SURGICAL ANATOMY OF THE BLOOD SUPPLY OF THE DISTAL COLON

Arris and Gale Lecture delivered at the Royal College of Surgeons of England on 27th March 1956

by

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IT MAY BE recalled with advantage that the Arris Lectures from 1753 to 1766 were delivered by Percivall Pott and John Hunter, at that time Masters of Anatomy of the Company of Surgeons. It is to these two great men that we owe our heritage of surgery as a scientific craft based upon sound principals of anatomy and pathology. In this lecture their tradition is humbly followed and endeavour is made to show the importance in the surgery of the large intestine of an exact knowledge of the topographical anatomy of the colic vessels.

The recent and progressive adoption of the procedure of high ligation of the inferior mesenteric artery in colonic resection for carcinoma of the rectum and distal colon has occasioned this present re-examination of the precise vascular pattern underlying such techniques. This re-examination was thought to be necessary since authoritative descriptive accounts of the colic arteries (in particular of the inferior mesenteric artery) were found to be incomplete or even misleading, while, remarkably, statistics were lacking with regard to the frequency and topography of variations in the arterial pattern of the distal colon. In particular, information has been sought regarding the all-important subject of the nature and extent of anastomosis between the superior and inferior mesenteric arteries.

The eighteenth- and nineteenth-century anatomists paid scant attention to the precise anatomy of the vessels of the large bowel. One of the earliest diagrams showing the vascular pattern in any clarity is that by Tiedemann (1812) published in his *Plates of the Arteries of the Human Body*. Cloquet in his *Human Anatomy* (1831) depicts an identical diagram but makes no reference to Tiedemann, whose plates he would appear to have borrowed.

At the beginning of the present century the attention of a number of surgeons became focused on the blood supply of the rectum and sigmoid colon because of gangrene of the colon and rectum which occurred following the perineal pull-through operation for carcinoma of the rectum. Sudeck (1907), Manesse (1907), Rubesch (1910), in Germany, Okinczyc (1907) in France, and Archibald (1908) in Canada, and later Drummond (1914) in this country, investigated the sigmoid vessels by means of injection techniques. Their main interest lay in the effectiveness of the anastomosis between the sigmoid and the superior rectal arteries, and they demonstrated the occurrence of a critical point in the anastomosis between the last sigmoid artery and the superior rectal artery. In recent years Sunderland (1941) and Goligher (1949) have revived interest in this

region and have described certain clearly defined arterial patterns of the sigmoid arteries.

Method of investigation

In the present investigation, the arterial system of the inferior mesenteric artery and its branches was dissected in 100 subjects ; forty of these were embalmed dissecting-room cadavers, dissected before disturbance of the viscera ; sixty were necropsy subjects, injected with radio-opaque material and radiographed before dissection. The distribution of the inferior mesenteric artery was also traced on twenty aortograms performed on patients under investigation for peripheral vascular disease.

In connection with this investigation certain technical points require emphasis. (1) Injection with radio-opaque material and subsequent X-ray of the cadaver is not a satisfactory method of investigating vascular anatomy unless the radiographic findings can be duly verified by dissection, as complete filling of the vessels can never be guaranteed, and hence erroneous data may result. (2) The course of the colic vessels must be identified with the undisturbed viscera *in situ* and the correct topographical relationships of the parts subsequently removed from the cadaver for dissection must be carefully maintained.

A review of the work of Sudeck, Rubesch, Drummond and others shows a want of attention to these two criteria, hence their conclusions remain somewhat unreliable and are often indeed misleading.

The dissecting-room bodies investigated were injected with starch and red lead during their routine embalming and the filling of the inferior mesenteric was generally good. The exact topography of the large vessels was easily determined by dissection (Fig. 1) and was recorded on a standard diagram. (A minor disadvantage of this method is that the smaller vessels are sometimes difficult to dissect and the marginal artery and its branches are not always so easily demonstrable.)

X-ray technique

In the vascular examination of necropsy material an X-ray technique was developed to render obtainable a permanent record of vessel distribution. A barium and gelatine mixture was injected into the abdominal aorta, preferably with the viscera *in situ*, at a temperature of between 60 to 65 deg. C., at a pressure of about 200mm. of Hg. This was best done by cannulating the lower thoracic aorta and ligating the external iliacs to prevent the injection mass from entering the vessels of the lower limbs. Immediately following injection, cold water was run into the abdominal cavity so as to cool the injection mass, which thus solidified at room temperature.

Although the cadaver could have then been radiographed without further dissection, the resulting picture would have proved unduly confusing owing to the filling of the lumbar arteries. The abdominal viscera (including the pelvic organs and the rectum down to the anus)

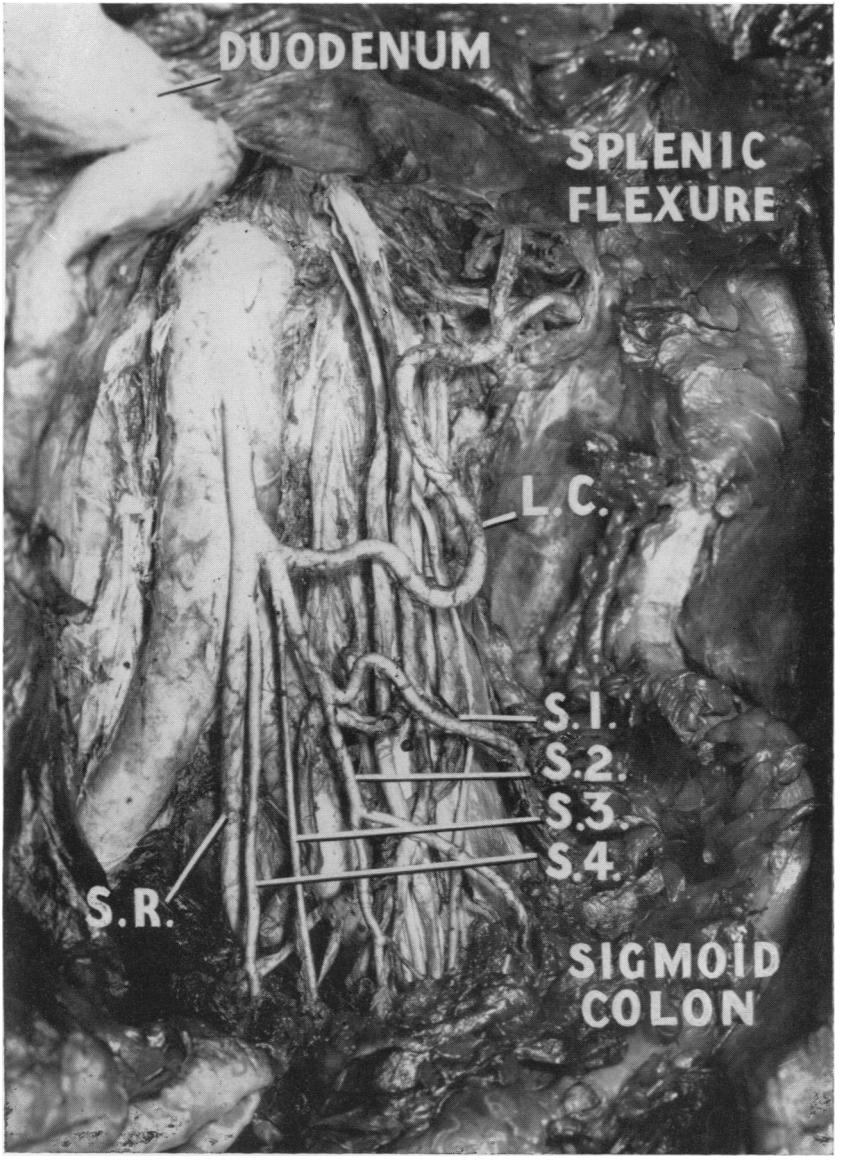

Fig. 1. Dissection showing the distribution of the inferior mesenteric artery in a dissecting room cadaver.

L.C. — Left colic artery. S. — Sigmoid arteries.
S.R. — Superior rectal artery.

were therefore removed in a single block by a retroperitoneal dissection. (This procedure maintained the colon in its correct anatomical relationships, since the peritoneum remained intact.) The small intestine was next removed and the specimen was radiographed (Fig. 2). An accurate picture of the colonic blood supply and of its relationship to the colon was thus obtained. The viscosity of the injection mass was such that it did not pass through the capillary bed, hence venous filling was obviated.

Demonstration of colic vessels on aortograms

The inferior mesenteric artery and its larger branches are often traceable on abdominal films taken during X-ray aortography performed for investigation of peripheral vascular diseases. Of seventy-one such aortograms, examined in the Professorial Surgical Unit at St. Bartholomew's Hospital, the course of these vessels was traceable in twenty only (for reasons which will appear later), but the vascular patterns displayed by these twenty aortograms confirmed the findings obtained by anatomical means (Fig. 3*a*).

In aortograms from cases of aortic block it has been possible to demonstrate the anastomosis which clearly exists between the inferior mesenteric artery and the branches of the internal iliac (i.e., between the

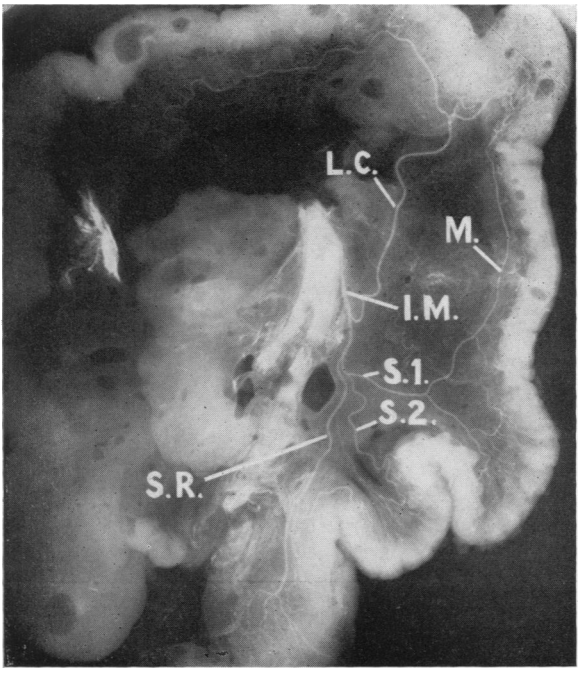

Fig. 2. Radiograph of autopsy specimen injected with radio-opaque material showing distribution of the inferior mesenteric artery.

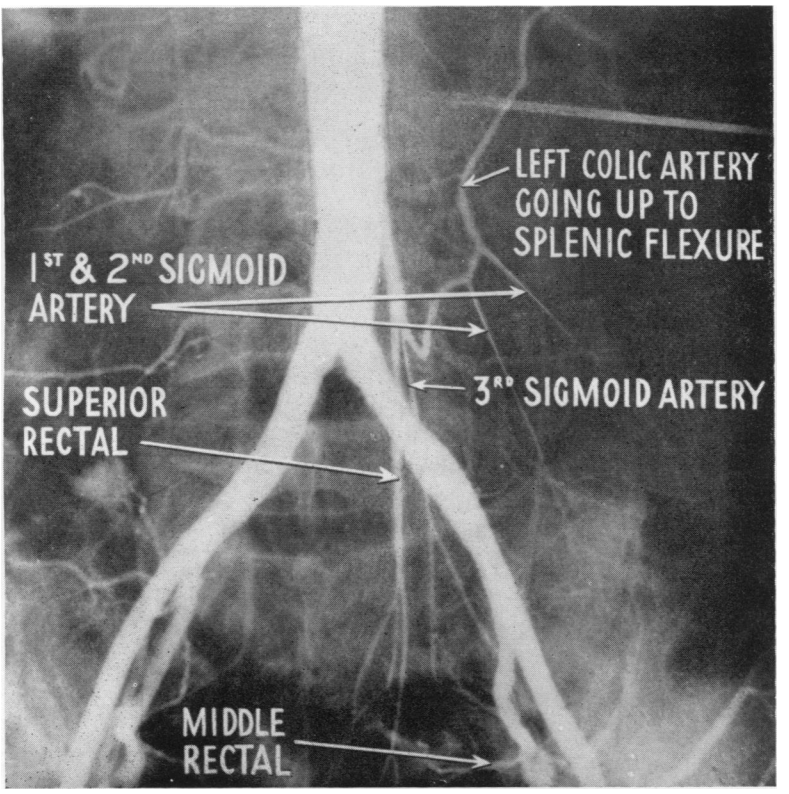

Fig. 3*a*. Aortogram showing the inferior mesenteric artery and its distribution.

terminal superior rectal artery and the middle and inferior rectal arteries). The terminal branches of the superior rectal artery can be seen to establish a very efficient anastomosis with the middle rectal artery, which, itself a branch of the internal iliac artery, affords a collateral pathway for the blood supply to the lower limbs in cases of lower aortic block. Although there has been much argument concerning the effectiveness of this anastomosis, and although some anatomists have denied its existence (Drummond, 1913 ; Sunderland, 1941), its validity has been satisfactorily established both operatively and by means of the techniques here described (Fig. 3*b*).

Summary of the anatomical pattern found and of the variations therein

The differences in the mode of division of the inferior mesenteric artery are numerous, but most are referable to a common pattern, with two main variations (Fig. 4), and four less common patterns (Fig. 5). The inferior mesenteric artery arises from the abdominal aorta about $1\frac{1}{2}$ to 2 inches above the aortic bifurcation, i.e., from 1 to $1\frac{1}{2}$ inches below the third

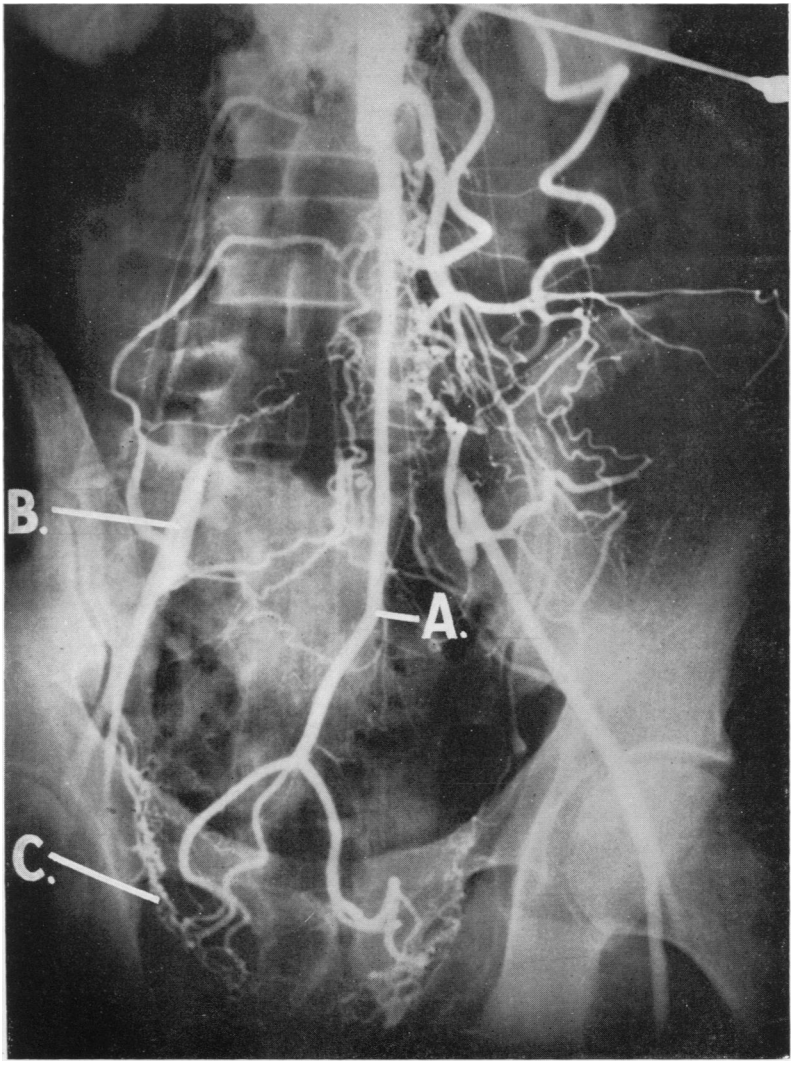

Fig. 3*b*. Aortogram in a case of aortic block showing the anastomosis between the superior rectal artery (A) and the common iliac artery (B) via the middle rectal branches (C) of the internal iliac artery.

part of the duodenum. Proceeding towards the pelvis its stem makes an angle of 30 deg. with the aorta, and gives off its first branch, the left colic, usually 1 to 1½ inches from its origin. The left colic artery ascends directly towards the splenic flexure, before reaching which it divides.

In 89 per cent. of the dissections and radiographs examined the left colic did not divide until within 2 inches of the splenic flexure. In 25 per

cent. of cases the left colic gave off a small branch (ramus transversus) which went to join the marginal artery of the descending colon.

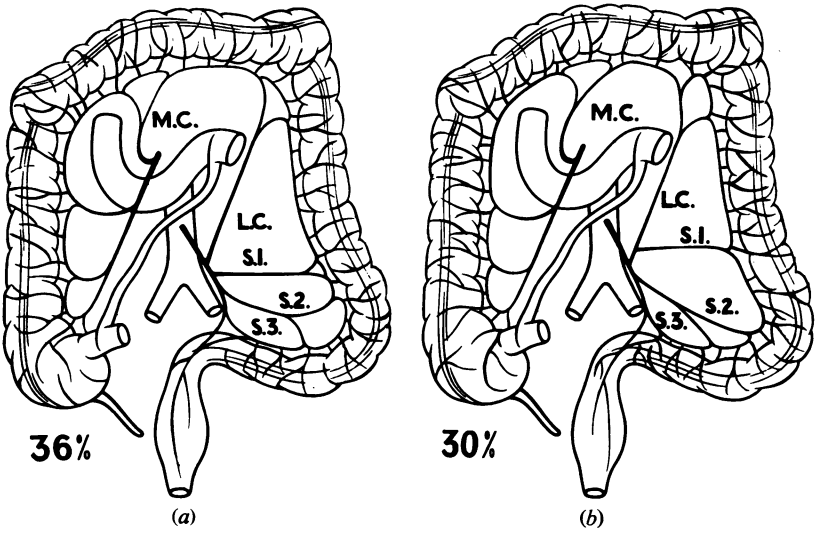

Fig. 4. Diagrams showing the two variations of the common pattern of distribution of the inferior mesenteric artery.
M.C. — Middle colic artery. L.C. — Left colic artery.
S. — Sigmoid artery.

The sigmoid arteries exhibit two principal modes of origin. In 36 per cent. of cases they arose from the inferior mesenteric (shown in Fig. 4*a*); in 30 per cent. of cases the first sigmoid artery arose from the left colic artery (as shown in Fig. 4*b*). Much confusion has arisen in the past from the varied nomenclature of these vessels. The sigmoid vessels should be (and are here) defined as those, irrespective of their precise origin, which travel for some part at least of their course in the sigmoid mesocolon. An extra-mesocolic vessel running to the descending colon must be called accessory left colic artery.

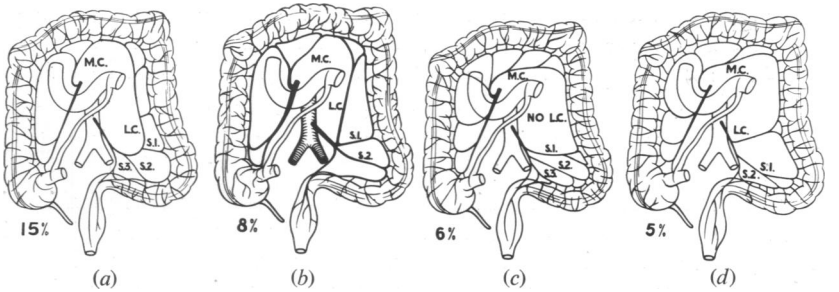

Fig. 5. Less common pattern found in 100 dissections.
M.C. — Middle colic artery. L.C. — Left colic artery.
S. — Sigmoid artery.

There are four variations to the pattern shown : Fig. 5*a* shows a loop formation of left colic with sigmoids coming off it, this occurring in 15 per cent. of cases. Fig. 5*b* shows all the branches of the inferior mesenteric arising from a common stem, this being encountered in 8 per cent. of specimens.

The left colic artery was completely absent in 6 per cent. of cases (Fig. 5*c*) but in these the 1st sigmoid artery was always a large vessel. In 5 per cent. of cases the left colic proceeds directly to the descending colon (Fig. 5*d*), the arrangement depicted as normal in most anatomical text-books. The middle colic artery in this pattern comes over into the splenic flexure.

There is great variability in the mode of division of the sigmoid arteries, but, happily, the exact topographical pattern of these vessels is of small surgical importance.

Inferior mesenteric vein

The venae comitantes of the sigmoid arteries join the main vein at the point at which the inferior mesenteric artery gives off its sigmoid branches. Passing upwards, the inferior mesenteric vein runs on the lateral side of the left colic artery for about two inches ; it then passes behind that vessel to enter the free edge of the para-duodenal fold, if present, or to skirt the lower pole of the left kidney. The left colic vein from the splenic flexure joins the inferior mesenteric vein before that vein passes under the pancreas to join the splenic vein.

The marginal artery

The vessels of the large bowel differ from those of the small intestine in not forming so many arcades and in having, alongside the mesenteric border of the colon, a marginal artery from which the vasa recti arise. The vasa recti, as shown in Steward and Rankin (1933), do not mutually anastomose. The marginal artery, first described by von Haller (1786) and later by Drummond (1913), is here defined as the artery from which the vasa recti arise. This definition prevents any confusion in nomenclature between the arcades sometimes formed by the main vessels and the marginal artery proper. This marginal artery is supplied with blood by branches of the inferior and superior mesenteric arteries, and therefore forms an important anastomosis between them, as was stressed by von Haller (1786). It was constant and well developed in all the specimens examined, in conformity with the findings of all previous investigators.

Sudeck (1907) and others described a critical point in the anastomosis between the lowest sigmoid and the superior rectal arteries, and considered the marginal artery to be absent in this region. Ligation of the last sigmoid at its origin was held to occasion necrosis of part of the sigmoid colon and to be responsible for gangrene of the rectum during conservative operation for rectal carcinoma, performed through a perineal or para-rectal and para-sacral approach.

Present injection experiments have demonstrated that the anastomosis between the superior rectal artery and the last sigmoid artery is always adequate, and that Sudeck's critical point is devoid of surgical or anatomical importance, representing, indeed, nothing more than a false conclusion based upon the inadequate injection of too insufficient a series. After ligation of all terminal branches of the inferior mesenteric as they join the marginal artery the rectal vessels have filled adequately upon injection of the superior mesenteric artery.

A truly critical point exists, however, at the splenic flexure, where the marginal artery is often small. The left colic artery as it approaches the splenic flexure usually divides about two inches from the gut. One branch (v. sinister) passes to the distal loop of the flexure; the other branch (v. dexter) goes to the transverse colon, effecting an anastomosis with the left branch of the middle colic artery. The terminal form of the left colic artery should always be preserved after ligation of the inferior mesenteric at its origin, since it forms a secondary marginal artery, otherwise the distal colon is dependent solely on the very fine marginal artery of the splenic flexure.

Reference to aortograms has already shown that the anastomosis between the middle rectal and the superior rectal arteries provides an adequate collateral circulation in cases of aortic block. Contrary to statements of many previous observers, this anastomosis is capable of supplying blood to the whole of the sigmoid colon and to most of the descending colon, as may be demonstrated both at operation and by injection experiments.

Middle colic artery

The middle colic artery, being a branch of the superior mesenteric, was found to be absent in 22 per cent. of the specimens examined. In such cases the right colic joined the marginal artery near the hepatic flexure, the left colic artery was unduly large and its terminal branches extended into the transverse mesocolon. In 10 per cent. of cases an anastomosis obtained between the left and middle colic arteries in the root of the mesocolon, the anastomotic vessel often accompanying the left colic vein from the splenic flexure. This vessel is seldom seen at operation due to its position. Normally the two vessels anastomose with one another through the marginal artery.

The surgical importance of the anatomical findings

In recent years with the advent of chemotherapy resection of the large bowel has become less hazardous and the attention of surgeons has been directed towards more radical resection for carcinoma of the colon and rectum, with a greater clearance of the lymphatic field. Jamieson and Dobson (1909) showed in their classical paper that the lymphatic drainage of the colon follows very closely the main blood supply, that of the rectum and descending colon being to the inferior mesenteric group of glands. It is therefore necessary when performing radical excision of the left

colon to ligate the inferior mesenteric artery as high as possible (if practicable on the aorta) and thus to ablate the greatest possible lymphatic field.

Archibald (1908) and Rubesch (1910) showed by injection experiments that, after ligation of the inferior mesenteric artery, filling of the colic vessels followed injection into the superior mesenteric artery. This experiment has been personally repeated in a large number of specimens and extended by ligation of the branches of the inferior mesenteric as they join the marginal artery; subsequent filling of the vessels in the colon and rectum with radio-opaque material has always proved sufficient to yield a satisfactory radiograph.

The adequacy of the blood supply to the distal colon is dependent on the marginal artery. In the absence of arterial disease the entire colon and rectum may be vascularised from branches of the superior mesenteric artery through the medium of this marginal vessel.

The following points regarding the marginal artery require careful attention:

(1) It lies often 1 to 1½ inches from the medial border of the colon,

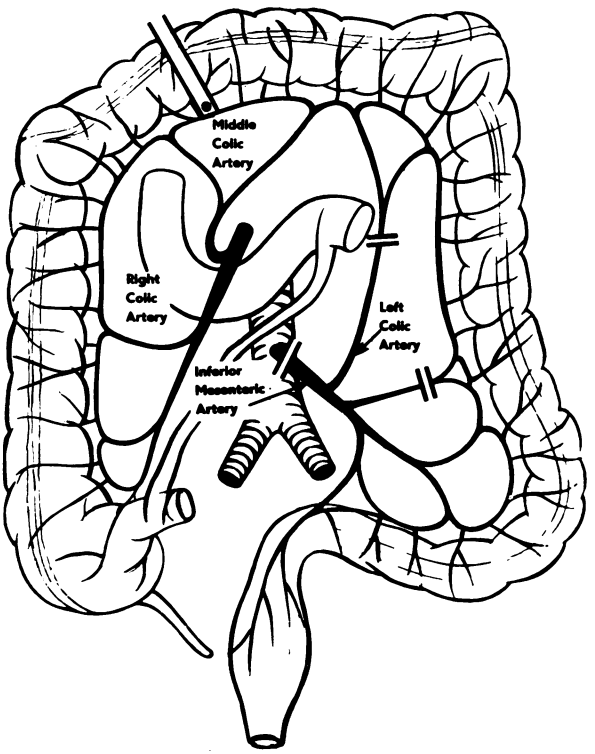

Fig. 6. Diagram showing site at which a temporary transverse colostomy should be performed; the site of ligature of the vessels during high ligation of the inferior mesenteric artery is also shown.

and in obese patients is very difficult to identify. The greatest care must be taken not to damage it during operative mobilisation of the colon.

(2) The vasa recti arising from the marginal artery must never be divided as there is very little anastomosis between these small arteries; the reported operative cases of colonic and rectal gangrene are commonly the result of the separation of the bowel from its marginal artery and of concomitant damage to the vasa recti.

(3) When a temporary transverse colostomy is necessary it should be placed well to the right of the mid-line to avoid damage to the left branch of the middle colic artery (Fig. 6). If such a colostomy is impracticable, then high ligation of the inferior mesenteric artery during resection of the colon or rectum is contra-indicated, since damage to the marginal artery at the site of colostomy may well have interfered with the anastomosis between the superior and inferior mesenteric arteries. This caution also holds when the middle colic artery is absent.

As emphasised earlier it is important to preserve the terminal bifurcation of the left colic artery so as to provide a secondary arcade at the splenic flexure. In absence of the left colic artery the marginal artery in this region is a bigger vessel than usual.

Since the middle colic is absent in 22 per cent. of cases the presence of this vessel in the right portion of the transverse mesocolon must always be verified before ligation of the inferior mesenteric artery, although in the presence of a large right colic the blood supply to the distal colon will usually be adequate.

Ligation of the inferior mesenteric artery on the aorta necessitates dissection of the artery at its origin, adequate exposure being essential as the duodenum often requires retraction upwards. The abdominal incision, therefore, must be adequate. The artery is tied on the aorta leaving enough of a pedicle to ensure a safe ligation. The left colic artery and inferior mesenteric vein are ligated as they run upwards on the posterior abdominal wall about two inches above the origin of the left colic artery. If the first sigmoid artery bifurcation is near the marginal artery, its ligation should be effected proximal to this bifurcation (Fig.6).

The most important fact to determine at operation is not the exact topography of the colic vessels but the viability or otherwise of the bowel remaining after resection. Pulsation in the marginal artery is often difficult to see or to feel, and is therefore not a good guide to the adequacy of colic vascularisation ; a better indication is the colour of the intestine. A simple procedure to verify the adequacy of the blood supply is to divide the marginal artery before applying an artery forceps, at the site of performance of the terminal colostomy or anastomosis. If the bowel blood supply appears poor then it may be necessary to mobilise the descending colon and splenic flexure to obtain a segment of colon which has a blood supply sufficient for the intended operative procedure, i.e., of anastomosis or colostomy. In 100 cases of high ligation reviewed below it was not found necessary to effect such mobilisation.

Pathological changes in the colic vessels

After high ligation of the inferior mesenteric artery pathological changes in the colic arteries, particularly in the marginal artery, may be the dominant factor in determining the adequacy of the blood supply to the distal colon. Although the topographical anatomy of these vessels has been partially and sporadically investigated, their pathological anatomy has received surprisingly little consideration.

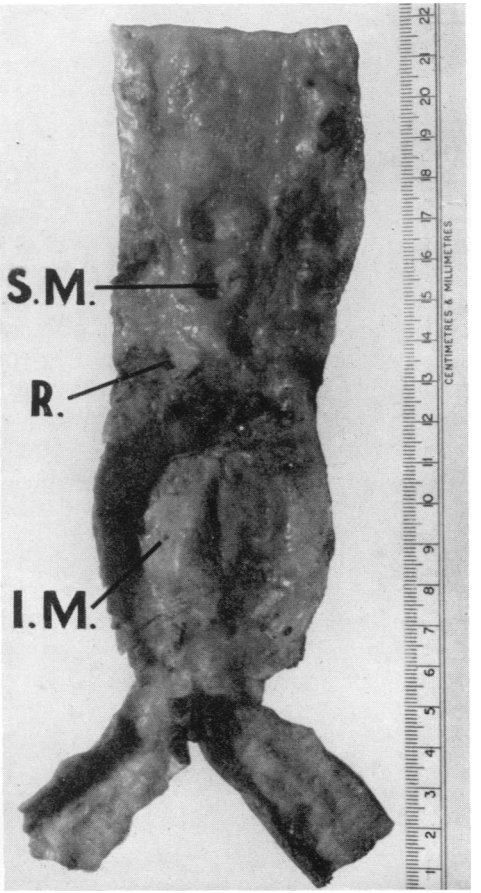

Fig. 7. Aorta at autopsy showing atheromatous changes in the wall. Stenosis of the orifice of the inferior mesenteric artery (I.M.). The orifices of the renal artery (R) and superior mesenteric artery (S.M.) are not narrowed.

In seventy-one aortograms, performed mainly on patients with peripheral vascular disease at St. Bartholomew's Hospital, the inferior mesenteric system was outlined in twenty only. This corresponds to what was found in a comparable series by Edwards and May (1955). This discrepancy prompted investigation of its cause as the radiological technique employed

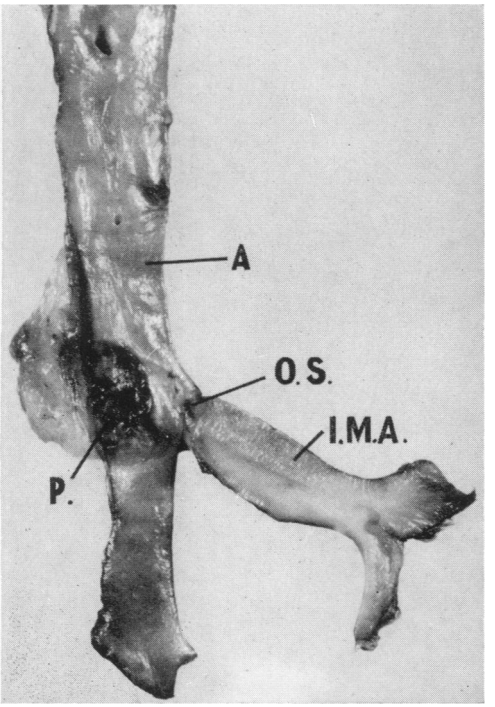

Fig. 8. Dissection of the aorta (A) to show ostial stenosis (O.S.) of the inferior mesenteric artery (I.M.A.). The artery itself is free from disease. Atheromatous plaque can be seen in the wall of the aorta (P).

remained standard. Necropsy examination of aortas in atheromatous subjects revealed a frequent and marked stenosis of the origin of the inferior mesenteric artery, amounting in some instances to its complete occlusion by an atheromatous plaque.

In twenty-five consecutive aortae examined at necropsy the orifices of the inferior and superior mesenteric arteries were measured. In normal healthy aortae that of the superior mesenteric measured 10 mm., that of the inferior 5 mm. in diameter. In diseased aortas the origin of the inferior mesenteric artery was completely occluded in two cases and reduced in the remainder to a diameter of some 2 mm. Further dissection of the inferior mesenteric arterial system in these stenosed specimens showed that the main stem and the branches of the artery were free from any gross arteriosclerotic lesion (Fig. 8).

One reason for this remarkably frequent and pronounced stenosis of the origin of the inferior mesenteric artery may lie in its obliquity of origin from the aorta, for, in contrast, the superior mesenteric artery, arising at a greater angle to the aorta and a much larger vessel, escapes comparable narrowing (Fig. 9).

The pathological changes affecting the marginal artery have been studied in specimens removed at operation and in some of the injected autopsy subjects. Most of the arteries secured operatively showed no appreciable luminal narrowing. In hypertension cases there was reduplication of the elastic lamina and in mild arteriosclerosis there was often some subintimal fibrosis, but neither condition affected the vessel lumen to any appreciable extent. In twenty-five patients, including some in their sixth and seventh decade, in which high ligation was carried out the marginal artery showed no gross change.

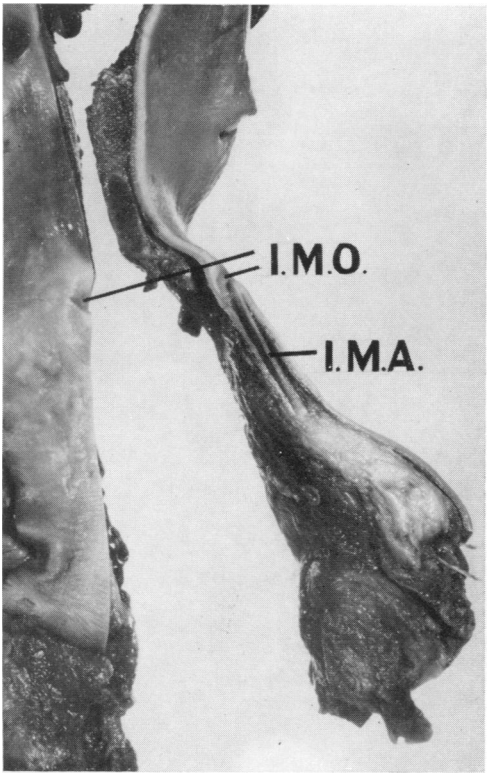

Fig. 9. Section through normal aorta showing the obliquity of the course of the inferior mesenteric artery (I.M.A.). Orifice of the artery (I.M.O.) is normal in size.

A necessary prerequisite for serious impairment of the vascularisation of the distal colon is gross arteriosclerosis of the colic arteries themselves.

Study of the pathology of the colic vessels has shown that, although ostial stenosis of the inferior mesenteric artery is an early change in atheroma of the aorta, it does not adversely affect the blood supply to the distal colon, the anastomosis between the inferior and superior

mesenteric arteries being sufficient to ensure an adequate colic circulation. Gross arteriosclerosis is the only disease of the marginal artery capable of impairing the arterial nutrition of the distal colon.

High ligation of inferior mesenteric artery

In a personal series of 100 cases performed by Mr. C. Naunton Morgan of ligation of the inferior mesenteric artery at its origin, during resection of the rectum or distal colon, the vascularisation of the anastomosis or terminal colostomy was adequate in all cases. In one case only was there any complication which might have been referable to this procedure, viz., a faecal fistula following a restorative resection: this, however, resolved in a few days, and was probably due to mechanical distension of the anastomosis in a case with some degree of intestinal obstruction and not to deficient blood supply.

HIGH LIGATION OF THE INFERIOR MESENTERIC ARTERY IN 100 CASES OF CARCINOMA OF DISTAL COLON AND RECTUM

(Average age is 55—but age ranges from 30-70 years.)

CA. COLON		CA. RECTUM AND RECTO-SIGMOID			
Duke's classification		Excision of rectum	Restorative resection	Hartmann	Percentage
A	3	15	2	—	20
B	6	15	5	1	27
C_1	7	32	7	1	47
C_2	-	3	3	—	6
Total	16	65	17	2	100

In 1,000 cases of combined excision at St. Mark's Hospital—(in which high ligation was not performed) 13.8 per cent. were C_2 cases.

Therefore in the above series the number of C_2 cases has been reduced by half.

In the restorative resections performed in this series, the blood supply of the distal colon was dependent on the inferior and middle rectal arteries and this was found to be adequate even when the anastomosis was performed at the sigmoid colon. In carcinoma of the descending colon, high ligation of the inferior mesenteric artery is imperative, as the lymphatic vessels from this bowel segment run but a short course to their receptive glands situated at the origin of the vessel or the aorta.

The procedure described increases the hazards of the operation but is ill-advised in poor-risk patients, i.e., those suffering from gross arteriosclerosis and those wherein the exact vascular anatomy cannot be readily ascertained beforehand. There is as yet no statistical proof that high ligation will improve the overall results of resections of the rectum and colon for carcinoma.

In this small series of 100 cases, the number of C_2 cases (Duke's classification) is low which may be an indication that some C_2 cases have been converted into C_1 cases (i.e. at least one free lymph node below site of ligature), with a consequent improvement in prognosis.

To conclude, I would like to quote Lord Moynihan who wrote in 1913 :

> " My own view is that however vessels are ligatured and whatever sacrifice of the mesentery may be thought necessary it is almost impossible to deprive the cut end of the colon, when resection is being done, of an adequate blood supply—the marginal artery affords an ample supply of blood to all parts. The importance of the marginal artery as far as the procedure of intestinal resection is concerned cannot be over-estimated."

I have tried to show that the conclusion drawn by this great surgeon was amply justified.

I am indebted to many at St. Bartholomew's Hospital for assistance in preparing this lecture : to Mr. C. Naunton Morgan for his suggestive help and guidance throughout; to Sir James Paterson Ross and Mr. G. W. Taylor for their constant encouragement ; to Professor A. J. E. Cave and the staff of the Anatomy Department for their untiring help ; to Professor Blacklock and his staff for facilities in the Pathology Department ; to Dr. R. A. Kemp Harper and his staff for help with the radiography and aortograms ; and to the Photographic Department for technical help. Mr. Hitchins prepared the diagrams. To the Pathology Department of St. Mark's Hospital I am indebted for cooperation in collecting the cases of high ligation. To all these I express my gratitude.

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