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Chapter I

Introduction

When a surgeon operates upon the large bowel to carry out relatively wide resections which involve transection of a big arterial trunk, he often has to face anatomical vascular arrangements different from those described as normal by standard texbooks.

This happens because the number, topography, origin, course, connections and distribution of the colic arteries show such a variability that one is led to doubt that the so-called normal situation really exists. Mayo [411] asserted that "in no two individuals are the colonic vessels the same" and Sonneland [576], in his research on the vascularization of the colon concluded that "it will be established that variants of the classical patterns are the rule, not the exception".

From the extremely copious literature on this subject and from what we have observed in our cases, we can assert that no human arterial tree shows as many anomalies as those we can observe in the celiac-mesenteric distribution. For this reason we have to second the opinion of Dufour [200], that there are not real anomalies but only different kinds of vascularization.

The literature on this subject is extensive as it spans four centuries: the reported findings were often different even when identical methods were employed in the research. Consequently it is impossible to give a unified description of this arterial bed which comprises even the most frequent variations.

Many Authors have tried to classify the most common variants of vascularization with drawings, photos of anatomical material injected and dissected or infiltered and corroded, etc...

We want to give particular credit to: Sudeck [594] who can be considered the leader of the modern Authors (1907:6 photos); Rubesch [536] (1910:6 photos); Drummond [195, 196] (1914:6 photos); Pikkieff [483] (1931:10 drawings); Steward and Rankin [590] (1933:12 photos and 2 drawings); Balice [30] (1949:34 drawings); Basmajian [41, 42] (1955:30 drawings); Bickham [88] (1956:32 drawings); Imperati [319, 320] (1958:in two papers 32 photos and 8 drawings); Tommaseo [618] (1959: 15 photos and 3 drawings); Guyader [283, 284] (1964/65: 12 drawings); Martin [398, 399] (1964:12 drawings and 3 schemes); Guntz [281] (1968:36 drawings); Popovici [490] (1977: 5 photos and 50 drawings).

To illustrate the variability of the vascularization of the colon the modern surgical treatises refer to drawings published some centuries ago, from those of Haller up to those of Quain [494], despite the availability of more recent and systematic research (Adachi [5, 6] etc...).

It is notable that up to 1950 anatomists have been the biggest contributors on this subject, and the French schools have distinguished themselves particularly. Their careful dissections and direct observations were painstaking though carried out on a limited number of specimens. After number of observations, a norm was established, based on the most frequent anatomical variants. The fact that these findings did not agree with the results of formers was ascribed to the limited number of cadavers examined. Later on, anatomists were supplanted by surgeons because the latter had access to new methods for imagin, and had plentiful clinical material to study.

However, while the methodologies used by surgeons such as selective arteriography, can give anatomic detail with great accuracy, the surgeon cannot follow and control an arterial tree beyond the limits permitted by the operative field. Furthermore, radiological representation of arterial anatomy is only bidimensional even if carried out upon the most modern equipment.

From an anatomists point of view, this issue could be considered worn out if we accept the conclusion that the main vascularization of the colon takes place through tiers of arches of different shapes, which in most cases act also as intermesenteric connections.

However, from a surgical point of view, it is the conformation of the colic vascular arcades that is relevant because, depending upon their arrangement, a surgical operation planned to be curative of a certain pathology, can or cannot be safely carried out.

For this reason we have undertaken a review of the arterial anatomy of the colon by systematic radiological research, extending the work initiated by Olivero [458], not only to confirm the existence of the relatively well known variants, but above all to classify, whenever possible, those varieties that the surgeon may meet. The aim of our review was to establish the most common topographical situations and to distinguish the genuine anomalies from the anatomical curiosities.

We wish to make clear that our review does not have as its goal the recording of original contributions, unlikely in the light of the careful studies performed by those who preceded us in the last four centuries.

It seemed important to us to remind the young doctors, who are approaching abdominal surgery, of the possible vascular connections existing among the splanchnic arterial beds, often ignored or forgotten.

The young abdominal surgeons must understand that their activity cannot be carried on without a good radiologic knowledge which enables them to reach the anatomic representation of a pathologic process. The simple lecture of the report of a radiologic examen, even well drawn up by the radiologist, is rarely sufficient to give a surgeon the right landmarks of a lesion and the limits within which he can extend or restrict his action. This becomes particularly evident in the field of the abdominal angioradiology, where the collaboration between surgeon and radiologist must be very close. This collaboration is necessary for the exact identification of the branches of the two biggest splanchnic arteries, their course and their anastomoses, often among superimposing images of other vessels.

We believe that our research can be helpful to surgeons and radiologists for the many variations in number, course and connections of the colic arteries illustrated in the selected radiogramms of 1500 patients.

The research shows once more the necessity for a surgeon to know the arrangement of the colic arteries of a patient before subjecting him to a large colonic resection, particularly if the restoration of the intestinal continuity is requested.

Method

The rather simple research method was based on two procedures:

a) *Angiographic study on the living being of the distribution patterns of the two mesenteric arteries and of the coeliac trunk.* Obviously, the research was performed on patients with pathology requiring an abdominal surgical operation for which this examination was necessary, both for diagnostic reasons and to learn in advance their abdominal vascular anatomy. Our observations were made on over 1500 X-ray examinations, performed at the Institute of General Surgery and the Institute of Radiology of the University of Siena and Perugia and from the Catholic University "Sacro Cuore" of Rome.

b) *Injections of anatomic specimens taken from operated patients.* The specimens were injected in the operating room after their resection and then radiographed.

Generally, the time between the resection and the injection was no longer than 5-10 minutes, and between the injection and the radiography no longer than half an hour. Two hundred fifty bowels were examined with this procedure.

The resected anatomical material comprised all the large intestine, but the left colon and the rectum were examined more frequently.

On the other hand the angiographic studies involved the right colon for the most part. It was very often possible to compare the pre-operative angiography with the injected material.

We want to remind the reader that every reference to the results obtained by other Authors who worked on cadavers is merely comparative, because the conditions observed in the cadaver and in the living being cannot be considered identical.

Literature

According to Galeno [244, 245, 246], the word "mesenteric" goes back to Erasistratos [211] (Aselli:[20]), who called "meseraic" (extreme) these arteries which are the last arteries stemming from the aorta. The appellation of "mesenteric arteries" was introduced during the second half of 1500. The past illustrators from Zerbi [672, 673] to Berengario da Carpi [63, 64], Eichmann [204], Estienne [587], Massa [405] only described more or less superficially the digestive apparatus. Figures 1 and 2 give an idea of the limited knowledge of that time. Only in 1549 Vessaei [644] mentioned the meseraic arteries accompanying the veins.

Fuchs (Fuchsii) [240] in 1555 wrote, even if generically, about arteries and veins going to the colon, and he mentioned arterial branches which from the lienal a. went to the omentum and from there to the colon.

We have only posthumous works by Eustachio B. (1520-1574) [213, 214, 215], but it seems that his plates were prepared in the same period as those of Fuchsii [240], though they were printed

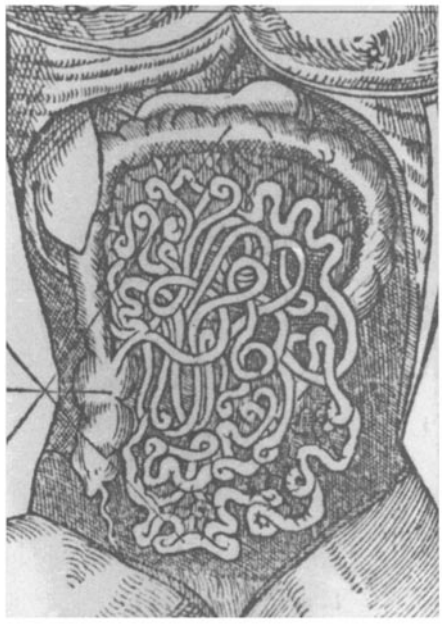

Fig. 1
From Riuerio (1545)

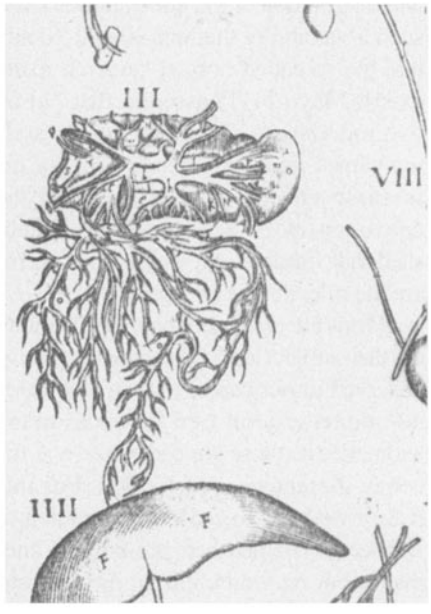

Fig. 2
From Valverdo (1556 and 1589)

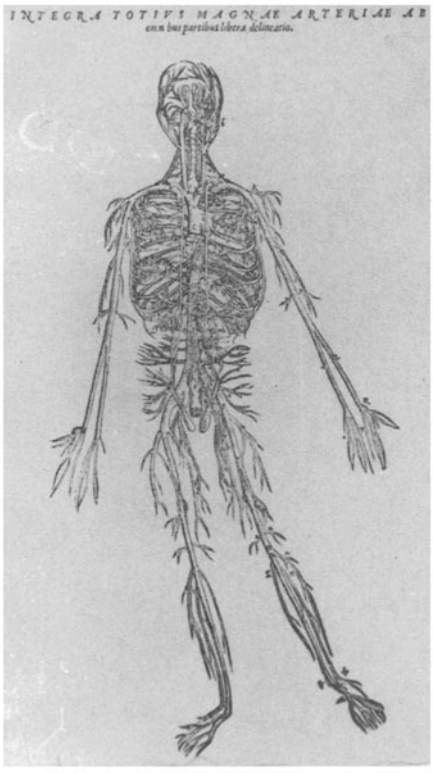

Fig. 3
From Vesalio (1568)

Vesalio (1568) [641, 642] was the first careful illustrator of the human body. He described the two mesenteric arteries, stemming separetely from the aorta, but he did not refer any link between the colic arteries (Fig. 3). Actually, the later Authors [630, 631, 40, 465, 363] have followed the descriptions and the drawings of Vesalio.

Valverdo (1559) [630, 631], following Vesalio [641, 642], added some details but without mentioning the mesenteric arteries: he generically described a "radix praecipuae arteriae intestina petenti" (root of the main artery going to the intestines).

These Authors were followed, rather than by general illustrators, by specialists like Colombo [154], Falloppio [219], Casserio [128], who added nothing new, because they devoted themselves to the special studies for which they are remembered.

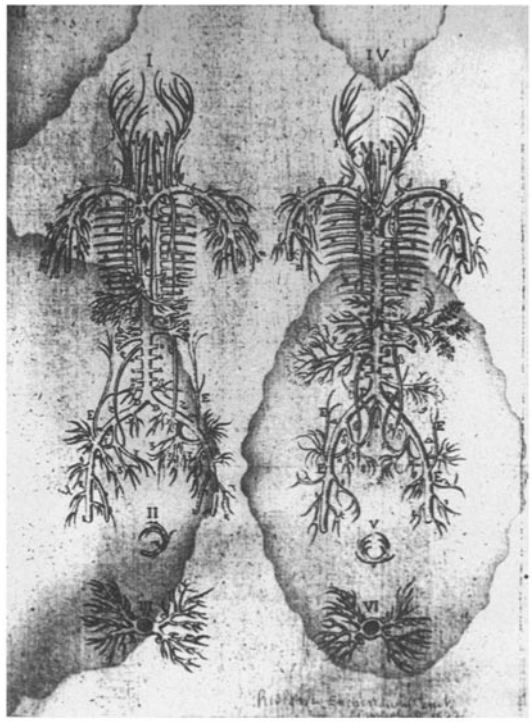

Fig. 4
From Riolan: editions from 1614 to 1677

by Lancisi [355], Albini [10, 11, 12], Caldani [124, 125], Petrioli [475] long after his death. Eustachio [213, 214, 215] has the merit to have delineated before Vesalio [641, 642] the distribution of the intestinal arteries. According to these Authors and to Haller [287, 290, 291], Eustachio [213, 214, 215] knew of the existence of the anastomosis between the middle colic a. and the left colic a. which seemed to be already known by some English Authors of that time (truncus huius colicae sinistrae denique in sinistro coli angulo amplissima anastomosi, cui aequalis in homine adulto non reperitur, cum trunco ultimo rami superioris arteriae mesocolicae unitur. Eam anastomosin Eustachius [213, 214, 215] non ignoravit, deinde angli potissimum ornaverunt: Haller [287, 290, 291])[1]. But we could not find any trace of the description of this anastomosis in the texts of Eustachio which we consulted (see Petrioli [475]).

Bauhin (1605) [47, 48] mentioned "a superior and an inferior mesenteric artery", which were directed to the intestine, right and left colon, and rectum.

Riolan (1614) [521-525] merits particular attention. We were not able to find any description of the "arcade" carrying his name. In his first papers he stated that the intestinal arteries came from the coeliac artery, while in subsequent papers he confirmed that the arteries giving off the branches which accompany the roots of the portal vein were two. The coeliac artery divided into a mesenteric (superior) branch and a splenic branch (possible in reality even if rare). On the contrary the inferior mesenteric artery arose from the aorta at the level of the sacrum. Only in 1677 he confirmed the presence of two mesenteric arteries stemming from the aorta. (Concerning the famous "arcade" we agree with Bard [35], Bertocchi [82-85], and others who believe that it was so called by the pupils of Riolan).

On the other hand, neither Winslow [666], who spoke of the famous "communication" with the inferior mesenteric artery, nor Mascagni [401-404] who spoke of a"mirabilis anastomosis", nor Kulmo [350] who briefly referred to it, nor Sabatier [542] who defined it "one of the most considerable anastomoses", mentioned the primacy of Riolan, who should have been well known at that time. It should be noticed that a drawning, reported by Riolan in the "Enchiridium anatomicum" [518] about the general blood circulation, is exactly like a drawning printed by Bartholin [40] in the same year (Fig. 4).

Aselli (1640) [20] described a superior and an inferior mesenteric branch, without any other specification.

Veslingii (1666) [643] stated that the intestinal arteries came from the two mesenteric arteries.

Bartholin (Bertelsen 1677) [40] referred to the drawings reported by Vesalio and stated that the two mesaraic arteries came from the sup. mesenteric artery (mesenterica superior... et arterias mesaraicas constituit). Furthermore he recognised their nourishing function for

[1] The trunk of this left colic artery ends in the left colic flexure, joining with the last branch of the twig of the superior mesocolic artery, in such a wide anastomosis, that a similar one does not exist in adult man. Eustachius did not ignore that anastomosis which thr English illustrated particularly

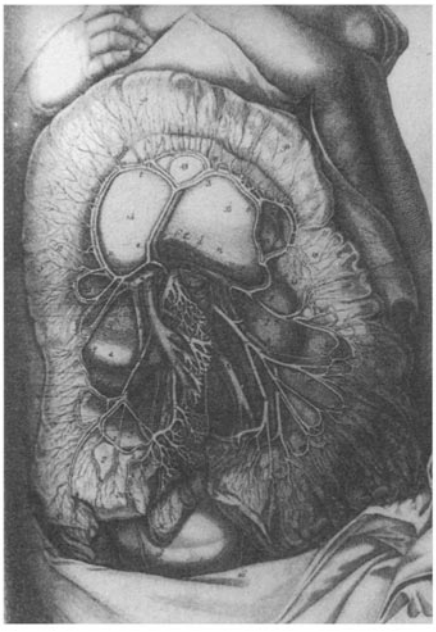

Fig. 5
From Haller: editions from 1723 to 1740

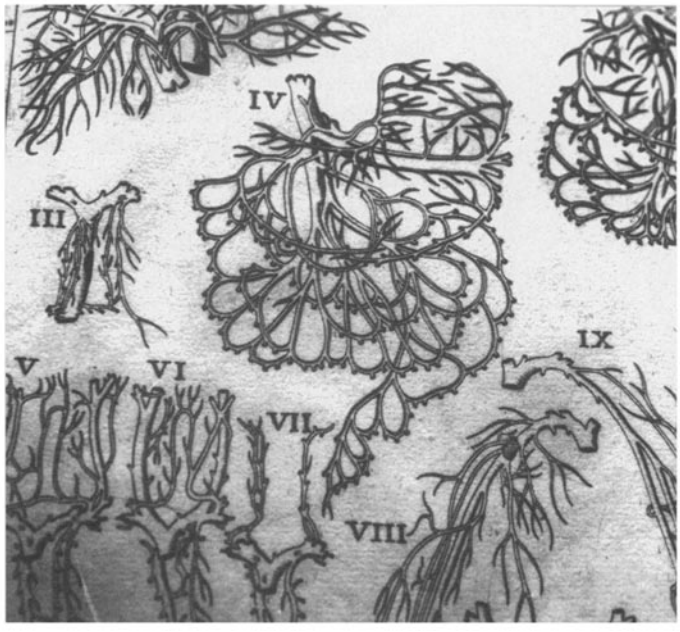

Fig. 6
From Petrioli: 1740

the intestine, perhaps already surmised by Vessaei [644].

Diemerbroeck (1679) [182] stated that the superior mesenteric artery divided into two branches: the superior (infra coeliaca enata..) goes to... while the inferior places itself... The inferior mesenteric artery was thus described as a branch of the superior mesenteric artery.

Dionis (1694) [186] simply described the presence of two mesenteric vessels: the first going to the left portion of the mesentery and then to the intestines, and the second to the inferior portion of the mesentery (inferior mesenteric artery).

Pascoli (1700) [467]: the superior mesenteric arteries(two)come from the coeliac artery, the inferior mesenteric arteries (two) come from the aorta.

Verheyen (1717) [639] was the first Author who spoke of "arcades" referring to the superior mesenteric artery.

Kulmo (1732) [350], describing the superior mesenteric artery, mentioned "that branch running along the colon connects through anastomosis to the inferior mesaraic artery" (ramus ille, qui secundum ductum intestini coli excurrit, jungitur per anastomosim cum mesaraica inferior). But strangely the statement of Kulmo is not recognized by any subsequent Authors; it is the first precise reference to the connection between the two mesenteric arteries, even if it is not reported in the drawing.

In the same year Winslow [666] gave a more detailed description of this arterial connection: the superior colic artery divides into two branches, the larger rises along the superior wall of the colon where it forms "the famous communication" with the inferior mesenteric artery (later Lauth [364] will call it "arcade of Winslow"). Such a description led us to believe that some Authors had previously mentioned it, though we could not find any bibliographic reference. Furthermore Winslow [666] described the union among the various branches of the mesenteric arteries and stated that they can be interpreted as arcade anastomoses.

Haller (1733) [287-292], through superb drawings, gave the first accurate description of the morphology and topography of the intestinal arteries. Firstly he described the mesenteric arteries of the ileum (later claimed by Dwigth [201, 202]). Then, he dealt with the colic arteries, describing their bifurcations and the arcades coming from them (less numerous than the arcades of the ileum). He stated that "only one continuous tier of intestinal arcades extends from the stomach to the anus" (Ex eius novi arcus convexitate iterum rami minores veniunt, qui et ipsi, et hinc et inde cum proximis suique similibus, in arcum speciem uniuntur. Ita unica non interrupta arcum intestinorum series a ventriculo ad anum continuatur, gastricae primo.....)[2].

The areas inscribed by the biggest vascular branches are empty. Haller described the wide arcade (of Riolan), sometimes double, between the left colic artery and the mesocolic artery (middle colic artery) (Fig. 5) and the branches of the inferior mesenteric artery going to the iliac colon (sigmoidal arteries), which anastomose each other in arcades repeating themselves two and even three times. He observed the right colic artery sometimes arising from a common trunk with the ileo-colic artery.

Petsche (1736) [479] observed the inf. mesenteric a. arising from the left primitive iliac a.(the aortic bifurcation was very high).

[2] From the convexity of that new arch, other smaller branches, which unite with each other in the form of arch, stem off. This unique uninterrupted tier of intestinal arches extends from the stomach to the anus...

Petrioli (1740) [475], annotator of Lancisi [355] who was, in his turn, annotator of B. Eustachio [213, 215], uses a figure attributed to the latter (Table XXVII) which seems to describe a main arcade with some secondary arcades (Fig. 6)[3] without clear explanations: "the mesenteric artery coming from the celiac artery divides into superior and inferior"; the latter was called by B. Eustachio [213-215] "arteria inferior mesenterii" in his work "DE RENIBUS".

Atthalin (1753) [21] wrote about numerous anastomoses between the two mesenteric arteries.

Mascagni [401-404] was a contemporary of Haller. However, since a precise date of his publications does not exist (according to Major [389] the first one goes back to 1719, the last one, posthumous, to 1827), he can only be placed in the second half of 1700. His drawings speak for themselves and the wide connection between the two mesenteric arteries (anastomosis mirabilis) shows up splendidly. As in Haller's work, a complete vascular connection between the coecum and the rectum is illustrated.

Albini (1761) [10-12] referred to three colic arteries, one originating from the sup. mesenteric a. and two from the inferior with bifurcations and anastomoses to form a long and wide arcade (the so called arcade of Riolan). It is of interest that an anastomotic trunk between the splenic and the left part of Riolan's arcade is reproduced in a drawing.

Vicq d'Azyr (1777) [645] observed the lack of an anastomosis between the inf. mesenteric a. and the middle colic a.: fine arterial vessels replaced the missing tract.

Sabatier (1775) [542] was much more precise and thorough in the description of the colic arteries, whose bifurcations and anastomoses were considered by him "the most considerable to be seen in the animal machine". Moreover, he stated that the right colic a. may stem from the ileo-colic a. or, more seldom, from the middle colic a.

Leber (1808) [368] reported findings already known: anastomosis between the ileo-colic a. and the sup. mesenteric a., and the fact that the anastomosis between the right colic and ileo-colic arteries can occur through numerous fine branches.

Caldani (1810) [124, 125] followed Sabatier and described two right and two left colic arteries anastomosed in arches.

Fleischmann (1815) [228] described the lack of the inf. mesenteric a., replaced by the sup. mesenteric a. and by a left colic a., this latter stemming from the sup. mesenteric a.

Bayle (1831) [50], followed by Cloquet (1834) [149, 150] and Boyer (1837) [101] gave descriptions quite similar to the modern ones.

Dubrueil (1847) [197] was perhaps the first Author to treat the arterial anomalies as a particular chapter of angiology. He illustrated the possible origin of the sup. mesenteric a. from the celiac a., and its duplication, even though rare; the origin of the hepatic a. or of hepatic branches from the sup. mesenteric a. and the origin of the right middle colic a. from the right inferior colic a. (referred to also by Meckel [413], while Bichat [87] believed that this artery always arises as a separate trunk).

The later Authors are referred to in the text.

[3] The same figure is from Aselli and reported also by Rio Branco