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Original Research Article

ANATOMICAL VARIATIONS IN THE BRANCHING PATTERN OF SUPERIOR MESENTERIC ARTERY IN ADULT HUMAN CADAVERS

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ABSTRACT

Background: In the medical field, the trend of the surgical branches has moved towards minimal invasive surgeries for reasons of decreased morbidity and mortality. To achieve this is thorough knowledge of the anatomy, with the variations of the concerned structure is required. Hence for a structure like superior mesenteric artery, the anatomic variations of its origin and branching pattern is important for accurate interpretation in diagnostic imaging, as well as in deciding the optimum elective procedure in surgical radiological, and interventional management.

Materials and methods: The study was carried out in 50 well embalmed cadavers of South Indian origin irrespective of age and sex. Variations in the branches of superior mesenteric artery were noted.

Results: Inferior pancreaticoduodenal artery arose from the first jejunal artery. Middle colic and right colic arteries arose as common trunk. The right colic artery was absent. Ileocolic artery arose as common trunk with right colic artery.

Conclusion: A thorough knowledge of the anatomy of colonic mesenteric arteries is necessary to accomplish successful uncomplicated abdominal operations, especially laparoscopic colonic resection for cancer using proximal vascular ligation and wide-en-block resection in which the mesenteric vessels cannot be palpated.

KEY WORDS: Superior Mesenteric Artery, Common Trunk, Midgut, Colon Resection.

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INTRODUCTION

Superior mesenteric artery is the second ventral branch of abdominal aorta. It arises from the abdominal aorta about 1cm below the celiac trunk, at the level of intervertebral disc between the first and second lumbar vertebrae. At the origin the artery is overlapped by the body of the pancreas and is sand-witched between the splenic vein above and the left renal vein below. The superior mesenteric artery passes

downwards, forwards and to the right in front of the uncinate process of pancreas, third part of the duodenum, inferior vena cava, right psoas major and right ureter. It runs along the root of the mesentery towards the right iliac fossa. The trunk of the artery shows a slight concavity to the right, is surrounded by a plexus of nerves and is accompanied with the superior mesenteric vein on its right side. Its calibre progressively decreases as successive branches are given off to lower half of duodenum, loops of jejunum and ileum. It terminates by anastomosing with its ileocolic branch. From its convex left side, the artery provides jejunal and ileal branches.

They form arcades within the mesentery to a varying extent before giving rise to multiple vasa recta and are distributed to the jejunum and ileum. Ileal branches are more numerous than the jejunal branches but smaller in caliber. From its concave right side it gives off inferior pancreaticoduodenal artery, middle colic artery, right colic artery and ileocolic artery successively from above downwards. Inferior pancreatic artery arises from the superior mesenteric artery or from its first jejunal branch. It divides into anterior and posterior branches that collateralize to the coeliac artery. Middle colic artery arises from the superior mesenteric artery at the lower border of pancreas and immediately enters the root of transverse mesocolon. Within the layers of mesocolon the artery runs downwards and to the right and divides into right and left branches.

The right branch reaches the right colic flexure and anastomoses with the ascending branch of the right colic artery, the left branch anastomoses close to the left colic flexure with the ascending branch of left colic artery which in turn is a branch from inferior mesenteric artery. Right colic artery arises from the middle of the concave side of superior mesenteric artery and passes retroperitoneally to the right. On reaching the ascending colon the artery divides into ascending and descending branches to anastomose respectively with the middle colic and the ascending branch of the ileocolic arteries. Ileocolic artery arises from the right side of superior mesenteric artery and passes retroperitoneally downwards and to the right to enter the right iliac fossa. The artery divides into ascending and descending branches.

The ascending branch anastomoses with the right colic artery and the descending branch with the termination of the superior mesenteric artery. The descending branch of the ileocolic artery divides into four sets of branches – anterior caecal, posterior caecal, appendicular and ileal branches. The ileocolic artery vascularizes the terminal ileum, right colon, caecum and appendix [1].

The marginal artery of Drummond is a potential collateral pathway that connects the superior and inferior mesenteric arterial systems. This anastomotic channel originates from the descending branch of the ileocolic artery. It involves the communication of this branch to the right colic artery via the right colic artery's descending and ascending branches, then the right and left branches of middle colic artery, the ascending and descending branches of the left colic artery and the sigmoid branches of the inferior mesenteric artery terminating in the superior rectal artery. When well developed, this can be a rich source of collateral circulation to the colon, particularly in the event of colonic resection.

Less than 50% of the time, this collateral pathway may not be complete at the splenic flexure, a location named Griffith's point. This void of collaterals from the left branch of the middle colic artery to the ascending left colic artery can result in colonic ischemia in the setting of bowel surgery or occlusive disease [2, 3].

Meandering mesenteric artery of Moskowitz or arc of Riolan represents another collateral pathway between superior and inferior mesenteric arteries. It was named after anatomist Jean Riolan. When present, this connects the middle colic artery of the superior mesenteric artery with the left colic branch of inferior mesenteric artery [4].

The preservation of the continuity of the 'Riolan's arc' and Drummond's artery after transverse colon resection is important for the prevention of development of necrosis. The recognition of variant colonic arterial supply has important diagnostic and therapeutic implications. Ignorance of these variations may result in either a

false positive diagnosis such as branch occlusion or in a false negative diagnosis in the supplied segment of the colon. Consequently this study has been carried out to provide a knowledge of the anatomical variations of the superior mesenteric artery for the operating surgeons.

MATERIALS AND METHODS

The present study was carried out on 50 embalmed cadavers in the Department of Anatomy, Rajah Muthiah Medical College, Chidambaram. The superior mesenteric artery and its branches were exposed by following standard methods of dissection. The anterior abdominal wall was incised and reflected. The peritoneum and the viscera were carefully separated and cleaned from the field of view. Superior mesenteric artery was then traced proximally and distally and the study was conducted under the following parameters. Origin of superior mesenteric artery, number of jejunal and ileal branches arising from the superior mesenteric artery and the pattern of origin of inferior pancreatico duodenal artery, middle colic, right colic, ileocolic artery [5].

RESULTS

Study of variations in the branching pattern of superior mesenteric artery was carried out and the following results were concluded. The origin of superior mesenteric artery is from the abdominal aorta in all the 50 specimens. Number of Jejunal and ileal branches ranged from 12-20. In 84% of cases inferior pancreaticoduodenal artery arose from the superior mesenteric artery and in 16% of cases the artery arose from the first jejunal artery (Fig.1). In 72% of cases the middle colic artery arose as a separate branch and in 28% of cases as a common trunk with right colic artery from superior mesenteric artery (Fig.2). The right colic artery was absent in 2% of cases (Fig.3). The artery arose as a separate branch from superior mesenteric artery in 54% of cases and as a common trunk with middle colic and ileocolic artery in 28% and 16% of cases respectively. Ileocolic artery arose as a separate branch in 84% of cases and as common trunk with right colic artery in 16% of cases from the superior mesenteric artery (Fig.4).

Fig.1: Origin of inferior pancreaticoduodenal artery from first jejunal artery.

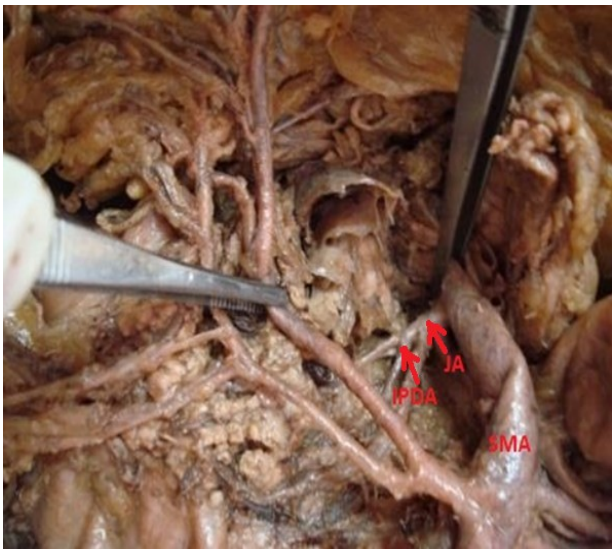


Fig. 2: Common trunk of middle colic artery and right colic artery from superior mesenteric artery.

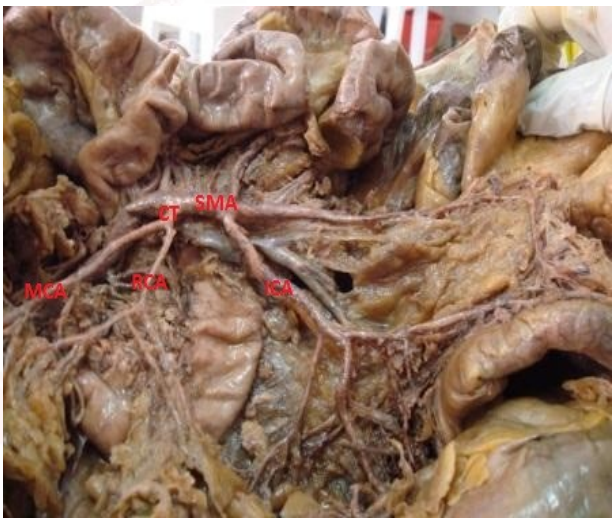


Fig.3: Absent right colic artery.

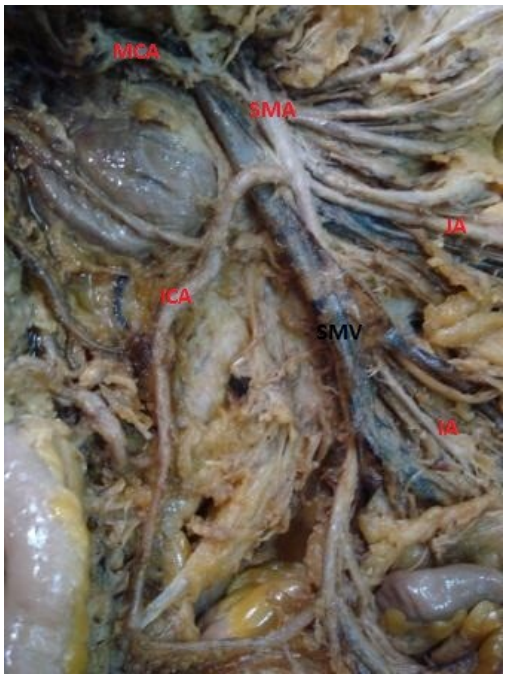
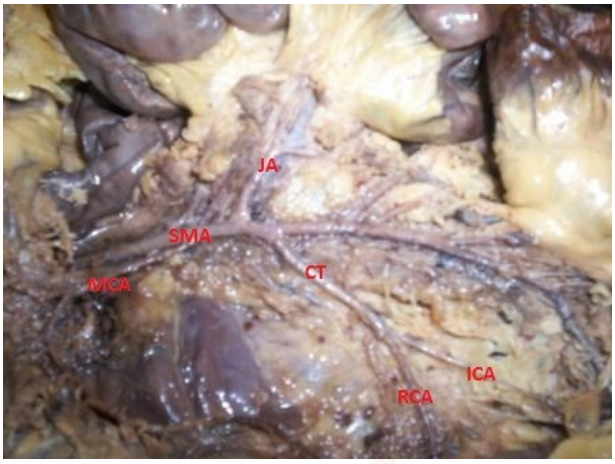


Fig.4: Common trunk of right colic artery and ileocolic artery from superior mesenteric artery.



SMA – Superior Mesenteric Artery, **IPDA –** Inferior Pancreatico Duodenal Artery, **JA –** Jejunal Artery, **CT –** Common Trunk, **MCA –** Middle Colic Artery **RCA –** Right Colic Artery, **ICA –** Ileo Colic Artery , **IA –** Ileal Artery, **SMV –** Superior Mesenteric Vein.

DISCUSSION

Vasculogenesis begins with the development of extraembryonic vascular system in the early part of 3rd week and intraembryonic vessels and the primitive heart in the later part of 3rd week. The extraembryonic blood vessels and blood cells develop from the angioblasts which are differentiated from the mesenchyme of three regions- the wall of yolk sac, the connecting stalk and the chorion. The vessels arising from the capillary plexus of the wall of the yolk sac form the vitelline vessels; those developing in the chorion and the connecting stalk constitute the umbilical vessels.

The intraembryonic blood vessels and blood cells differentiate in situ from the angioblast cells of the intraembryonic mesoderm and establish secondary connections with the extraembryonic blood vessels. The pattern of blood vessel formation in the embryo is regulated by inductive signals from the underlying endoderm. Two longitudinal vessels known as the dorsal aorta appear in the flattened embryonic area on each side of the notochord and along the dorsal wall of the yolk sac. The right and left dorsal aorta develop in parallel with the developing heart and gains access to it via the aortic arches.

In a lengthy process the paired dorsal aorta unites and finally forms the unpaired descending aorta of the adult. 3 groups of collateral anastomotic arteries arise from the abdominal aorta named as ventral (visceral) segmental branches, lateral (visceral) segmental branches, dorsolateral (parietal) intersegmental branches. These branches are modified in various ways until they reach the definitive adult form. The ventral visceral segmental branches of dorsal aorta initially appear as paired vessels. These ventral branches are called vitelline or omphalomesenteric arteries as they supply blood to the gut tube and its derivatives. The ventral branches surround the intestine and the umbilical vesicle from dorsal to ventral aspect. With the further development of the intestine, the two layers of the mesenterium dorsale approach each other. so that the ventral paired branches coalesce in the median line to form the four roots of vessels for the gut. Between the 4th and 7th gestation week a longitudinal paraaortic anastomosis appears between the four roots of the omphalomesenteric artery. Of the four roots the two central roots disappear and the longitudinal anastomosis now joins the first and the fourth root. The first omphalomesenteric artery forms the truncus coeliacus and the fourth root forms the superior mesenteric artery.

The hepatic, splenic and left gastric arteries originate at the longitudinal anastomosis connecting the first and fourth roots. Then the anastomosis disappears from the fourth root which is the future superior mesenteric artery upto the level below the last of the three celiac branches.

The superior mesenteric artery migrates more caudally with the ventral migration of the gut. The variations in these arteries arise from difference in the pattern of the partial disappearance or the survival of the ventral splanchnic arteries and the ventral longitudinal channel. If the separation of the longitudinal anastomosis occurs at a more cranial level one of the branches of celiac trunk will be displaced to the superior mesenteric artery. If the first or fourth root disappears a celiacomesenteric trunk can develop [6].

Several anatomic and radiological descriptions of variation in the origin of the ventral branches of abdominal aorta had been reported earlier. Sridhar Varma et al reported a variation of common celiacomesenteric trunk which divided

into hepato mesenteric and gastrosplenic trunk.The hepatomesenteric trunk was divided into common hepatic and superior mesenteric artery. The anatomical variations of these vessels are due to developmental changes in ventral splanchnic arteries. The chance of compression of common celiacomesenteric trunk by the overlying large median arcuate ligament and the aortic opening are high because of its large size and position. So during the evaluation of coeliac trunk compression syndrome the existence of a common coeliacomesenteric trunk should be kept in mind [7].

Nayak et al reported a rare origin of the superior mesenteric artery and the common hepatic artery arising from the abdominal aorta as a common trunk and named as hepatomesenteric trunk. In such case the coeliac trunk is reduced in size and is called as gastrosplenic trunk. The common hepatic artery usually passes in front of the portal vein when it originates as a branch of hepatomesenteric trunk. The knowledge of common hepatic artery originating along with the superior mesenteric artery is important for surgeons performing pancreaticoduodenectomy. The common hepatic artery is liable to get damaged in such surgical intervention. Sometimes the artery may loop around the bile duct and compress it. Such abnormal course of the artery might confuse the radiologist doing endovascular procedure on the artery**.** Another variation of a celiacomesenterico phrenic trunk has also been reported by Nayak.

Prior knowledge about the common trunk is essential to successfully accomplish surgical, oncologic or interventional procedure during lymphadenectomy around a hepatosplenomesenteric trunk, aortic replacement with reimplantation of the trunk or chemoembolisation of liver malignancies as all of which can potentially create significant morbidity because of the large visceral territory supplied by a single vessel. And also knowledge of this type of variation is important for the surgeons performing kidney transplants and suprarenal surgery [8]. In the present study, the superior mesenteric artery took its origin from the ventral surface of abdominal aorta in all the 50 specimens.

In a previous report of Basmajian the number of jejunal and ileal branches arising from the superior mesenteric artery ranged between 12 to 20 which is similiar to the present study [9]. But according to Anozeng oyono Igiri et al the number of jejunal and ileal arteries ranged from 8 to 15. They also observed a single large jejunal artery with several smaller branches arising from this large artery to supply the jejunum in one cadaver [10]. Mane RM et al reported that the number of jejunal and ileal branches were around 7 to 13 and also noted two cases of additional supply to transverse colon and pancreas by jejunal artery [11]. According to Gourley EJ et al superior mesenteric artery supplies entire small bowel by 12-20 jejunal and ileal branches [12].

Paul butter et al reported the incidence of origin of inferior pancreatico duodenal artery as a separate branch from superior mesenteric artery as 60% and as a common trunk from the first jejunal artery as 40%. Anozeng Oyono Igiri et al reported the origin of inferior pancreatico duodenal artery from the aorta under the root of superior mesenteric artery [10].In this study inferior pancreatico duodenal artery, had a separate origin from superior mesenteric artery in 84% of cases and from the first jejunal artery in 16% of cases.

Ronald.A.Bergman et al found that the middle colic artery arose independently from the superior mesenteric artery in 60% of cases and from a common stem with the right colic artery in 25% of cases. Accessory middle colic or superior left colic artery arose from superior mesenteric artery in about 9% of individuals. In 27% an additional large left branch coursed to the left colic flexure, ramifying to supply that area. They also noted that the inconstant branches arising from the middle colic artery are the dorsal pancreatic and the inferior pancreatic arteries. Numerous anastomoses were found between the branches of left colic and middle colic arteries which are of some interest to the surgeons.

Contrary to this Vicq.D.Azyr reported the absence of anastomosis between the middle colic and the left colic arteries. Ronald.A.Bergman et al also noted the incidence of right colic artery arising independently from superior mesenteric artery only in 28% and absent in 13% of the studied specimen. The right colic artery was found

to originate from the ileocolic artery, which is a major branch of superior mesenteric artery. Also ileocolic artery arose independently from the superior mesenteric artery in 63% and in the remainder as a common trunk with the right colic artery. Variation in the anatomy of the middle colic artery is the most problematic configuration encountered in patients undergoing colon interposition following esophagectomy. The most favourable situation is a single common trunked middle colic artery. This allows division of the artery proximal to the branch and preserved blood flow to the distal portions of the graft. Ligation of multiple middle colic arteries results in marginal blood flow and a tenuous graft in its most distal portion [13].

Jeffrey.H. Peters et al found that the middle colic artery arose independently from the superior mesenteric artery in 80% and from a common stem with the right colic artery in 8%. They also reported that the superior and inferior mesenteric artery anastomoses were seen in 52% of individuals. Other variations observed by Jeffrey.H.Peters et al were multiple middle colic arteries in 12% cases, absent middle colic artery in 8% cases and in 4% cases middle colic artery arose from inferior mesenteric artery. Jeffrey. H.Peters et al concluded the incidence of missing right colic artery as 4% and multiple origin of right colic artery as 16% and common origin of right colic and middle colic arteries as 8% [14]. Sonneland et al studied 600 specimens and reported the classical pattern of the colic arteries in 23.8%, absence of middle colic artery in 3.6%. And also two middle colic arteries with two separate origin was observed. They also stated that, in 12.6% there is absence of right colic artery, in 78% right colic artery arose as a single vessel, in 8.7% right colic artery arose as a two vessels and in 0.7% three right colic arteries arose from superior mesenteric arteries [15].

A.Fleancu et al observed a common trunk of the ileocolic artery with the middle colic artery [16]. Poynter noted a middle colic artery that arose as a large branch from the left colic artery near its origin [17]. Common stem which shares middle colic and right colic arteries in 30% to 40% was reported earlier by Hollinshead. It may share a common stem with both right colic and the ileocolic. It may also arise from the celiac trunk or one of its branches [18]. In a study on 25 cadavers done by M Haywood et al, right colic artery originated from the right branch of the middle colic artery in nine cadavers, while it arose from the superior mesenteric artery in eight cases. The right colic artery was absent in two individuals and the remaining arose from the ileocolic or root of the middle colic artery [19].

Jiji.P.J et al presented a case of dorsal pancreatic artery that originated from the common hepatic artery and communicated with the middle colic artery thus forming a rarely described variant of Buhler's arcade [19]. A similar case was reported in 1989 by Makomaska- Szaroszyk . The arc of Buhler is an embryological persistence of the portion of ventral longitudinal anastomosis between the coeliac trunk and the superior mesenteric artery. Bertelli et al stressed upon the importance of this anastomosis in pancreatic surgeries. Although the incidence of the arc of Buhler is rather rare (<4%) aneurysms of this variations are more common, in association with stenosis or occlusions of coeliac origin.

The knowledge of anatomical variations of the vascular junction between the coeliac trunk and superior mesenteric artery can aid a surgeon in vital decision making about the surgical procedure to be adopted while performing pancreatectomies, splenectomies and resections [20]. Harold.S.Amonoo.Kuofi et al studied the anomalous origin of colic arteries and noted variant vascular patterns. These constituted of an anomalous middle colic artery arising from the proximal segment of the splenic artery. The precarious course of the middle colic artery and its dominance in the formation of the marginal artery were thought to predispose the ascending and transverse colon to an increased risk of vascular damage. In this case the only contribution of the superior mesenteric artery to the marginal artery was through the anastomosis of its ileocolic branch with the right branch of the aberrant middle colic artery [21]. The marginal arteries of the right colic and ileocolic arteries might not be continuous. This discontinuity was explained by Steward and Rankin [22]. Michels et al noted the ileocolic artery failing

to anastomose with the right colic artery and that the right colic artery very commonly originated from the middle colic or ileocolic arteries. Sometimes a large branch, the Arc of Rioland may connect the stem of superior mesenteric artery with the left colic artery in the posterior abdominal wall [23].In the present study middle colic artery arose as a seperate branch in 72% of cases and as common trunk with right colic artery in 28% of cases. Right colic artery arose as a separate branch from superior mesenteric artery in 54% of cases and as a common trunk with middle colic and ileocolic arteries in 20% and 16% of cases respectively. The artery was absent in 2% of cases. The ileocolic artery was seen arising as a separate branch in 84% of cases and as common trunk with right colic in 16% of cases.

Colonic resection and anastomosis for malignancy has existed for almost 200 years with a clear understanding of the underlying vascular anatomy, one of the most important aspects of good oncological surgery .The procedure, right hemicolectomy undertaken for benign and malignant diseases of the right colon has remained essentially unchanged but over the last two decades the application of minimally invasive surgery such as laproscopic and robotic techniques has dramatically increased in the field of colon cancer because it has a number of advantages over open surgery [24]. But it has limitations such as limited operative field of view, lack of tactile sensations and an increased risk of visceral and vascular injuries especially in the patients with anatomical variations. Since the last century there has been several anatomical studies on variations in the arteries of the right colon; these mainly focused on the incidence of ileocolic, right and middle colic arteries which showed that the ileocolic artery was constantly present while the middle colic artery was present in 98%-100% of cases.

In contrast the rate of right colic artery presence was highly variable, ranging from 10% to 63% [25-28]. Furthermore the definition of this vessel varies considerably between different authors. In 1933, Steward and Rankin considered the act of defining the right colic artery with respect to its origin. They proceeded to regard it as any anastomosed vessel arising from the superior mesenteric, middle colic or ileocolic artery and supplying the hepatic flexure region [22]. Sonneland et al suggested that the right colic artery should be considered the major feeding vessel independent of its origin, directed to the ascending colon between the ileocaecal junction and the hepatic flexure[15]. Therefore a clear understanding of the distribution of the colic branches is of paramount importance to the success of the precision surgery in the region of the hepatic flexure and ascending colon and it is proposed that pre-operative imaging of the vascular supply to this area should be routine as part of the work-up of surgical procedures.

CONCLUSION

The material reported here includes a review of the basic anatomic relationship of the superior mesenteric artery, the important variations in the origin of its branches and a consideration of the applied anatomy. It is hoped that this will provide some information and will be helpful to successfully accomplish surgical, oncological or interventional procedures to be carried out in the vicinity of the vessel.

Conflicts of Interests: None

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