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Arc of Riolan revisited-proposal of a new classification system

Filip Kęska et al., Arc of Riolan revisited

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Abstract

Background: The arterial supply of the large colon is provided by the superior mesenteric artery (SMA) and inferior mesenteric artery (IMA). A particularly important area, especially in the field of colorectal surgery is the splenic flexure of the colon. There is a noticeable misunderstanding in the correct nomenclature of the major arterial anastomoses between SMA and IMA – Drummond's Marginal Artery (DMA), Arc of Riolan (AOR), and Moskovitz Artery (MA). The aim of this study is to organize the nomenclature and propose a new simplified one to facilitate communication between physicians of various specialties.

Materials and methods: Fourteen formalin-fixed cadavers (9 male, 5 female) accessible from the Chair of Anatomy of the Jagiellonian University Collegium Medicum were dissected to examine and describe the anatomical variations of anastomoses between SMA and IMA.

Results: The artery of Drummond was present in all 14 specimens maintaining the continuity of the vessel along its entire course. The Arc of Riolan was found in 7 out of 14 cadavers (50%). The artery of Moskovitz was not found. The average length measured between IMA and aortic bifurcation and between IMA and SMA was 51,00 mm and 84,68mm respectively.

Conclusions: SMA and IMA anastomoses form an arterial network that is characterized by high variability and trail in surgically strategic areas. For this reason, simplifying the terminology and using unambiguous names of these vessels based on their trail and anatomical relationship with IMV are crucial for the proper planning and execution of surgical procedures performed on the colon.

Keywords: intermesenteric anastomosis, IMA, SMA, Moskowitz artery, inferior mesenteric vein, cadaveric study

INTRODUCTION

The arterial supply of the large colon is provided by the superior mesenteric artery (SMA) and inferior mesenteric artery (IMA). These two arterial vessels arise from the abdominal aorta consecutively at L1 and L3 vertebrae level. IMA arises from the abdominal aorta slightly to the left from the median line of the human body on average 4-5 cm above the aortic bifurcation. IMA normally divides into superior rectal artery (SRA), sigmoid arteries (SA), left colic artery (LCA) with descending (DBLCA) and ascending branch (ABLCA). However, in the subject literature up to 43% of cases have an additional artery, that emerges from IMA or LCA and joins the Drummond's Marginal Artery (DMA) medially to splenic flexure of colon, known as the Arc of Riolan (AOR).[18] The issue is, that in a significant number of papers the Riolan's Arc is confused with the Moskowitz Artery (MA) also known as the meandric mesenteric artery, meso mesenteric artery, arch of Treves, central intermesenteric arch or the artery of Gonzalez[11]. Moskowitz artery is an anastomosis between IMA and SMA which can also be found as direct connection of their trunks or branches, for example between LCA and middle colic artery (MCA), LCA and accessory middle colic artery (AMCA).[3] Moskovitz artery is a vessel that runs medial to the Arc of Riolan, therefore closer to the inferior mesenteric vein (IMV) and the duodenum[8]. Specific trajectory of AOR and MA can be substantial to preoperative imaging, evading the injury of these vessels, which can easily provide an ischemia of the large colon. The purpose of this paper is, to describe the different pathways of AOR and to indicate why the differentiation between MA, AOR and the ascending branch of LCA must be made especially in surgical cases requiring mobilization of the left colonic flexure and preparation of Splenic Flexure Avascular Space (SFAS) above the Ventral Edge of Pancreas (VEOP).[8] Bearing in mind that branches and anastomoses mentioned above are not the only vascular variations of this anatomical region, the authors recognize AOR and MA the most important ones considering incidence, clinical implications and reports, especially considering the anatomical relationship to IMV and IMA branching pattern itself.[13]

MATERIALS AND METHODS

For the purpose of this work, the authors dissected 14 formalin-fixed specimens (9 Male, 5 Female) accessible from the Chair of Anatomy of the Jagiellonian University Collegium Medicum. The access to the abdominal cavity was obtained by the bilateral longitudinal incision on anterior axillary line from the level of the first costa, down to anterior superior iliac spine and the transverse incision on the level of the first rib. The small bowel was mobilized and moved to the right to expose the parietal peritoneum on the posterior abdominal wall containing the aorta, IMA and its branches. Beforehand, every fold with probable vessels was established in order to protect them while stratifying the parietal peritoneum.

To receive clinically meaningful results three measurements were conducted:

1. The distance between the Aortic Bifurcation and the origin of IMA from the abdominal aorta
2. The distance between the origin of IMA and SMA
3. The vertebral level of Aortic Bifurcation and the origin of IMA

In order to take valuable measurements, the authors used an electronic calliper GEKO G01494 accurate to 0,01 mm. Long anatomical needles were used to mark the crucial points. Each time for the first and the second survey, four measurements were performed. Whereas the vertebral level was determined by palpating the promontory (S1/L5) with wing of sacrum and by going upwards, finding consecutive transverse process and projecting them for proper anatomical tags. The statistical analysis and Student’s Test was conducted with Statistica version 13.3 (StatSoft) provided by Jagiellonian University Collegium Medicum. It should be mentioned that two of the fourteen specimens, were taken to the crematory during the measuring process, hence the absence of two morphometric measures. All specimens that underwent a surgical procedure on the abdomen, with destroyed vascular net due to an accident or every other reason causing change of the vascularization, were excluded from the study.

RESULTS

Anatomical variation

Fourteen formalin fixed specimens were dissected and examined. IMA, SMA and Drummond's Marginal Artery (DMA) were found in 100% of cases. Riolan's Arc (AOR) was present in 50% of the specimens, creating an additional anastomosis between IMA and SMA by connecting left colic artery (LCA) or it's ascending branch (ABLCA) and left branch of the middle colic artery (LBMCA) or Drummond's Marginal Artery (DMA). Moskowitz Artery (MA) – the direct anastomosis between the trunks of IMA and SMA was not found. Respectively, each AOR crossed superficially the inferior mesenteric vein (IMV). [Figure 1.] [Figure 2.]

Morphometric measures

The aortic bifurcation was most frequently projected at the level of the fourth lumbar vertebrae L4 [Table 1], whereas the origin of IMA at third lumbar vertebrae L3 [Table 2]. The mean length between the origin of IMA to aortic bifurcation was 51mm +/- 1,37mm. The Distance from SMA to IMA was measured as 84,68mm +/- 1,94mm. Student's test showed p-value=0,08176 for IMA-SMA as compared to Nakayama et al. 2017, whilst p-value=0,00939 for IMA-aortic bifurcation as referred to Cai et al.2017.[4, 12]

DISCUSSION

The main purpose of this article is to organize anatomical nomenclature of the main anastomoses between SMA and IMA and to propose a simpler and clinically relevant one. Substantially there is a complete unison regarding the course and the name of Drummond's

Marginal Artery. The authors have observed however, a tendency in the subject literature to confuse the term AOR with MA. [2, 6, 10, 11, 16, 18] Despite the fact that many reports emphasize the necessity to systematize anatomical nomenclature of the arterial connections of the left flexure of the colon, together with the clinical implications relating to colon ischemia, anastomotic leakage and damaging vessels running in the vicinity of the IMV during surgical procedures in this area, the differences can still be observed at the level of understanding such terms as: Riolan's arc or Moskovitz's artery. Some authors claim that the anastomosis between IMA and SMA is named intermesenteric artery whereas the names Moskowitz Artery and Arc of Riolan are just eponyms, that simply neglects the pathway of these two vessels. [10, 19] It is worth emphasizing the existence of articles in which the distinction between the terms AOR and MA is described. [8, 9]

Bruzzi et al. released a paper with a certain approach to unifying the nomenclature in this matter. They claim that all the eponyms like Arc of Riolan, Moskowitz Artery, Meandric Mesenteric Artery, etc. should no longer be used. In order to identify them correctly, other phrasing was suggested, such as the following: Arch of the first order, the most peripheral and the most frequent: the Marginal Artery, arch of the second order, the "V" termination of the ascending branch of the left colic artery, arch of the third order, more central: the inter-mesenteric trunk.[3]. The concept of the Arch of the first, second and third order is surely simplifying and unifying this classification yet the authors could not find any other sources using it.

Garcia et al. has accurately described the reduction in Splenic Flexure Avascular Space (SFAS) associated with the presence of the Arc of Riolan or the Artery of Moskovitz.[8] The conclusion of the above-mentioned study confirms that the presence of a central anastomosis (Moskovitz Artery) significantly reduces the avascular space of the colon, thus increasing the risk of damage to important anastomosis running in the vicinity of the IMV with all its consequences. The presence of the Riolan's Arc may cause technical problems, yet the risk of damage to this vessel is much lower due to the greater distance from the ligated vein. Figure 8 shows all three main anastomoses between SMA and IMA with marked SFAS. It is easy to observe the different course of the vessels, which was the basis of authors' reflections and the classification itself. Clinical consideration is desirable and frequent in a great number of papers. [1, 5, 14, 15] High ligation of IMV is a stage of many surgical procedures performed on the colon that require splenic flexure mobilization. [1, 7, 8, 14, 17] It is crucial to understand that Moskovitz Artery is an arterial vessel directly adjacent to the IMV (central intermesenteric anastomosis), thus when the high ligation of IMV is performed there is a high probability of damaging MA causing arterial oozing with further consequences. Figure 8 shows the course of MA with marked IMV course. Second, more frequent anastomosis is Arc of Riolan which course is presented in Figure 7. When AOR is present there is also a probability of damaging this vessel during high IMV ligation/preparation of SFAS, however the avascular space of critical zone is present, yet reduced. (Contrary to the situation with MA where there is no avascular space). Nonetheless, looking for and preserving AOR during high IMV ligation is a crucial step in preventing colon ischemia.[17]

If anastomosis between IMA and SMA exists, the additional portion of blood is flowing from SMA to IMA's branches.[5] When an SMA obstruction occurs, reverse flow from the IMA to the SMA territory through the Intermesenteric Artery (IA), due to reduced blood pressure in the SMA and its branches, is able to supply the entire small bowel and the right half of the colon.[5] Additionally, anastomoses such as MA and AOR significantly avert local ischemia in Griffith's Point (splenic flexure), where the vascularization is often inconsistent.[3, 18]

During research the authors detected other misconceptions between AOR and ascending branch of left colic artery (ABLCA) [Figure 12]. The authors could not find any source that tried to distinguish when calling an artery AOR or ABLCA is legitimate. This problem should also be addressed in other scientific papers. Knowing that Drummond's Marginal Artery is created owing to the connection between branches of sigmoid, left colic and middle colic arteries and the authors have seen the divisions of LCA very near the descending colon thus they assumed a classification showed in Figure 5. and Figure 6. Due to this incoherence they saw some authors for whom AOR is ABLCA and Moskowitz artery, so direct connection between SMA and IMA was named Arc of Riolan.[16]

In authors' opinion, ordering the anatomical nomenclature of the main arterial anastomoses between SMA and IMA requires referring the course of these arterial vessels to IMV. Otherwise, the multitude of anatomical variants of anastomoses between IMA and SMA prevents proper diagnosis of the vessel and the use of this knowledge in practice. The probable reason for the lack of consensus on this issue may be an overly theoretical approach to the matter.

Hereby, the authors depict their proposition of classification for these arteries.

- The Drummond’s Marginal Artery - DMA or arch of the first order

As already mentioned, there is a unison on the pathway of DMA created by branches of MCA, LCA and Sigmoid branches.

- The Arc of Riolan – AOR or arch of the second order

In the authors’ view, the AOR is the indirect anastomosis between IMA and SMA. It does not matter whether the beginning of this branch is directly attached to the trunk of IMA or the left colic artery, but the trajectory of AOR is in the beginning always related to the pathway of the inferior mesenteric vein (IMV) in the parietal peritoneum [Figure 7]. On a certain level these two vessels go separate ways- AOR more laterally and IMV more medially. Because of this AOR relevantly minimizes the Splenic Flexure Avascular Space (SFAS) which can be dangerous while operating in this area[8]. AOR adjoins the Drummond’s Marginal Artery – DMA/left branch of middle colic artery-LBMCA medially to the splenic flexure of colon.

- The Moskowitz Artery – MA or arch of the third order

There are three possible pathways of Moskowitz Artery which is a more direct anastomosis between IMA and SMA. It is crucial to understand that the course of MA is strictly related with that of IMV. MA completely abolishes SFAS due to its more medial course than AOR [Figure 9,10,11] . It is possible to find the origin of MA attached to the trunk of IMA [Figure 9], to left colic artery or its branches [Figure 10] or even to the AOR [Figure 11]. Finally MA abut to the trunk of SMA or to the trunk of MCA. In Figures 9,10,11 it was shown MA connecting the trunk of SMA but it could also be connected to the trunk of MCA.

CONCLUSIONS

SMA and IMA anastomoses form an arterial network that is characterized by high variability and trail in surgically strategic areas. For this reason, simplifying the terminology and using unambiguous names of these vessels based on their trail and anatomical relationship with IMV are necessary for the proper planning and execution of surgical procedures performed on the colon. In authors' opinion, the anatomical classification of the main anastomoses between SMA and IMA should be based on the course of IMV in relation to arterial connections. This point of view facilitates a practical approach to nomenclature and eliminates the impact of the enormity of anatomical variations in this region. Awareness of the not uncommon occurrence of arteries in the vicinity of IMV should reduce the rate of arterial bleeding during high ligation of IMV.

Author contribution

Initial authors, Filip Keska and Julian Radon oversaw the cadaveric study, statistical analysis, concept, and processing of this paper. Professor Jerzy Walocha, Professor Artur Pasternak, and Doctor Aleksiej Juszczak, second authors, were supervising and having custody of this scientific work.

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Conflict of interest: None declared

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Table I. Projection of aortic bifurcation

	L3/L4	**L4**	**L4/L5**	**L5**
Bifurcatio aortae	2	7	1	2
Bifurcatio aortae [%]	16,70%	58,30%	8,30%	16,70%

Table II. Projection of IMA

	L2	**L3**	**L3/L4**	**L4**
IMA	3	7	1	1
IMA [%]	25,00%	58,30%	8,30%	8,30%

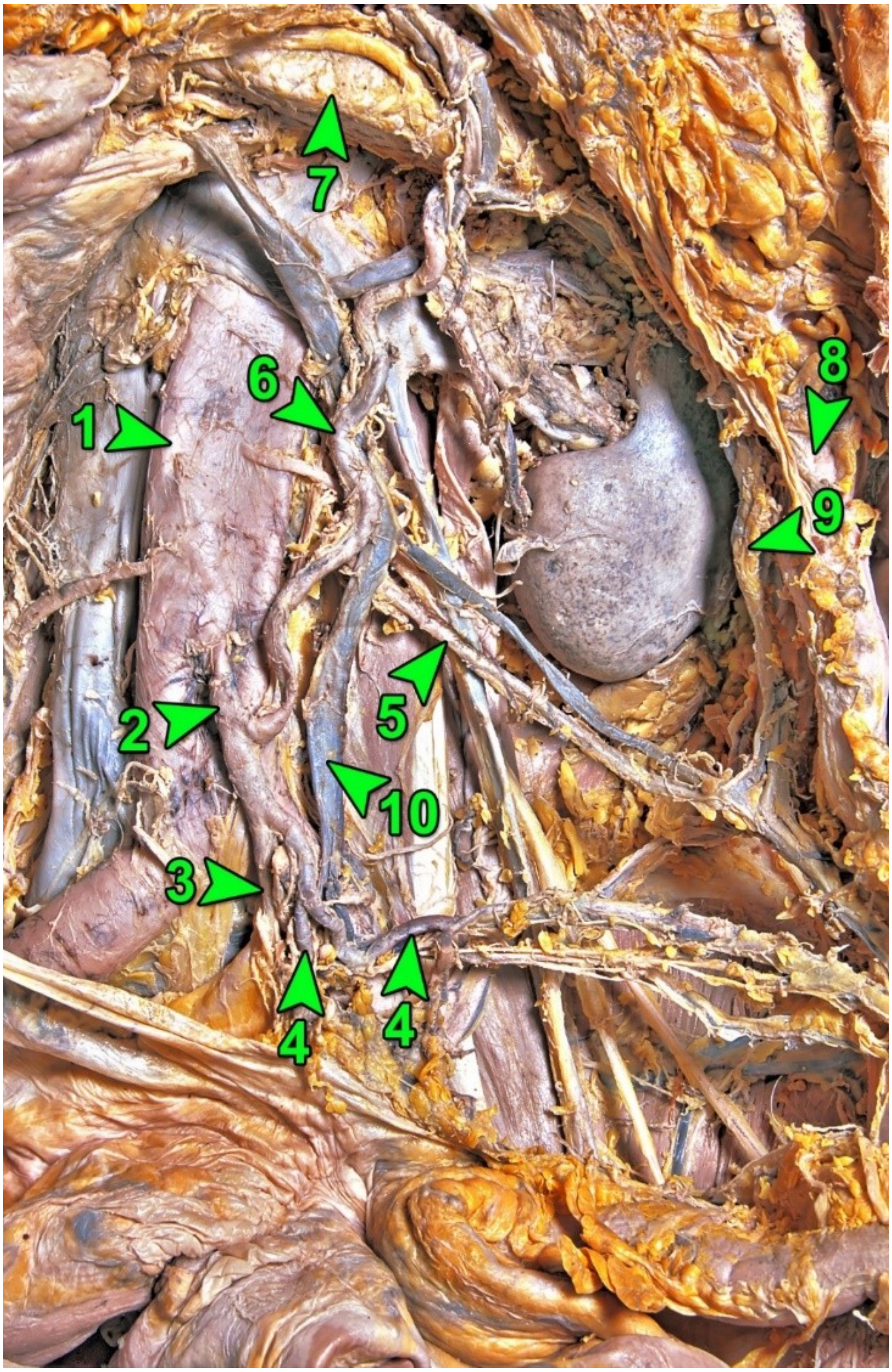

Figure 1. Specimen with dissected abdominal aorta and splenic flexure avascular space. Visible Inferior mesenteric artery branches including Arc of Riolan crossing Inferior mesenteric vein; 1 — abdominal aorta; 2 — inferior mesenteric artery; 3 — superior rectal artery 4 — sigmoid arteries; 5 — left colic artery; 6 — Arc of Riolan crossing the IMV; 7 — ventral edge of the pancreas; 8 — descending colon; 9 — Drummond's marginal artery; 10 — inferior mesenteric vein.

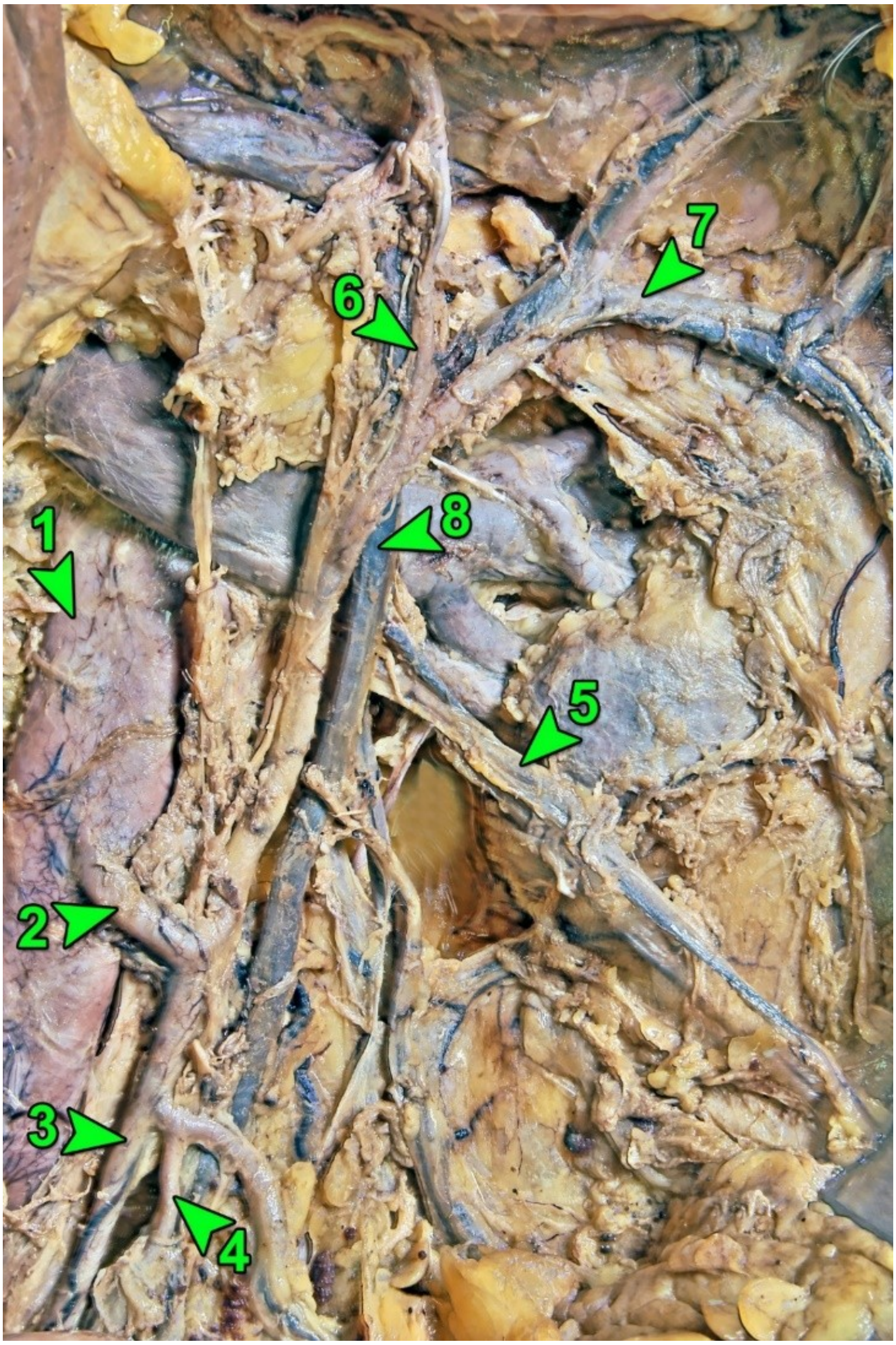

Figure 2. Specimen with dissected abdominal aorta and splenic flexure avascular space. Visible inferior mesenteric artery branches including Arc of Riolan crossing inferior mesenteric vein; 1 — abdominal aorta; 2 — inferior mesenteric artery; 3 — superior rectal artery; 4 — sigmoid arteries; 5 — descending branch of left colic artery; 6 — Arc of Riolan crossing the IMV; 7 — ascending branch of left colic artery; 8 — inferior mesenteric vein.

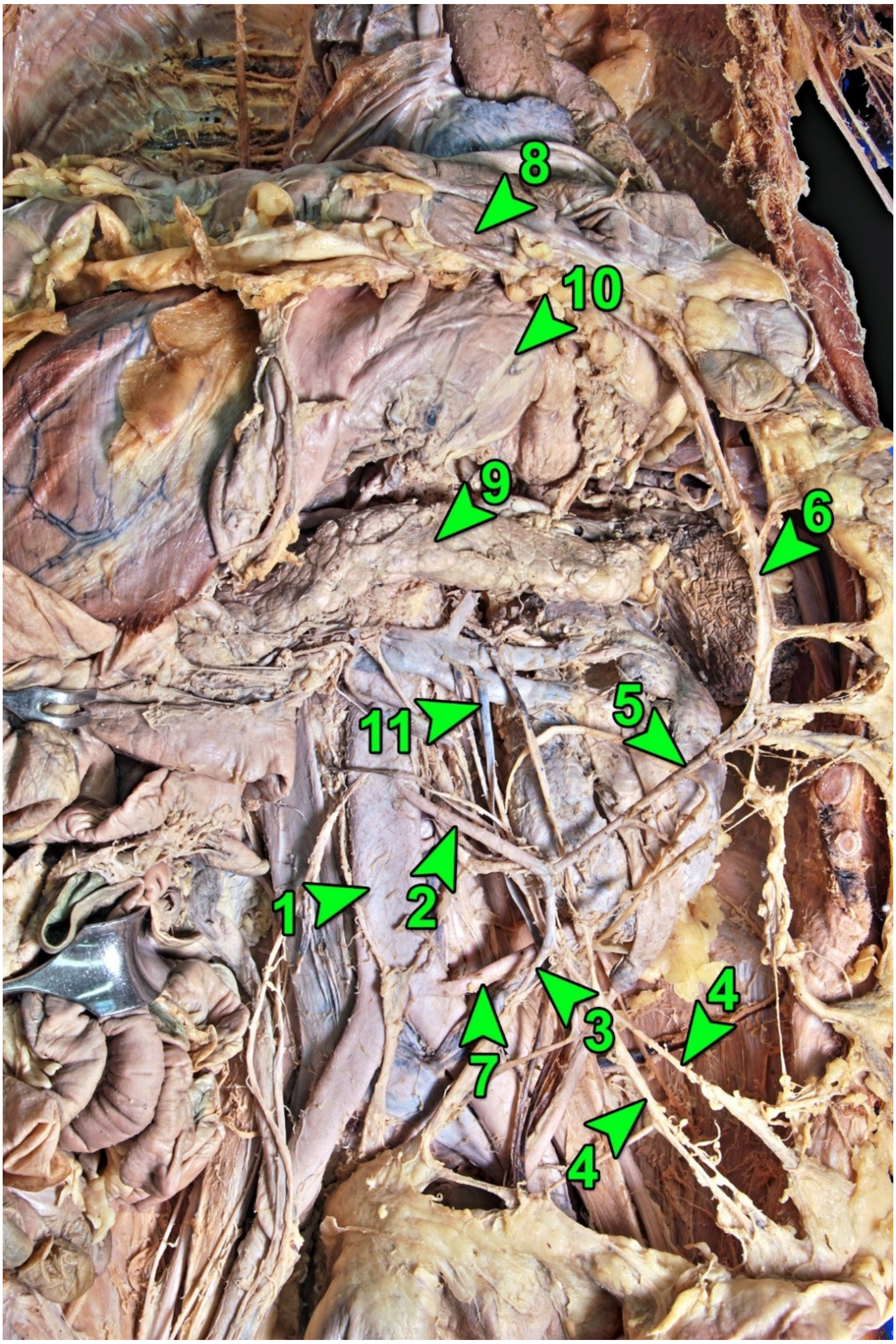

Figure 3. Classic variant of vascularization; 1 — abdominal aorta; 2 — inferior mesenteric artery; 3 — superior rectal artery; 4 — sigmoid arteries; 5 — left colic artery; 6 — Drummond's marginal artery; 7 — accessory renal artery; 8 — transverse colon; 9 — pancreas; 10 — stomach; 11 — inferior mesenteric vein.

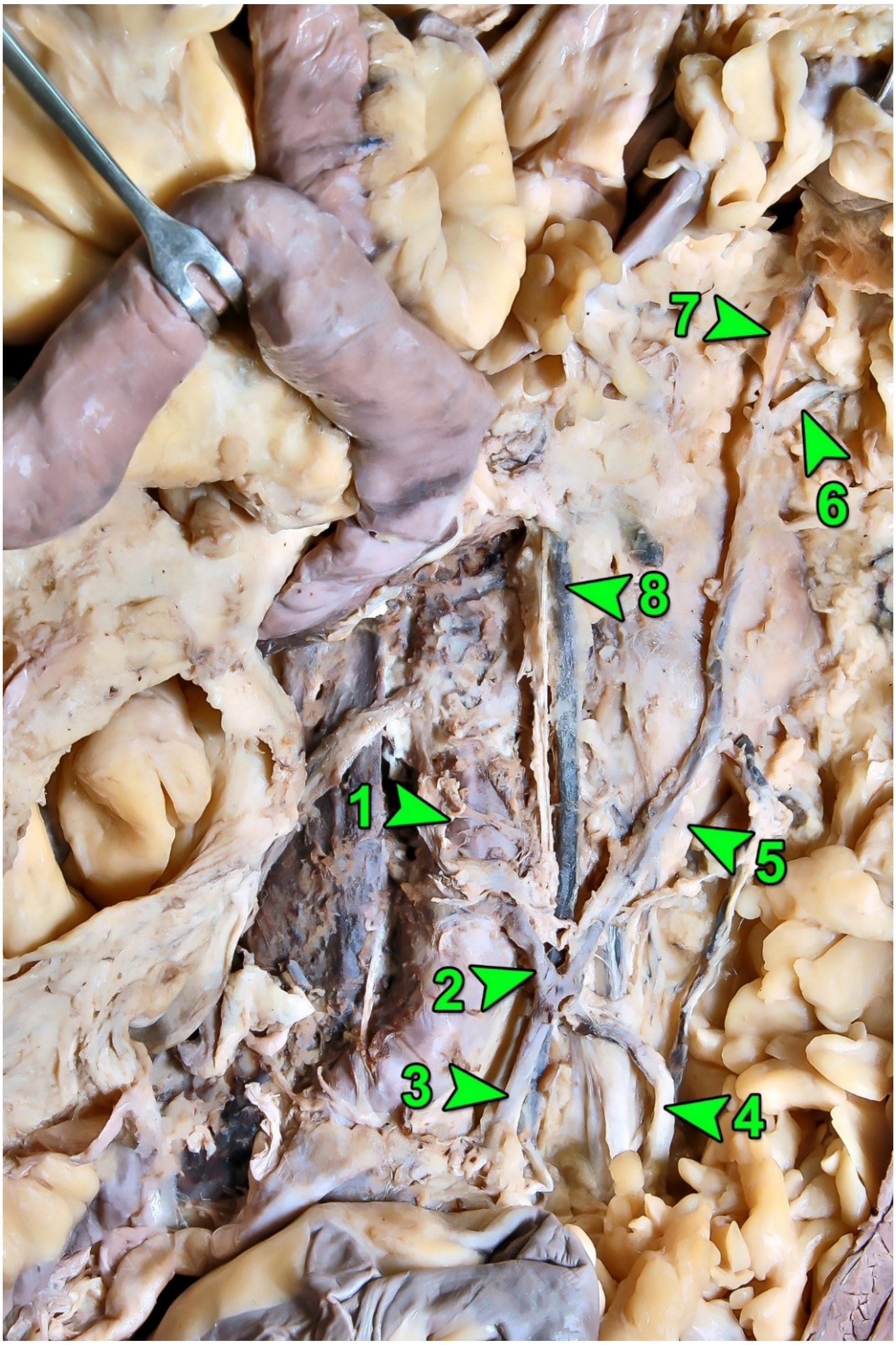

Figure 4. High division of left colic artery; 1 — abdominal aorta; 2 — inferior mesenteric artery; 3 — superior rectal artery; 4 — sigmoid arteries; 5 — left colic artery; 6 — descending branch of left colic artery; 7 — ascending branch of left colic artery; 8 — inferior mesenteric vein.

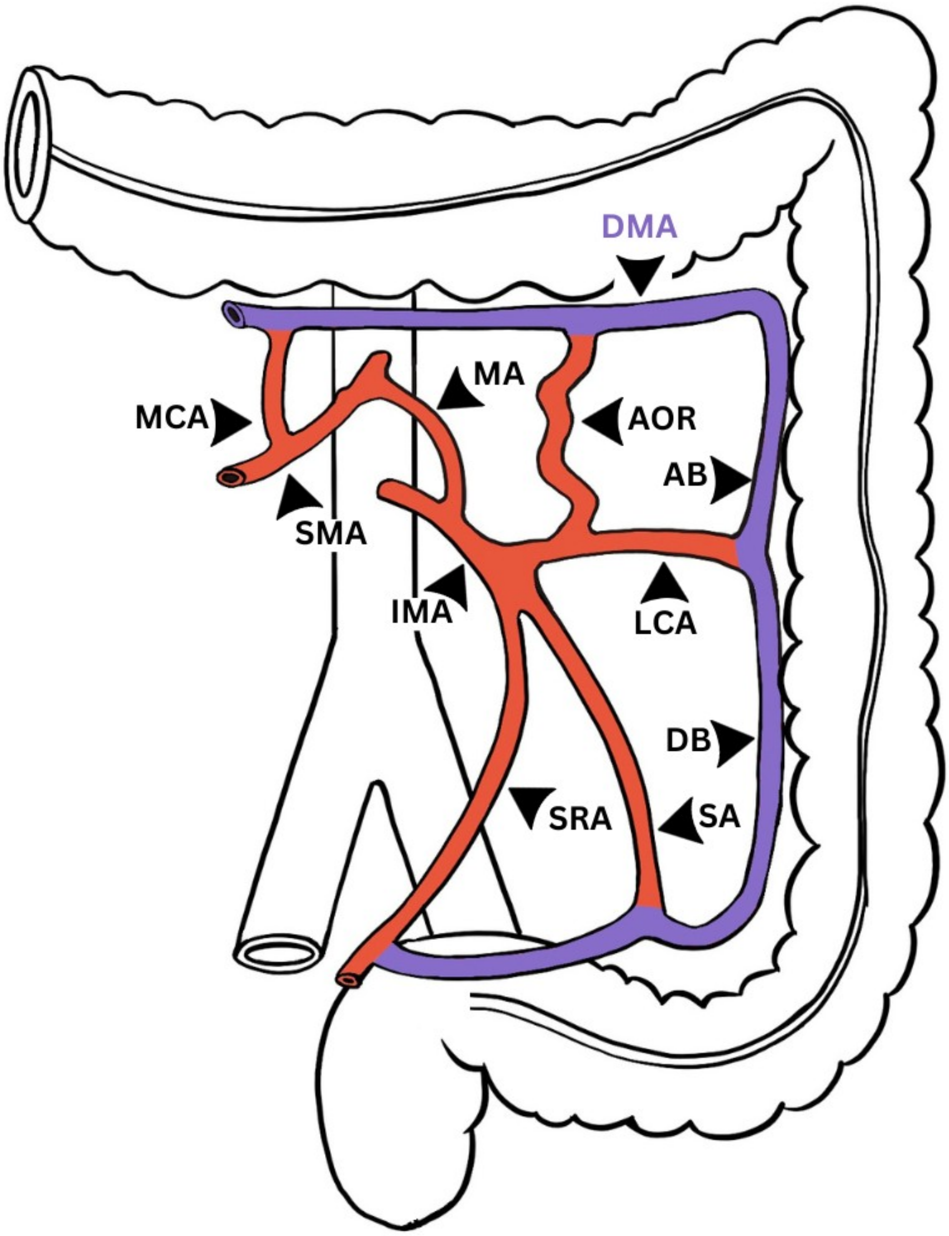

Figure 5. Variants of vascularization of the large colon; MCA — middle colic artery; SMA — superior mesenteric artery; MA — Moskowitz artery; AOR — Arc of Riolan; DMA — Drummond's marginal artery; IMA — inferior mesenteric artery; SRA — superior rectal artery; SA — sigmoid artery; LCA — left colic artery; AB — ascending branch; DB — descending branch.

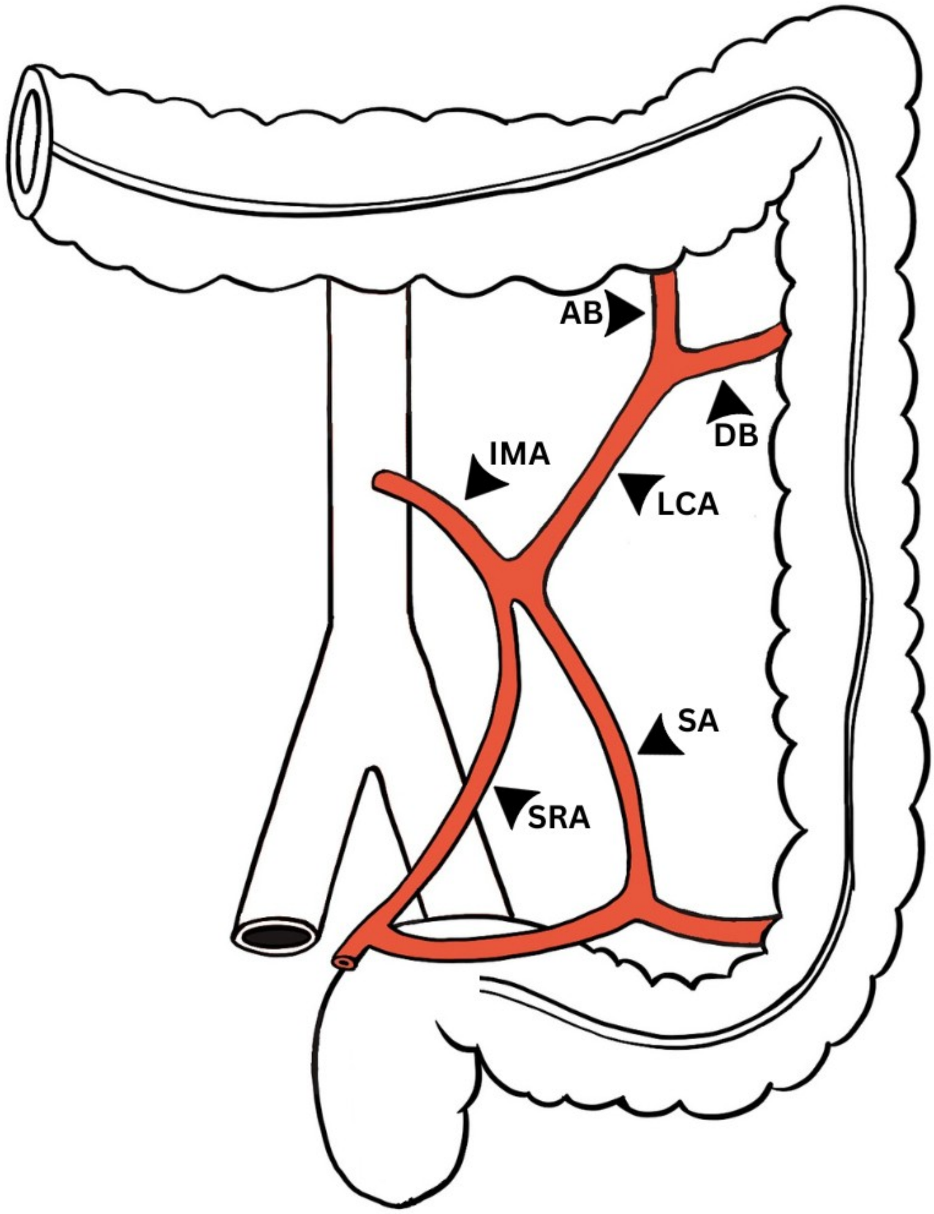

Figure 6. Variant with high division of LCA (Fig. 4) without AOR; IMA — inferior mesenteric artery; SRA — superior rectal artery; SA — sigmoid arteries; LCA — left colic artery; DB — descending branch; AB — ascending branch.

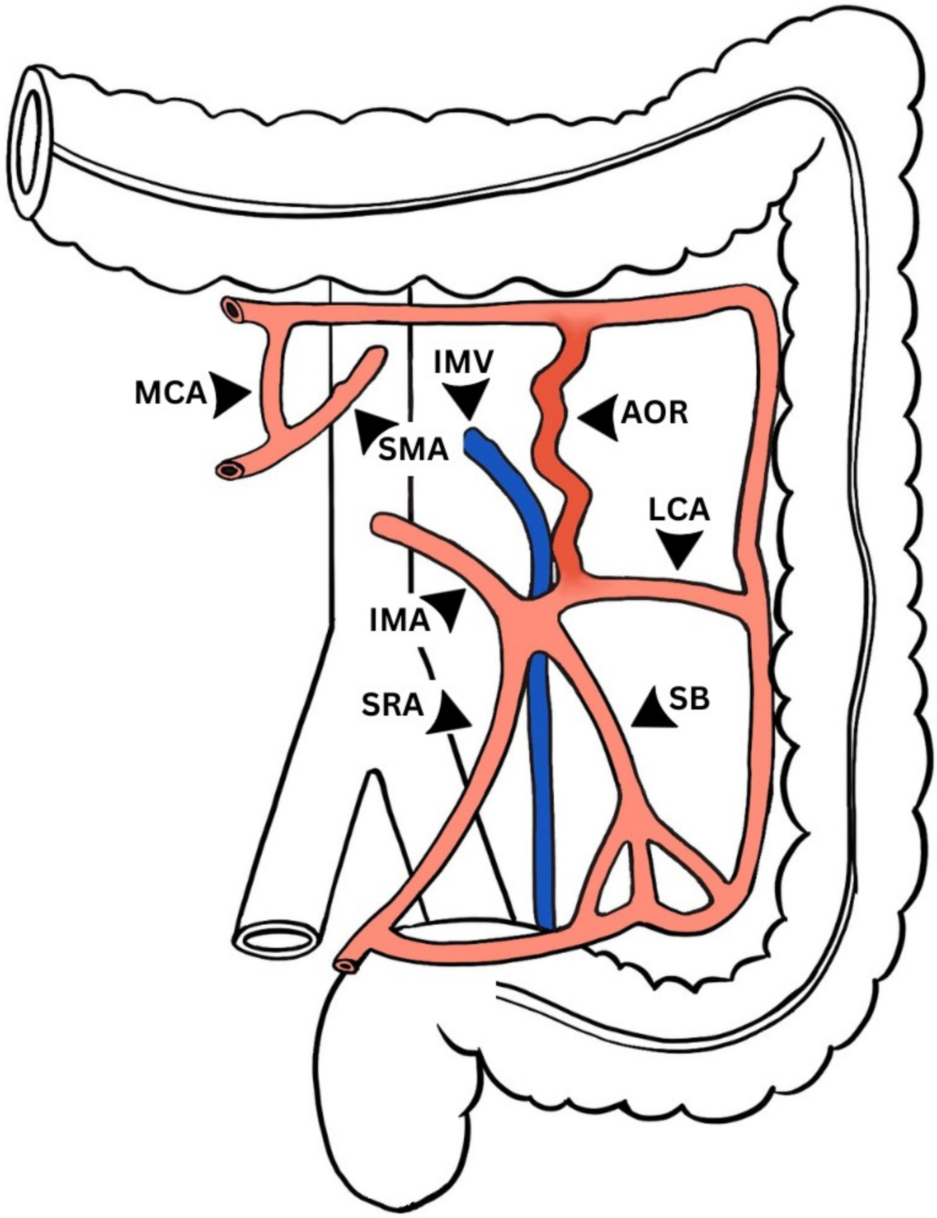

Figure 7. The anatomical relation between Arc of Riolan and Inferior mesenteric vein; MCA — middle colic artery; SMA — superior mesenteric artery; AOR — Arc of Riolan; IMV — inferior mesenteric artery; IMA — inferior mesenteric artery; SRA — superior rectal artery; SB — sigmoid branches; LCA — left colic artery.

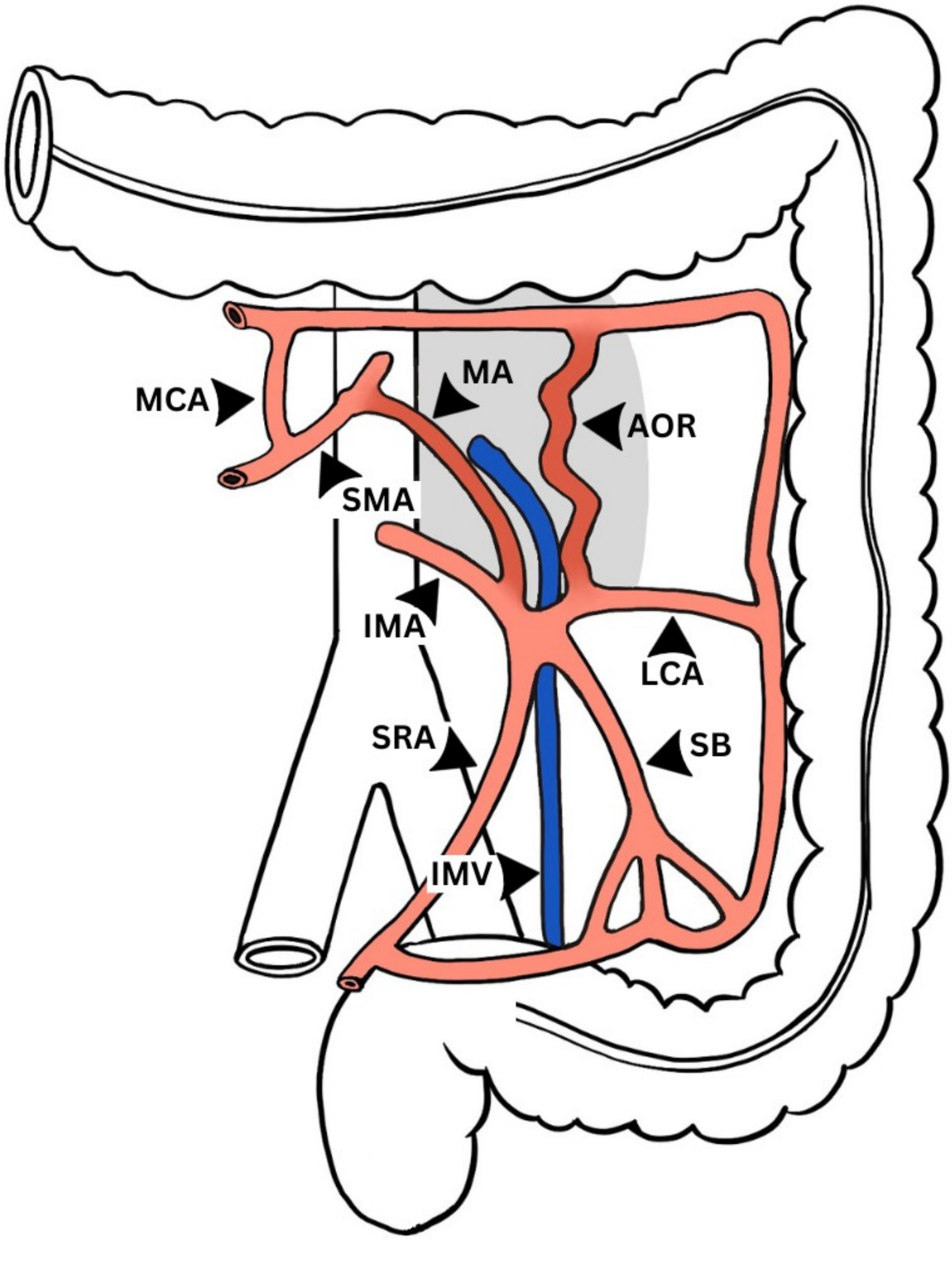

Figure 8. The anatomical relation between Arc of Riolan, Moskowitz Artery and Inferior mesenteric vein with marked splenic flexure avascular space (grey area); MCA — middle colic artery; SMA — superior mesenteric artery; AOR — Arc of Riolan; MA — Moskowitz artery; IMV — inferior mesenteric vein; IMA — inferior mesenteric artery; SRA — superior rectal artery; SB — sigmoid branches; LCA — left colic artery; SFAS — splenic flexure avascular space marked as the grey space.

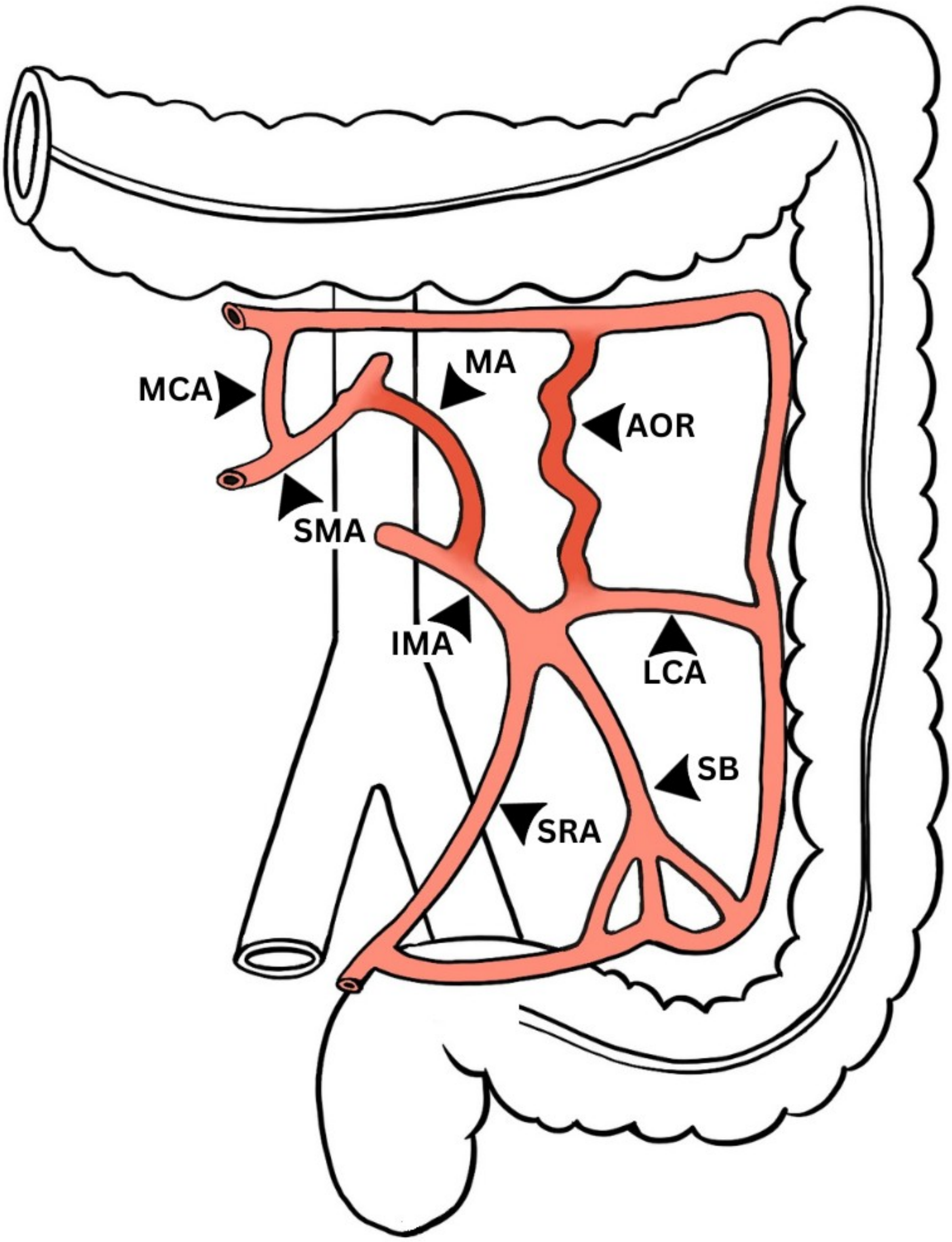

Figure 9. Scheme of possible anatomical relation between Arc of Riolan and Moskowitz artery; MCA — middle colic artery; SMA — superior mesenteric artery; AOR — Arc of Riolan; MA — Moskowitz Artery; IMA — inferior mesenteric artery; SRA — superior rectal artery; SB — sigmoid branches; LCA — left colic artery.

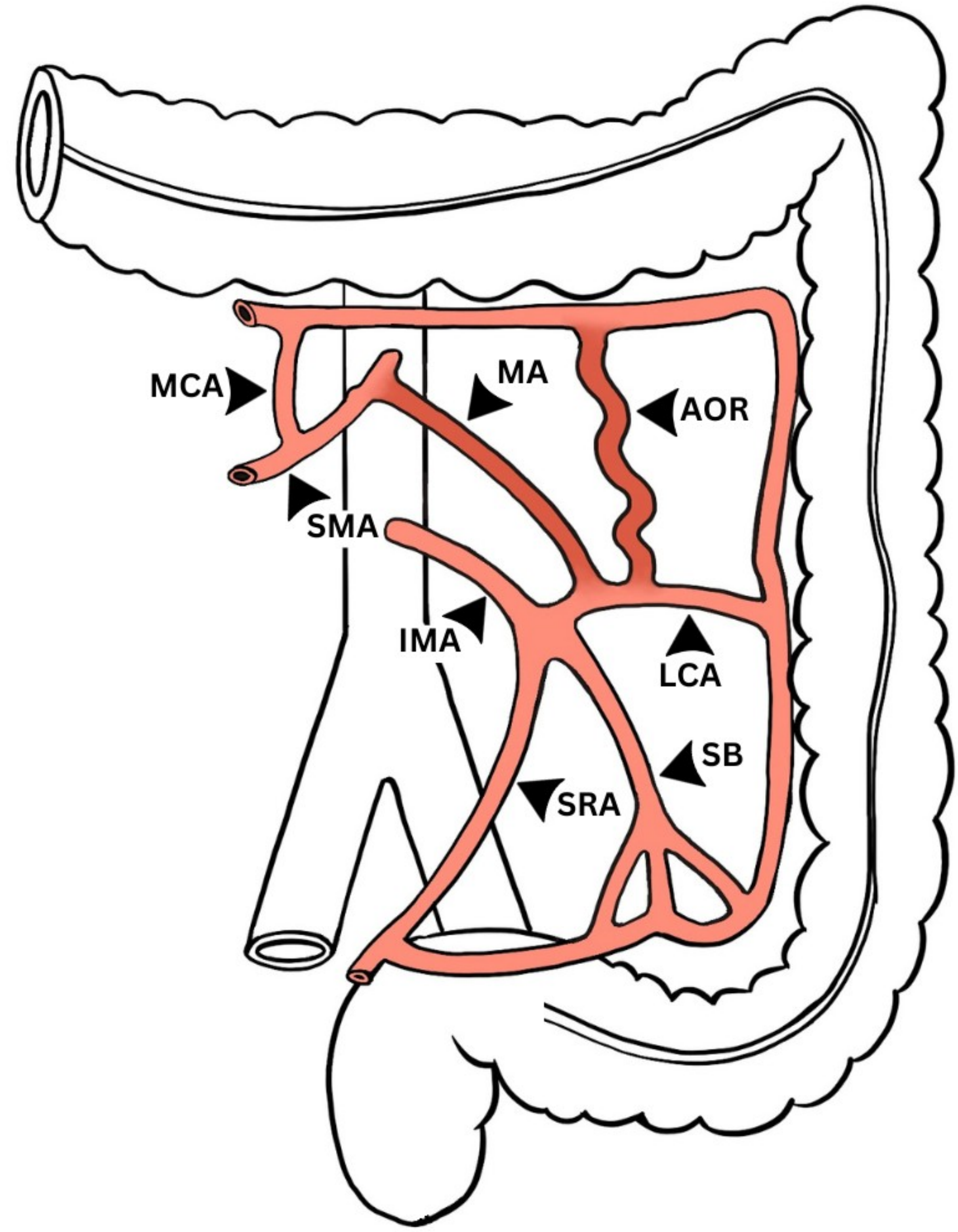

Figure 10. Scheme of possible anatomical relation between Arc of Riolan and Moskowitz artery; MCA — middle colic artery; SMA — superior mesenteric artery; AOR — Arc of Riolan; MA — Moskowitz artery; IMA — inferior mesenteric artery; SRA — superior rectal artery; SB — sigmoid branches; LCA — left colic artery.

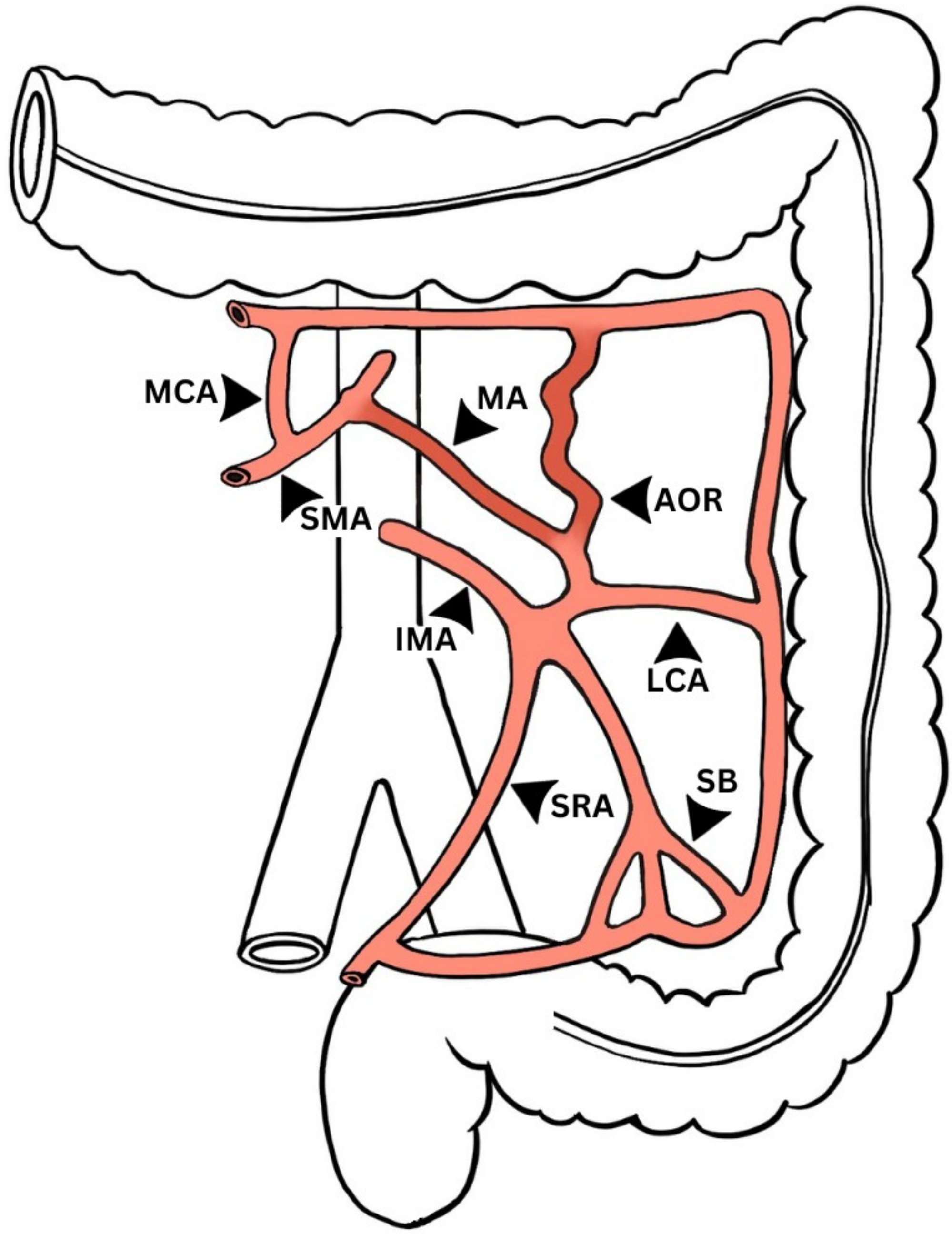

Figure 11. Scheme of possible anatomical relation between Arc of Riolan and Moskowitz artery; MCA — middle colic artery; SMA — superior mesenteric artery; AOR — Arc of Riolan; MA — Moskowitz artery; IMA — inferior mesenteric artery; SRA — superior rectal artery; SB — sigmoid branches; LCA — left colic artery.

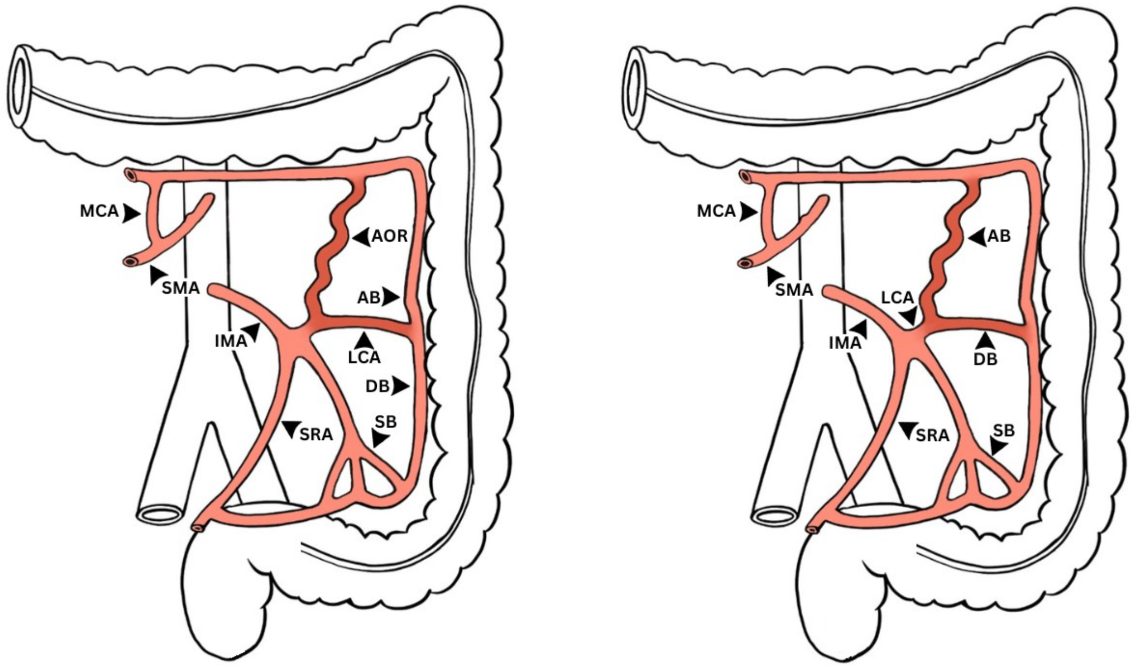

Figure 12. Two possible interpretations of the left colic artery division; MCA — middle colic artery; SMA — superior mesenteric artery; AOR — Arc of Riolan; IMA — inferior mesenteric artery; SRA — superior rectal artery; SB — sigmoid branches; LCA — left colic artery; AB — ascending branch; DB — descending branch.