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Review

Riolan's arch: confusing, misnomer, and obsolete. A literature survey of the connection(s) between the superior and inferior mesenteric arteries

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Abstract

Background: There are 2 interpretations of Riolan's arch: (1) Riolan's arch is identical to a central part of the marginal artery (MA), connecting the superior (SMA) and the inferior mesenteric (IMA) arteries; and (2) Riolan's arch represents a rare artery, connecting the SMA and the IMA. The current review aims to emphasize the clinical importance of the colon's vasculature and to show the feasibility of abolishing the terms "Riolan's arch" and "meandering mesenteric artery."
Methods: A literature survey was performed.
Results: It appears that no distinct identity can be ascribed to Riolan's arch and that the "meandering mesenteric artery" represents an angiographically hypertrophied MA and/or the ascending branch of the left colic artery. However, a rare, centrally located, communicating artery has been described. Generally, the MA is sufficient for left colic circulation after ligation of the IMA, but at the splenic flexure, patency of the ascending branch of the left colic artery can be primordial.
Conclusion: As connections between the SMA and the IMA can be adequately described using structures mentioned in *Terminologica Anatomica*, the terms "Riolan's arch" and "meandering mesenteric artery" should be abolished.

Keywords: Riolan; Arterial circulation of colon; Marginal artery of Drummond; Colon resection; Aorta surgery

Jean Riolan the Younger (1580–1657), a famous 17th century French anatomist, was a great admirer of the views of Galenus, which, at that time, had survived for 14 centuries. As a great dissector he greatly contributed to anatomical knowledge, as one could conclude from the eponyms carrying his name like Riolan's muscle, Riolan's bouquet, and Riolan's arch. The latter anatomical term has remained, despite the attempt of the Paris Anatomical Conference (1955) to refute all eponyms in anatomy, a well-known entity in radiology, aortic, and colon surgery [1].

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Interpretations and Synonyms of Riolan's Arch

In general, "Riolan's arch" refers to a connection between the superior (SMA) and inferior mesenteric (IMA) arterial systems. This connection is held responsible for collateral perfusion after, for example, ligation of the IMA during aortic and colon surgery and after atherosclerotic stenosis or occlusion of SMA or IMA [2,3]. However, there is no consensus on which anatomical structure is represented by this eponym [4]. This is confirmed by the large number of synonyms that can be found in literature (Table 1). Two different interpretations of Riolan's arch can be found in literature: (1) a synonym for the marginal artery (MA) of the colon, also known as the MA of Drummond, arcus paracolicus, or paracolic arcade; and (2) a rare distinct anatomical entity connecting the SMA with the IMA.

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Table 1
Synonyms of Riolan's arch

Central anastomotic artery of colon
Mesomesenteric artery
Middle-left colic collateral
Intermesenteric artery or arcade
Meandering mesenteric artery
Anastomosis (magna) of Riolan
Meandering artery of Riolan
Great colic artery of Riolan
Arch of Treves
Artery of Moskovitch
Artery of Gonzalez
Anastomosis maxima of Haller
Arcus magnus mesentericus

Note. Data from Ernst [3], Bertelli et al [16], Moneta [27], Davis [33], Van Gulick and Schoots [45], and Lanz and Wachsmut [47].

Several authors do not mention Riolan's arch and consider the MA to be the crucial connection between the SMA and the IMA [5–15]. Others do mention Riolan's arch but are merely considering it to represent the MA, with or without the ascending branch of the left colic artery (ALCA) (Fig. 1A) [2,16–27].

However, many authors consider Riolan's arch to be a distinct anatomical entity, additional to the MA and ALCA (Fig. 1B) [2,28–44]. This interpretation has been supported by the original radiological interpretation of the angiographic "meandering mesenteric artery," located between the middle colic artery (MCA) and the left colic artery (LCA), as a distinct anatomical entity [43] (Fig. 2).

To determine which anatomical structure Jean Riolan the Younger referred to by Riolan's arch, Riolan's texts were extensively explored by other groups, but no description of the arterial circulation of the colon was found [16,28]. Additionally, the authors of the current review were unable to find a description in Riolan's "Opera Anatomica." One chapter is devoted to the intestinal vascularization, only describing the celiac trunk (Fig. 3). Consequently, considering the fact that Riolan never specifically wrote about the colon's vasculature, it has to be assumed that the arch is named after him out of respect for this great anatomist [16,45], which was a common phenomenon at that time. Probably, Albrecht von Haller, one of Riolan's coworkers, was the first to refer to the collateral arterial anatomy of the colon and MA in 1743 [6,16,45,46].

The aim of the current report is to review the literature related to the vasculature of the colon, to emphasize its clinical importance, and to show the feasibility of abolishing the terms "Riolan's arch" and "meandering mesenteric artery."

Anatomy of Connections Between the SMA and IMA

Many dissection, angiographic, and arterial cast and corrosion studies concerning colic arterial anatomy have been published. Unfortunately, no reports could be found in which angiographic and/or cast and corrosion studies were systematically correlated to dissection of the arterial system. Another misfortune is the vast variety of specimen numbers and methods, even in the same study, which makes inter-

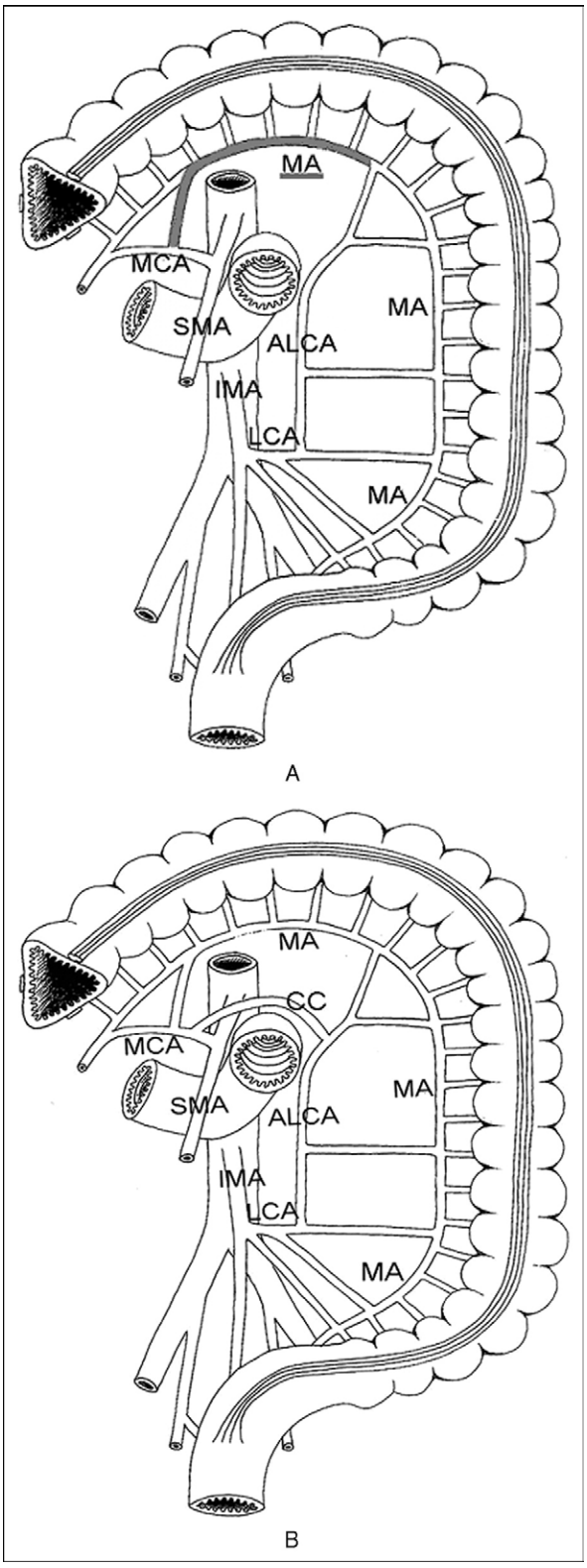

Fig. 1. (A) Schema of colic arterial circulation in which Riolan's arch is interpreted as the marginal artery of colon (of Drummond), marked arterial segment. ALCA = ascending branch of left colic artery; IMA = inferior mesenteric artery; LCA = left colic artery; MA = marginal artery; MCA = middle colic artery; SMA = superior mesenteric artery. (B) Schema of colic arterial circulation in which Riolan's arch is interpreted as a centrally communicating, additional collateral artery (CC).

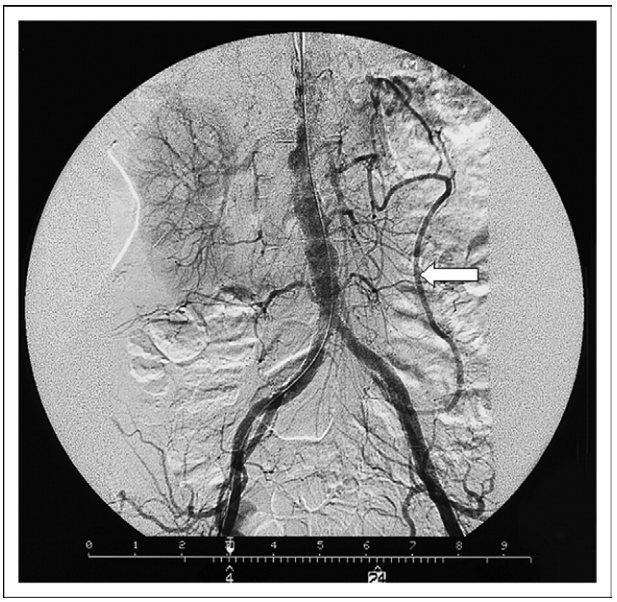

Fig. 2. The angiographic "meandering mesenteric artery," indicated by the arrow, in case of occlusion of the superior mesenteric artery.

pretation of the results extremely difficult. Therefore, all principal arterial structures between the SMA and the IMA will be discussed in subsequent order.

Middle colic artery

The MCA, representing the terminal arm of the SMA system, is absent in 2% to 22% of patients [6,16,28,29,46,47], in which case the transverse colon will be supplied by the right colic artery (RCA) and a pronounced "marginal Riolan anastomosis," according to Lanz and Wachsmuth [47]. The latter term is defined as the part of the MA, between the left branch of the MCA and the ALCA [47]. When the LCA is absent, the MCA can extend to the splenic flexure (7%) [23,48].

Marginal artery of colon (of Drummond)

Although angiographic evidence of a direct SMA–IMA connection is lacking, according to most authors, MA is always present, connecting the MCA with the LCA [3,6,16,23,41,46,47,49,50]. The MA–ALCA connection (Cannon-Böhm point) at the transverse colon is a common phenomenon as well, representing the boundary between the 2 autonomic nerve supplies and corresponding to the embryonic primary colic flexure at the fusion level of the midgut and hindgut [38].

Ascending branch of left colic artery

ALCA, representing the left arm of SMA–IMA connection and constituting an arch from the distal transverse colon down to the sigmoid colon secondary to the MA, is reported to be present in 63% to 100% of patients [6,29,46,50]. When present, it parallels the inferior mesenteric vein and extends up to the splenic flexure. When absent, the left branch of MCA is reported to extend to the splenic flexure [23,48]. In a few cases (14%), the medial branch of the ALCA's terminal bifurcation, localized at a few inches from the splenic flexure, is lacking, leaving the splenic flexure with a single arcade, constituted by the MA [29]. When the medial branch of the ALCA's terminal bifurcation is connected to the MA at the transverse colon, the importance of the ALCA is related to the functional patency of the MA at the splenic flexure and/or the descending colon [20].

Marginal artery at splenic flexure

Although clinical involvement of the splenic flexure ('watershed area') in ischemic colitis is a familiar syndrome, its prevalence is unknown [51,52]. Some authors consider the splenic flexure a predilection area for ischemic colitis, compared to the descending or sigmoid colon [53]. However, Keighley et al showed these segments to be equally involved [54].

DE ARTERIA COELIACA.

CAPVT XVIII.

PRIVSQVAM Intestina extrahas, Arterias quæ venæ Portæ ramos comitantur, obseruabis. Tanta est venarum & arteriarum societas, vt paucissimæ venæ in toto corpore reperiantur, arteriâ coniuge destituta. Quia inter se communicant per venarum Anastomoses. Itaque venæ Portæ ramos, duæ Arteriæ à trunco Aortæ descendentis prodeuntes comitantur, nempe *arteria Cœliaca, & Mesenterica inferior*, iuxta Os sacrum enata. Supra venæ Portæ truncum arteriæ Cœliacæ truncus considet, & inde persequenda illius propagatio ac distributio in Lienem & Mesenterium. *Cœliaca* in tot ramos & furculos diuaricatur, quot vena Porta; qui nominibus iisdem insigniuntur, & in easdem partes feruntur. Non est igitur opus singulatim propagines arteriarum exprimere, sufficiet discrimen assignare vtriusque vasis; quod Arteria candidior, crassior, & inanior apparet, quàm vena. Arteria Cœliaca, vt referunt omnes *Anatomici*, supra venæ Portæ truncum in duos Ramos Mesentericum & Splenicum findi-tur: sed habet Lien suam arteriam propriam, de qua videbis *Arantium in Obseruat. Anatom.* In hypochondriacis & inflammatoriis dispositionibus, micantis arteriæ Cœliacæ palpitationem supra Vmbilicum appressa manu non licet manifestè percipere, quam habeat supra se posita Intestina, nisi magnum intus conceptum fuerit incendium, vel abdomen macilentum fuerit, ac depressum.

Fig. 3. Chapter of Riolans's "Opera Anatomica", Leiden, 1650, p. 115, the only chapter about intestinal vasculature, with its translation, which follows (Courtesy of the library of the Leiden University Medical Centre). On the Arteria Coeliaca. Chapter XVIII: Before taking out the intestines you may observe the arteries, which accompany the branches of the vena portae. There is such a close association between veins and arteries that within the whole body only very few veins may be found which lack an accompanying artery. Accordingly they communicate by means of venous anastomoses. [We call them arterio-venous anastomoses.] And so there are 2 arteries originating from the trunk of the aorta descendens, which accompany the branches of the portal vein; these are: the celiac artery and the inferior mesenteric artery, which issues forth near the os sacrum. The trunk of the celiac artery is situated above the main-stem of the portal vein and from there its further continuation and distribution directed towards the spleen and the mesenterium can be followed. The celiac artery splits up into just as many branches and bifurcations as the vena porta; they [ie, the arterial branches] are indicated by the same terms [the portal branches] and they lead into the same parts. Therefore it is not necessary to describe the offshoots of the arteries one by one; it serves the purpose to label both kinds of vessels with their characteristic features, [Which means] that an artery has a lighter colour, is thicker and seems less filled than a vein. According to all anatomists the celiac artery is just above the stem of the vena portae divided into 2 branches, ie, the ramus mesentericus and the ramus splenicus; but the spleen has also its own proper artery, about which you may consult the *Anatomical Observations of Arantius*. [Arantius was a contemporary fellow-anatomist.] In the management of abdominal inflammations it is not permitted to ascertain the palpitation of the pulsating celiac artery by applying pressure with the hand above the umbilicus. The reason is, that the [inflamed] intestines are situated above the artery. [Therefore the pressure of the hand could be very painful.] There is an exception to this rule if there is a great motivation to gain knowledge of the internal situation and also if the abdomen is emaciated and flattened.

Inoue et al related the localization of colon ischemia to differences in dominance of the SMA, IMA, or the internal iliac arteries (IIA) [55]. It was found that splenic flexure ischemia after ligation (or atherosclerotic occlusion) of the IMA occurred more often in patients with an IIA dominant collateral colic circulation. From the perspective of the IIAs, the splenic flexure is the most remote colon segment, possibly explaining this finding. This logic was confirmed by the finding that in the majority of studied patients with a dominant SMA, ischemia of the rectosigmoid was more common.

There are anatomical arguments for a clinical role of the MA at the splenic flexure. For example, Steward et al reported 100% MA patency at the splenic flexure by injecting contrast into the SMA [46]. Binns et al confirmed these findings in their cadaver angiography study [56]. Contradicting these findings, Griffiths et al reported a frequent insufficiency of the MA at the level of the splenic flexure, currently referred to as Griffiths' critical point [6], which is confirmed by several other authors [7,29,57].

An explanation for this contradiction could be the fact that Steward and Binns did not ligate the 2 branches of the ALCA's terminal bifurcation, leaving the possibility that filling of the IMA system by the ALCA and thus "bridging" of a possibly insufficient MA at the splenic flexure could have occurred.

Considering these results, it is recommended to respect both terminal branches of the ALCA while resecting the left colon and/or rectum. As such, the possibility of bridging the MA at the splenic flexure remains [6,8,58]. However, its clinical importance is unknown, since the prevalence of an insufficient MA at the splenic flexure is unknown.

Central communications between the SMA and IMA

Quénu et al frequently observed tiny intermesenteric arteries at the level of the duodenojejunal flexure, running along the cranial part of the inferior mesenteric vein [17]. However, in general, such "central" communications between the SMA and the IMA have been described only in low frequencies (0% to 18%) [6,16,23,28,29,42,46,59]. They can be compared with the artery of Bühler (ramus anastomoticus) between the celiac trunk and the SMA [29,30].

In addition to the MA and the ALCA, a central artery between the SMA and the IMA might serve as a third pathway of collateral arterial circulation of the colon [16]. Such an artery is mentioned in *Terminologica Anatomica* as "arteria ascendens" [60]. Bertelli et al, denominating this communication by "intermesenteric trunk," discerned 3 different types, with a total incidence of 18% [16]: (1) the direct type (arteria ascendens), representing an extremely rare direct communication between the SMA and the IMA; (2) the indirect type, representing a connection between the MCA and the LCA (prevalence 9%); and (3) a communication between 1 of the 2 mesenteric arteries and 1 of the main branches, usually the LCA (prevalence 9%).

Van Damme et al observed a small central intermesenteric arcade, running at the level of the duodenojejunal angle, in 12% of cadavers [23]. In their opinion, this shunt was unreliable in acute vascular occlusion. A middle (third) mesenteric artery with a direct connection to the LCA, has been described in extremely rare instances [61]. To date, an additional, protective role of these rare central connections has never been demonstrated.

Other pathways between the SMA and IMA

Arterial connections between the retroperitoneal and intestinal vascularisation have been recognized for a long time [23]. Pereira et al have shown that several, although anatomically not defined, arterial channels must add to the collateral circulation of the left colon [4]. Michels et al have described minute parieto-visceral connections at the level of the left renal capsula, which might hypertrophy in atherosclerotic occlusive disease [26,29].

Summary of Connection(s) Between the SMA and IMA

Considering the previously reviewed studies, it can be stated that, to date, there is no evidence for the presence of any regular arterial entity, other than the MCA, MA, and ALCA and their anastomosis at the distal transverse colon. This was already supported in Orr's classical *Operations* (1944) by the introduction of the concept of "Riolan's space," in which no vessels can be encountered [62]. Subsequently, the ALCA can be regarded as the only common secondary arch, bridging the MA at the splenic flexure [6,20,26,29,41,46]. The importance of the ALCA is illustrated by the nomenclature of "arteria intermesenterica," as represented in Sobotta's *Atlas of Anatomy* [13].

Clinical importance of connection(s) between the SMA and IMA

The clinical importance of a functional arterial communication between the SMA and the IMA has been recognized for many decades. However, the results from clinical, mostly intraoperative, experiments on collateral colic circulation are not unequivocal. As with the anatomical studies, methodological variety allows only general conclusions.

In chronic atherosclerotic occlusive disease, intestinal ischemia generally only becomes manifest if all 3 main axes (celiac trunk, SMA, and IMA) show occlusive signs on angiography [3]. However, complete absence of intestinal necrosis in case of occlusion of all 3 main axes also has been described [19]. In atherosclerotic obstructive disease, for example, occlusion of the SMA or infrarenal aorta (Leriche's syndrome), the angiographic finding of a hypertrophic "meandering mesenteric artery" (Fig. 2), as introduced by Moskowitz et al in 1964, is a well-known phenomenon [2,33,43,44]. The meandering mesenteric artery supposedly is a thick, tortuous, uniform vessel connecting the proximal segments of the MCA and LCA, representing a central anastomosis. It can be distinguished from a normal MA, while this vessel is not tortuous, runs along the descending colon and is rarely visualized on angiography [43,44]. Besides the aforementioned features, a precise anatomical definition of the meandering mesenteric artery cannot be found. Some authors consider Riolan's arch and the meandering mesenteric artery to represent the same structure [44]. Others consider the meandering mesenteric artery to represent

the MA together with the ALCA, anastomosing at the level of the distal transverse colon [18,63,64].

Considering arterial perfusion of the greater part of the colic collateral vascular bed up to the descending colon, the SMA is more important than the IMA. Acute occlusion of the SMA will lead to intestinal necrosis, comprising the splenic flexure [55,65]. The IMA, however, can be ligated ("high-tie") in left colon and rectum resections without development of necrosis of the afferent colic loop [66,67]. In aortic surgery as well, it is an old adagium to ligate the IMA at its origin, respecting the LCA for collateral arterial circulation of the distal colon and rectum [68]. In the rare case of necrosis of the colon, it can be attributed to underdeveloped collaterals or intraoperative hypotension and possibly to absence of the MCA or occlusions of the IIA [4,67,69–72]. This is confirmed in a clinical study in which the IMA was clamped intraoperatively in patients undergoing colon surgery [73]. After an immediate MA-pressure drop, the authors observed collateral arteries taking over colic blood supply within 30 seconds and partial restoration of MA-pressure. The IIAs also play an important role in collateral rectosigmoidal arterial circulation, as ischemia of the colon and/or rectum is more frequent in case of occlusion of these vessels [4,74]. Pereira et al intraoperatively clamped the IMA, MCA, and MA at the transverse colon, without a significant drop of stump pressure in non-atherosclerotic subjects with sigmoid carcinoma, underlining the dominance of the IIAs [4]. It is suggested that the SMA–IMA collateral pathway does not play an important role for the left colon and rectum in non-atherosclerotic subjects. In congruence with these findings, a significant persistent decreased perfusion, up to 50%, of the afferent colic loop after rectosigmoid resection was found by laser Doppler flowmetry [75,76]. In addition, Fasth et al measured significant arterial pressure decreases in the MA at the left colon after clamping of the IMA, suggesting that postoperative systemic systolic pressures should be monitored in order to prevent anastomotic dehiscence [73]. A "high-tie" strategy (ligation of the IMA stem) in oncological rectal surgery will not result in ischemia of the proximal loop, provided the sigmoid colon is at least partially resected in view of an incomplete MA at sigmoid level, and no signs of SMA stenosis are present [58,73,77–81]. Hall et al observed that oxygenation of the descending colon was maintained or even improved after IMA ligation in distal colorectal resections, provided the sigmoid was resected [80]. Compared to the high-tie IMA ligation, Corder et al did not observe any improvement of anastomotic leak rate after selective preservation of the ALCA in low anterior resection, questioning the importance of this vessel as a collateral and underlining the role of the MA [78]. However, in both groups the terminal bifurcation of the ALCA at the splenic flexure was respected, so bridging, as mentioned before, could have occurred.

Unfortunately, necrosis of the afferent limb after colon resection has never, with certainty, been ascribed to an insufficient MA at the level of the splenic flexure. This renders the clinical value of the anatomical and angiographic findings, concerning the MA at this location, as yet unproven.

As for the functional role of the connection between the SMA and IMA systems, it can be stated that it is important with regard to viability of the afferent colic loop in oncological high-tie rectosigmoid resections. As a rule, the sigmoid colon should be at least partially resected. However, the individual capacity of the arterial collateral system of the left colon and rectum, being largely dependent on the anatomical and atherosclerotic status of the arteries involved, is unpredictable. Until modalities for pre-, intra-, and post-operative monitoring of colic perfusion in colon and aortic surgery are validated, ischemia of the left colon in colic and aortic surgery will continue to occur.

Conclusion

In literature, including surgical textbooks and atlases, there is ongoing confusion about the identity of Riolan's arch. This can be explained by 3 main factors: (1) the absence of publications by Jean Riolan himself on colic collateral arterial circulation; (2) the large interindividual variety of colon arterial anatomy; and (3) the application of many different methods of anatomical investigations on colon anatomy with often conflicting results.

Authors who appoint high prevalences (>50%) to Riolan's arch generally refer to the MA. Low prevalences (<20%) are reported by authors who, in some instances at least, refer to the rarely occurring more central connections [41,42].

From the present literature review it can be concluded that Riolan's arch is a misnomer. Because in all anatomical studies no other regular structures are reported than already mentioned in *Terminologica Anatomica*, a distinct identity cannot be ascribed to "Riolan's arch" [60]. Consequently, we propose to completely abolish the entity of Riolan's arch. In addition, the radiological denomination of "meandering mesenteric artery" also must be abandoned, as this term too does not reflect a distinct anatomical entity, but represents an angiographically hypertrophied MA and/or ALCA.

Although clinically the additional role of the ALCA to the MA with regard to the viability of the left colon in aortic and colon surgery has never been established with certainty, the connection of the MA with the ALCA at the level of the left transverse colon might be of importance in chronic atherosclerotic obstructive disease of the SMA, the IMA, and/or celiac trunk. Therefore, a hypertrophic ALCA must not be ligated during colon surgery. In addition, considering that the MA might sometimes be incomplete at the level of the splenic flexure and/or descending colon, respecting the ALCA's terminal bifurcation, bridging the MA at the splenic flexure is primordial under those circumstances. In abdominal aortic surgery, after IMA ligation, collateral arterial flow with regard to the left colon and rectum is at least as dependent on patent IIAs as on the SMA arterial system.

Mere consciousness in aortic and colon surgery of the importance of evaluating and respecting the MA, connecting the SMA and the IMA, and being bridged at the splenic flexure by the ALCA's terminal bifurcation, must replace ongoing confusion on Riolan's arch.

References

[1] Haubrich WS. Riolan of the arc of Riolan. Gastroenterology 2003; 124:607.

[2] Connolly JE, Kwaan JHM. Prophylactic revascularisation of the gut. Ann Surg 1979;190:514–22.
[3] Ernst CB. Colon ischemia following aortic reconstruction. In: Rutherford RB, ed. *Vascular Surgery*. 5th ed. Philadelphia: WB Saunders; 2000:1542–9.
[4] Pereira AH, Cutin J, Eggers E. Inferior mesenteric artery backpressure and collateral circulation to the distal colon. Cardiovasc Surg 1993;1:536–40.
[5] Drummond H. The arterial supply of the rectum and pelvic colon. Br J Surg 1913;1:677–85.
[6] Griffiths JD. Surgical anatomy of the blood supply of the distal colon. Ann R Coll Surg Eng 1956;19:241–56.
[7] Anson BJ, McVay CB. *Surgical Anatomy*. 5th ed. Philadelphia: WB Saunders; 1971.
[8] Siddharth P, Ravo B. Colorectal neurovasculature and anal sphincter. Surg Clin North Am 1988;68:1185–200.
[9] Nogueras JJ, Jagelman DG. Principles of surgical resection. Influence of surgical technique on treatment outcome. Surg Clin North Am 1993;73:103–16.
[10] Skandalakis JE, Skandalakis PN, Skandalakis LJ. *Surgical Anatomy and Technique*. New York: Springer Verlag; 1995.
[11] Olson TR. *ADAM Student Atlas of Anatomy*. 1st ed. Baltimore: Williams & Wilkins; 1996.
[12] Nyhus LM, Baker RJ, Fischer EJ. *Mastery of Surgery*. 3rd ed. Boston: Little Brown; 1997.
[13] Sobotta J. *Atlas der Anatomie des Menschen*. München, Germany: Urban & Fischer; 1999.
[14] Moore KL, Dalley AF. *Clinically Oriented Anatomy*. 4th ed. Philadelphia: Lippincott Williams & Wilkins; 1999.
[15] Morris PJ, Wood WC. *Oxford Textbook of Surgery*. 2nd ed. Oxford, UK: Oxford University Press; 2000.
[16] Bertelli L, Lorenzini L, Bertelli E. The arterial vascularisation of the large intestine. Anatomical and radiological study. Surg Radiol Anat 1996;18(suppl 1):S1–59.
[17] Quénu L, Chabrol J, Herelemont P. Le colon, ses variations, ses artères. CR Assoc Anat 1954;41:760–9.
[18] Kountz SL, Laub DR, Connolly JE. 'Aortioiliac steal' syndrome. Arch Surg 1966;92:490–7.
[19] Reinhart K. Verschluβ der drei unpaaren, viszeralen Aortenäste mit Ausbildung eines erweiteren Riolanischen Kollateralkreislaufes. ROFO Fortsch Rontgenstr Nuklearmed 1978;129:699–703.
[20] Welch JP, Welch CE. Operative management of cancer of the colon. In: Maingot R, ed. *Abdominal Operations.* 7th ed. New York: Appleton-Century-Crofts; 1980:2103–50.
[21] Goligher J. *Surgery of the Anus, Rectum and Colon*. 5th ed. London: Bailliere Tindall; 1984.
[22] Platzer W, ed. *Pernkopf Anatomy*. 3rd ed. Baltimore: Urban & Schwarzenberg; 1989:232.
[23] VanDamme JP. Behavioural anatomy of the abdominal arteries. Surg Clin North Am 1993;73:699–725.
[24] Keighley MRB, Williams NS. *Surgery of the Anus, Rectum and Colon*. 2nd ed. London: Saunders; 1997:2293.
[25] Hussmann J, Russell R. *Memorix Surgery*. Newe York: Chapman & Hall; 1997.
[26] Rohen JW, Yokochi C, Lütjen-Drecoll E. *Color Atlas of Anatomy*. 4th ed. Baltimore: Williams & Wilkins; 1998.
[27] Moneta GL. Diagnosis of intestinal ischemia. In: Rutherford RB, ed. *Vascular Surgery*. 5th ed. Philadelphia: WB Saunders; 2000:1501–11.
[28] Garcia-Ruiz A, Milsom JW, Ludwig KA, et al. Right colic arterial anatomy. Dis Colon Rectum 1996;39:906–11.
[29] Michels NA, Siddharth P, Kornblith PL, et al. The variant blood supply to the small and large intestines: its import in regional resections. J Int Coll Surg 1963;39:127–70.
[30] Netter FH. Lower digestive tract. In: Oppenheimer E, ed. *The Ciba Collection of Medical Illustrations, Digestive System Part II*. Summit, NJ: Ciba; 1973:67–70.
[31] Berk JE. Imaging (instruments, technique, normal displays)-angiography. In: Haubrich WS, Schaffner F, Berk JE, eds. *Bockus Gastroenterology*. 4th ed. Philadelphia: WB Saunders; 1985:500–1.
[32] Fischer DF Jr, Fry WJ. Collateral mesenteric circulation. Surg Gynecol Obstet 1987;164:487–92.
[33] Davis JH. Aorta and peripheral arteries. In: van Schaik T, Manning TA, eds. *Clinical Surgery*. 1st ed. Toronto: Mosby; 1987:2147–53.
[34] Grendell JH, Ockner RK. Vascular diseases of the bowel. In: Sleisenger MH, Fortran JS, eds. *Gastrointestinal Diseases*. 4th ed. Philadelphia: WB Saunders; 1989:1903–5.
[35] MacDonald PH, Beck IT. Ischemic disease of the intestine. In: Thomson ABR, Shaffer EA, eds. *First Principles of Gastroenterology*. Canadian Association of Gastroenterology; 263–86. Available at: http://www.gastroresource.com/GITextbook/En/Default.htm. Accessed April 20, 2007.
[36] Brandt LJ, Boley SJ. Ischemic and vascular lesions of the bowel. In: Sleisenger MH, Fortran JS, eds. *Gastrointestinal Disease*. 5th ed. Philadelphia: WB Saunders; 1993:1927–9.
[37] Hansen KJ, Murray SP, Stoney RJ. Visceral ischemic disease. In: Loscalzo J, Craeger MA, Dzau VJ, eds. *Vascular Medicine. A textbook of vascular biology and diseases*. Boston: Little Brown; 1996; 871.
[38] Thiel W. *Photographic Atlas of Practical Anatomy*. 1st ed. Springer: Berlin, 1997.
[39] Glasby MA, Owen WJ, Kristmundsdottir F. *Applied Surgical Anatomy. A Guide for the Surgical Trainee*. 1st ed. Oxford, UK: Butterworth Heinemann; 1998.
[40] Sternbach Y, Perler BA. Acute mesenteric ischemia. In: Yeo C, ed. *Shackleford's Surgery of the Alimentary Tract*. Philadelphia: WB Saunders; 2001; 5:17–31.
[41] Gray H. Cardiovascular: Inferior Mesenteric Artery and Superior Mesenteric Artery. In: *Gray's Anatomy*. 38th ed. Edinburgh, UK: Churchill & Livingstone; 1999:1553–6.
[42] Cheng B, Chen K, Gao S, et al. Colon interposition. Recent Results Cancer Res 2000;155:151–60.
[43] Mosckowicz M, Zimmerman H, Felson B. The meandering mesenteric artery of the colon. Am J Roentgenol 1964;92:1088–99.
[44] Gourley EJ, Gering SA. The meandering mesenteric artery: a historic review and surgical implications. Dis Colon Rectum 2005;48: 996–1000.
[45] Van Gulik TM, Schoots I. Anastomosis of Riolan revisited; the meandering mesenteric artery. Arch Surg 2005;140:1225–9.
[46] Steward JA, Rankin FW. Blood supply of the large intestine. Its surgical considerations. Arch Surg 1933;26:843–91.
[47] Lanz T, Wachsmut W. *Praktische Anatomie, Bauch*. Berlin: Springer-Verlag; 2004:379–83.
[48] Sierocinski W. Anastomoses of the arteries supplying the descending and sigmoid colon in man. Folia Morphol Warsz 1976;35:467–79.
[49] Ventemiglia R, Khalil KG, Frazier OH, et al. The role of preoperative arteriography in colon interposition. J Thorac Cardiovasc Surg 1977; 74:98–104.
[50] Peters JH, Kronson JW, Katz M, et al. Arterial anatomic considerations in colon interposition for oesophageal replacement. Arch Surg 1995;130:858–63.
[51] Marston A. Ischemic enterocolitis. In: Maingot R, editor. *Abdominal Operations*. 7th ed. New York: Appleton-Century-Crofts; 1980: 1803–19.
[52] Yamazaki T, Shirai Y, Tada T, et al. Ischemic colitis arising in watershed areas of the colic blood supply: a report of two cases. Surg Today 1997;27:460–2.
[53] Guttormsen NL, Bubrick MP. Mortality from ischemic colitis. Dis Colon Rectum 1989;32:469–72.
[54] Keighley MRB. Colic ischemia and ischemic colitis. In: Keighley MRB, Williams NS, eds. *Surgery of the Anus, Rectum and Colon*. 2nd ed. London: Saunders; 1997:2289–312.
[55] Inoue Y, Iwai T, Endo M. Determining variations in colic circulation during aortic surgery. Cardvasc Surg 1997;5:626–33.
[56] Binns JC, Isaacson P. Age-related changes in the colic blood supply: their relevance to ischemic colitis. Gut 1978;19:384–90.
[57] Meyers MA. Griffiths' point: critical anastomosis at the splenic flexure. Significance in ischemia of the colon. Am J Roentgenol 1976; 126:77–94.
[58] Phillips RKS. *Colorectal Surgery*. 1st ed. London: Saunders; 1998: 82–3.
[59] Stearns MW Jr. Benign and malignant neoplasms of colon and rectum. Surg Clin North Am 1978;58:605–18.
[60] Federative Committee on Anatomical Terminology (FACT) and the International Federation of Associations of Anastomists (IFAA). *Terminologica Anatomica*. Stuttgart, Thieme: 1998.
[61] Lawdahl RB, Keller FS. The middle mesenteric artery. Radiology 1987;165:371–2.

[62] Orr TG. *Operations of General Surgery*. 4th ed. Philadelphia: WB Saunders; 1946.
[63] Wind GG. *Applied Laparoscopic Anatomy: Abdomen and Pelvis*. Baltimore: Williams & Wilkins; 1997.
[64] Gonzales LL, Jaffe MS. Mesenteric arterial insufficiency following abdominal aortic resection. Arch Surg 1966;93:10–20.
[65] Leung FW, Su KC, Pique JM, et al. Superior mesenteric artery is more important than inferior mesenteric artery in maintaining colic mucosal perfusion and integrity in rats. Dig Dis Sci 1992;37: 1329–35.
[66] Wojczys R, Bednarz W. Effect of inferior mesenteric artery ligation on the healing of colic anastomosis in the rat. Eur J Surg 1997;163:215–7.
[67] Karmody AM, Jordan FR, Zaman SN. Left colon gangrene after acute inferior mesenteric artery conclusion. Arch Surg 1976;111:972–5.
[68] Siddharth P, Smith NL. An anatomic basis to prevent ischemia of the colon during operations upon the aorta. Surg Gynecol Obstet 1981; 153:71–3.
[69] Young JR, Humphries AW, Dewolfe VG, et al. Complications of abdominal surgery. Arch Surg 1963;86:51–9.
[70] Bast TJ, van der Biezen JJ, Scherpenisse J, et al. Ischaemic disease of the colon and rectum after surgery for abdominal aortic aneurysm: a prospective study of the incidence and risk factors. Eur J Vasc Surg 1990;4:656–7.
[71] Meissner MH, Johansson KH. Colon infarction after ruptured aortic aneurysm. Arch Surg 1992;127:979–85.
[72] Mitchell KM, Valentine RJ. Inferior mesenteric artery reimplantation does not guarantee colon viability in aortic surgery. J Am Coll Surg 2002;194:151–5.
[73] Fasth S, Hultén L, Hellberg R, et al. Blood pressure changes in the marginal artery of the colon following occlusion of the inferior mesenteric artery. Ann Chir Gynaecol 1978;67:161–4.
[74] Shigematsu H, Nunokawa M, Hatakeyama T, et al. Inferior mesenteric and hypogastric artery reconstruction to prevent colic ischemia following aortic aneurysmectomy. Cardiovasc Surg 1993;1:13–8.
[75] Boyle NH, Manifold D, Jordan MH, et al. Intraoperative assessment of colic perfusion using scanning laser Doppler flowmetry during colic resection. J Am Coll Surg 2000;191:504–10.
[76] Dworkin MJ, Allen-Mersh TG. Effect of inferior mesenteric artery ligation on blood flow in marginal artery-dependent sigmoid colon. J Am Coll Surg 1996;183:357–60.
[77] Schiedler MG, Cutler BS, Fiddian-Green RG. Sigmoid intramural pH for prediction of ischemic colitis during aortic surgery. A comparison with risk factors and inferior mesenteric artery stump pressures. Arch Surg 1987;122:881–6.
[78] Corder AP, Karanjia ND, Williams JD, et al. Flush aortic tie versus selective preservation of the ascending left colic artery in low anterior resection for rectal carcinoma. Br J Surg 1992;79:680–2.
[79] Karanjia ND, Corder AP, Bearn P, et al. Leakage from stapled low anastomosis after total mesorectal excision for carcinoma of the rectum. Br J Surg 1994;81:1224–6.
[80] Hall NR, Finan PJ, Stephenson BM, et al. High tie of the inferior mesenteric artery in distal colorectal resections: a safe procedure. Int J Colorectal Dis 1995;10:29–32.
[81] Hida J, Yasutomi M, Maruyama T, et al. Indication for using high ligation of the inferior mesenteric artery in rectal cancer surgery. Examination of nodal metastases by the clearing method. Dis Colon Rectum 1998;41:984–7.