm. However, in the present study, the length of IMA was observed to be within the range of 2 – 5.2cm. Griffiths[13], Michels, Siddharth, Kornblith, and Parke[6], Rekha and Charushila[20] reported mean length of IMA within the range of 2.5 – 5cm. However, the range of IMA length was higher in the results reported in the previous study[17,18-19]. Accidental ligation of aberrant colic artery may result in necrosis of colon due to ischemia or graft injury. The aberrant branches may also interfere with radiological interventional procedures. Therefore, apart from having academic significance, these arterial alterations assume relevance for surgeons and radiologists for improving patient care intra and postoperatively.

CONCLUSION

Precise knowledge of colonic vasculature and its variations is a prerequisite for Surgeons and Radiologists so as to avoid unwanted complication. However, the anatomical arcade in the present study is unaffected, unaltered by anomalous arterial pattern of IMA.

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