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 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. © 2007 Excerpta Medica Inc. All rights reserved.

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].

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.
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-

Table 1

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<thead>
<tr>
<th>Synonyms of Riolan’s arch</th>
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<tr>
<td>Central anastomotic artery of colon</td>
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<td>Mesomesenteric artery</td>
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<tr>
<td>Middle-left colic collateral</td>
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<tr>
<td>Intermesenteric artery or arcade</td>
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<tr>
<td>Meandering mesenteric artery</td>
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<tr>
<td>Anastomosis (magna) of Riolan</td>
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<tr>
<td>Meandering artery of Riolan</td>
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<td>Great colic artery of Riolan</td>
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<td>Arch of Treves</td>
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<tr>
<td>Artery of Moskovitch</td>
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<td>Artery of Gonzalez</td>
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<td>Anastomosis maxima of Haller</td>
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<td>Arcus magnus mesentericus</td>
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Note. Data from Ernst [3], Bertelli et al [16], Moneta [27], Davis [33], Van Gulick and Schoots [45], and Lanz and Wachsmut [47].

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).
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\(^54\).

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

**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).
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 Stewart 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. 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 Terminologia Anatomica as “arteria ascendens” [60]. Bertelli et al., denoting 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 transverse colon [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 Terminologia 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


