THE SURGICAL SIGNIFICANCE OF THE INTESTINAL VASCULAR PATTERNS

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It still repays the surgeon to review his knowledge of anatomy, and a complacent attitude towards the completeness of that knowledge should not be adopted even to-day. I need only mention the recent demonstration of arteriovenous anastomoses in the stomach wall by Professor Bentley and others (Barclay and Bentley, 1949; Walder, 1950) and the discoveries of Goormaghtigh and Trueta in the kidney, to emphasise that there are plenty of grains still to be picked up in that anatomical harvest-field which Dr Barclay considered so thoroughly gleaned over a hundred years ago.

The attempts made at the present time to restore the continuity of the bowel by end to end suture and preservation of the sphincter mechanism in cases of carcinoma of the rectum (Hamilton, 1946; Muir, 1948; Aylett, 1949; Mailer, 1949) focuses fresh attention on the blood supply of the large intestine. The vascular patterns of the intestines therefore form a subject of topical interest not only to the anatomist but also to the surgeon, and a suitable subject for a surgical lecture.

In the jejunum, the mesenteric vessels, coming off the superior mesenteric artery, form several arcades. These arcades increase in complexity distally as the intestine is traced down into the ileum, as Monks (1903) pointed out in his attempt at intestinal localisation, but there is no sharp demarcation. A segment of upper jejunum can, however, be readily recognised from a loop of lower ileum. An explanation for this complex system of vessels has been given by Franklin (1937) who considers it is for the accommodation and storage of blood—a blood-depot system. The arrangement of arcades, with anastomotic channels across the bifurcations must also be related to the movements of the intestines, the pattern of arcades being an adaptation to secure the passage of blood to the vessels nearer the intestine without interruption during the intestinal movements.

Coming off the arcades are the vasa recta; these run to the intestinal wall. They are all of similar size, anastomoses between their roots are infrequent, and they run without any union with their neighbours direct to the gut wall. Here they proceed on it in line with the fibres of the circular muscle coat. They give off a series of short side-branches on either side which form free communications with their neighbours thus constituting slender longitudinal anastomosing channels. In well-injected specimens, the vasa recta form complete arterial circles round the gut by junction of vessels from the opposite sides across the anti-mesenteric border. Cokkinis (1930) whose study of mesenteric

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thrombosis is often quoted, stated that there was absolutely no anastomosis either between the vasa recta in the mesentery or between the ramifying vessels in the gut wall. Eisberg (1925), however, had stated previously that the vasa recta of the small intestine were not end arteries, and the matter has been proved beyond any doubt more recently by Noer (1943) in his detailed investigation of the blood supply of the jejunum and ileum, by Doran (1949 and 1950) using the technique of vascular radiography and by work in the anatomy department here (Ross, 1947 and 1950), illustrated in the specimens shown in Figs. 1 and 2.

This arterial pattern is ideally adapted to preserve the free flow of blood to the intestine in the presence of the contractions going on all the time in the muscle of the intestine wall, and to expedite the venous return. Even in extreme distension an adequate blood-supply to the small intestine is assured. This rich vascularity allows the small intestine to tolerate a considerable sacrifice of blood supply in mesenteric injuries, as Bost (1929) has pointed out. He described 3 cases in which 4, 3, and 3½ inches of small intestine respectively were separated from the mesentery by traumatic lesions, but recovered without resection, the affected loop being wrapped round with omentum (as Sir David Wilkie (1911) had described in experiments with cats).

The human small intestine then, is a vascular structure. Let us now study the vascular pattern of the large intestine. Before doing so, however, it is as well to remember the variability of the length of this organ ; the range of length of the pelvic colon in particular is very considerable and should prevent us making any dogmatic statement about its blood supply. Figs. 3 and 4 illustrate two varieties—a short and a long loop of bowel, both of which are commonly encountered, and which have necessarily quite different blood supplies.

The usual vascular pattern of the main colic arteries is as illustrated in Fig. 5. The main vessels of the large intestine have been intensively studied by numerous authors—in particular by Stewart and Rankin (1933) ; Pope and Judd (1929) ; Sutherland (1942) ; Bacon and Smith (1948) ; and Goliger (1949). The intensive work of Bertocci of Turin (1949) must also be mentioned ; a translation of his researches has been made available for me through the kindness of Dr Rossi, Lecturer in Italian at Edinburgh University.

Stewart and Rankin found the ileo-colic artery a constant vessel, and the right colic artery the most inconstant of the colic arteries. Sometimes it originated from the superior mesenteric artery, sometimes from the middle colic, sometimes from the ileo-colic, and it was sometimes absent. The middle colic, and left colic, though variable in their course, were always present. Though these feeders varied, the peripheral vessel they ran to was found to be constant—a marginal artery produced by the anastomoses of their bifurcations, running at a varying distance from the wall of the colon with secondary loops in different portions of its course. This is the marginal artery described by Hamilton Drummond (1914*a* and *b*), whose importance, according to Moynihan (1913) cannot be over-estimated. It starts at the cæcum and runs regularly along the colon till the last sigmoid branch of the inferior mesenteric artery. It is a constant artery; in more than 100 specimens Stewart and Rankin found no failure of anastomosis of the

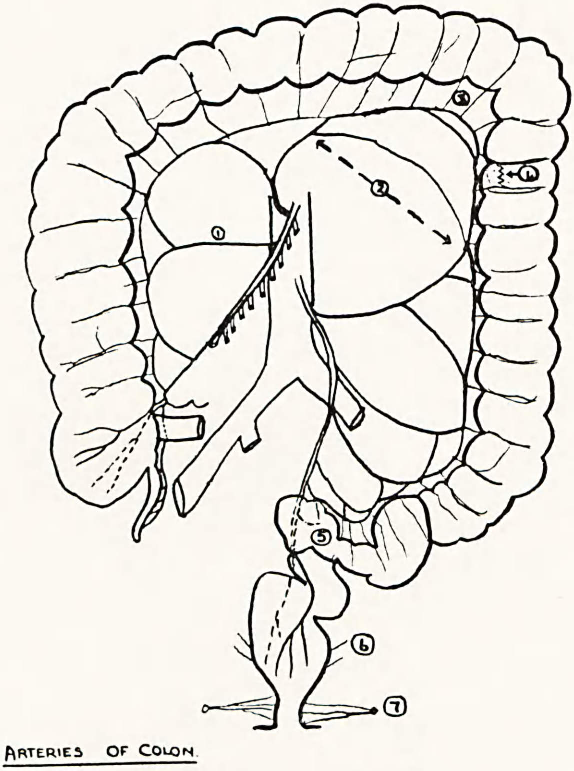

FIG. 5.—Arteries of large intestine.

(1) Variable right colic artery.
(2) Arch of Riolan.
(3) Accessory arcades in the marginal artery.
(4) Tertiary arcades of colon wall.
(5) Variable anastomosis of lowest sigmoid artery with superior rectal (present according to Cunningham (1935)).
(6) Middle rectal artery.
(7) Inferior rectal artery.

middle and left colic arteries, the arch of Riolan as this part of the marginal artery is called.

Beyond the last sigmoid, the continuous arterial channel is not so constant, and the inferior mesenteric artery continuing as the superior rectal, or the superior hæmorrhoidal, is really, as Hamilton Drummond (1914) described it, a terminal, or end artery. Sudeck in 1907 and Hartmann in 1909 described the point of union of the last sigmoid with the superior rectal artery as a point of weakness in the blood supply of the rectum because they found it the last point of union of the arcading sigmoids (the end of the marginal) to the main vessel (superior rectal). If ligated above this critical point blood could course along through the terminal sigmoid into the superior rectal ; if ligated below, that link was lost. The middle rectal arteries are small, and accounts of them vary. Mayo (1909) wrote " The superior rectal artery communicates freely with the middle hæmorrhoidal arteries," but Jamieson and Dobson (1909) criticised this view. Drummond concluded that " the middle hæmorrhoidal artery in most cases has not . . . a free anastomosis with the superior hæmorrhoidal." He found very little communication with the inferior hæmorrhoidal either. In the dissecting rooms here, I have found the middle rectal (hæmorrhoidal) vessels difficult to demonstrate at all.

The marginal artery has been formed by the anastomoses of the bifurcations of the feeding vessels ; these form the primary arcades. Secondary arcades form to a variable extent across these bifurcations, and there is a feebly developed system of tertiary arcades on the colon wall. This pattern of vessels is a great contrast to the pattern in the small intestine. A main gateway of surgical approach to the stomach is through the arch of Riolan, to the left of the middle colic artery. Division of an accessory anastomotic vessel sometimes found in the mesocolon there or division of one of the channels where a secondary arcade formation is present, is quite safe. Division of one of the main colic arteries, with the exception of the variable right colic artery, definitely jeopardises, at least temporarily, the blood supply of the affected segment of the colon. This is particularly so in respect to the middle colic artery, which constitutes the main flow into the arch of Riolan (Bertocchi, 1949) ; if damaged the central region of the colon runs a serious risk of sloughing.

Particular attention has been paid to the distribution of the inferior mesenteric artery. Before discussing this I would like to emphasise again the variability in length of the part of the colon supplied by this artery. Conservative resection of the rectum for carcinoma with conservation of the sphincters has formed a subject of a recent Honyman Gillespie Lecture—Mailer (1948)—and is well summarised by Maingot (1949). Bacon (1945) described 208 cases of resection of the rectum and sigmoid colon with sphincter muscle preservation and re-establishment of continuity, and referred to 105 other papers on the subject. He was, however, very much alive to the importance of the vascular pattern in this field of surgery. He illustrated clearly how in his operation " the inferior mesenteric vessels are ligated at the level of the common iliac bifurcation. Thus, virtually all sigmoidal vessels and their arcades are preserved and sufficient viable bowel is assured."

In abdominal segmental resection for carcinoma low in the sigmoid and rectosigmoid with primary end to end anastomosis—the " anterior resection " of Dixon (1944)—risk is run because in this operation the ligature is placed distal to the origin of at least one of the sigmoidal arteries which arise from the inferior mesenteric artery. Henceforth the blood supply to the rectosigmoid or rectum will come from the middle and inferior rectal vessels. Dixon stated that " the superior hæmorrhoidal (rectal) artery can be ligated and removed and even some of the marginal artery can be resected . . . without significantly damaging the blood supply to the remaining portion of the descending colon rectosigmoid or rectum." He based this statement on experience in more than 200 anterior resections in which both the superior rectal artery and a portion of the marginal artery were removed ; and he considered the blood supply to the distal portion of the bowel adequately cared for by the middle and inferior rectal arteries. Wangansteen (1945), however, whilst describing primary resection of the rectal ampulla for malignancy with preservation of sphincter function a feasible and practical procedure, admits that difficulty with wound healing and temporary rectal fistula are not uncommon ; primary healing not being usual owing to the interference with the blood supply.

I have no personal experience of sphincter-preservation operations in carcinoma—I use the radical perineo-abdominal and abdomino-perineal excisions with permanent colostomy. Anatomically, I would like to stress again the relatively poor arterial supply of the large bowel. The superior rectal artery is an end artery as Hamilton Drummond described it ; it connections with middle and inferior rectal arteries are very slight, and dissections in the anatomy department here confirm Drummond's view. The middle rectal artery cannot replace the superior rectal as the main blood supply of the rectum. On anatomical grounds, operations such as Bacon's and the Mikulicz operation (Gabriel, 1937) for prolapse of the rectum, when as much as 19 inches of bowel can be removed by a pull-through manœuvre (Fig. 6) and operations of the Pauchet type (Maingot, 1948) are safe enough as division is made through the inferior mesenteric artery above the level of the sigmoidal arteries whose loops are preserved. The bowel, supplied by the marginal artery and sigmoidal arcades, is sutured to the anal canal supplied by the inferior rectal artery. Both ends of bowel have therefore a good blood supply, always provided—and this is a very important proviso—the loop brought down is long and mobile enough to prevent its vessels being put on the stretch.

Operations where the arterial trunk—inferior mesenteric, superior rectal—is ligated below where it gives off the sigmoidal arteries, that is, in the critical area of Sudeck—and particularly when a portion of marginal artery or the lowest sigmoid has to be divided to get adequate length of bowel for the resection, are definitely jeopardising the blood supply, and in less practised hands than Dixon's may well cause serious trouble (Fig. 7).

So much for the feeding arteries to the large bowel. Coming off the marginal artery and the secondary arcades, are the vasa recta. These can be classified as vasa longa, vasa brevia and vasa intermedia. The origin of these vessels has been noted in the different specimens examined as (1) coming off singly to alternate sides of the colon,

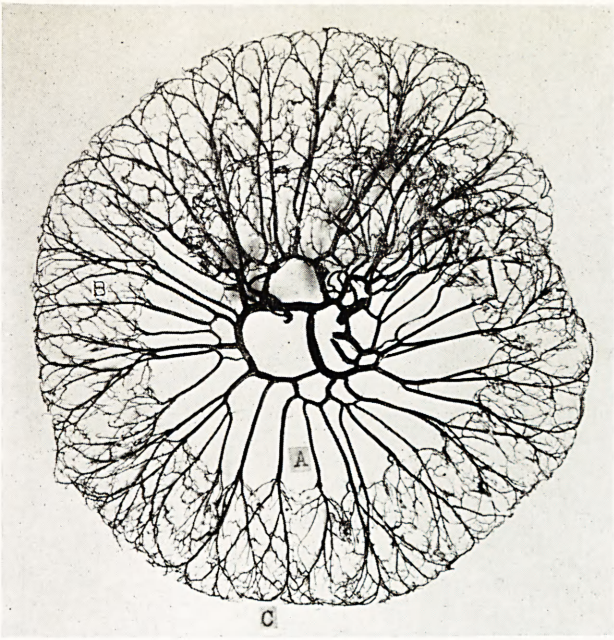

FIG. 1.—Celloidin cast of the arteries of a loop of upper jejunum of a healthy male aged 40 killed in a motor accident.

Shows (A) The vasa recta running without anastomoses from the terminal arcades to the intestine.
(B) The lateral offshoots on the intestine wall freely anastomosing with their fellows.
(C) Anastomoses across the anti-mesenteric border, better seen in Fig. 2.

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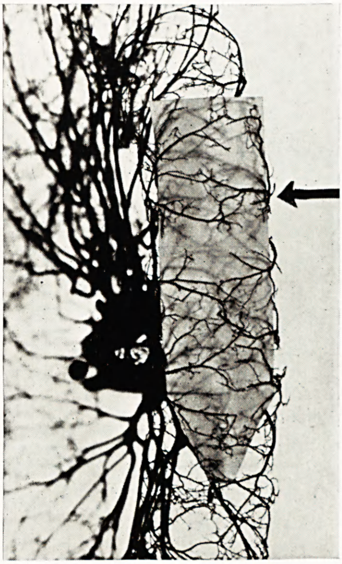

FIG. 2.—Lateral view of same specimen as in Fig. 1 showing the anti-mesenteric region, a piece of paper having been inserted to demonstrate the vessels better. Numerous anastomoses are seen between vessels of opposite sides, across the anti-mesenteric border.

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FIG. 3.—Barium enema showing the short variety of pelvic colon.

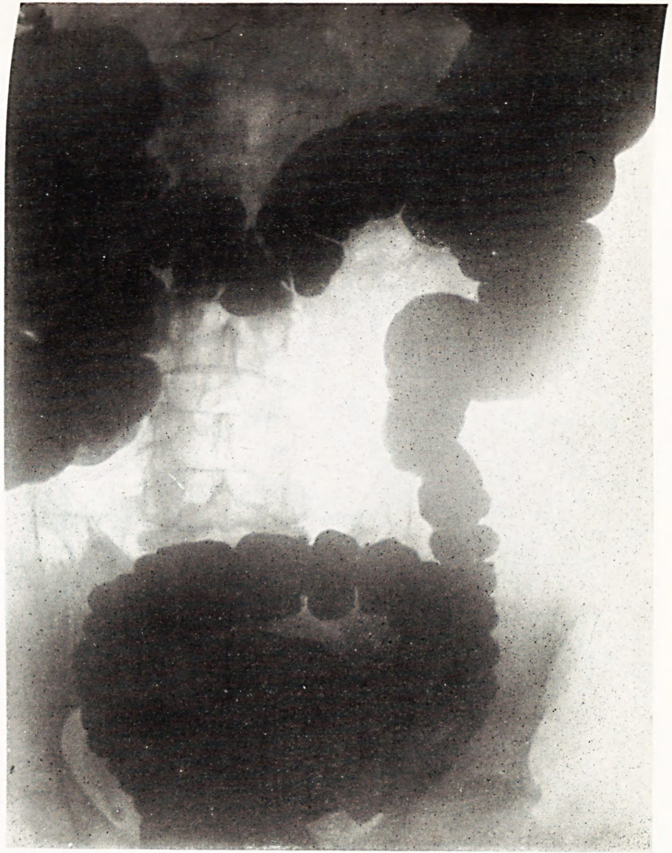

FIG. 4*a*.—Barium enema showing the long-loop variety of pelvic colon.

Fig. 4 (*b*).

Fig 4 (*c*)

Figs. 4*b* and 4*c*.—Barium enemas illustrating two other varieties of long colon.

Fig. 6.—Specimen of rectum and pelvic colon 19 ins. long removed by pull-through (Mikulicz) operation from a woman aged 57 for complete prolapse of rectum. Three previous operations unsuccessful; Result: Complete relief and no recurrence eighteen months after operation. (Leith Hospital; Mr W. W. Carlow's wards).

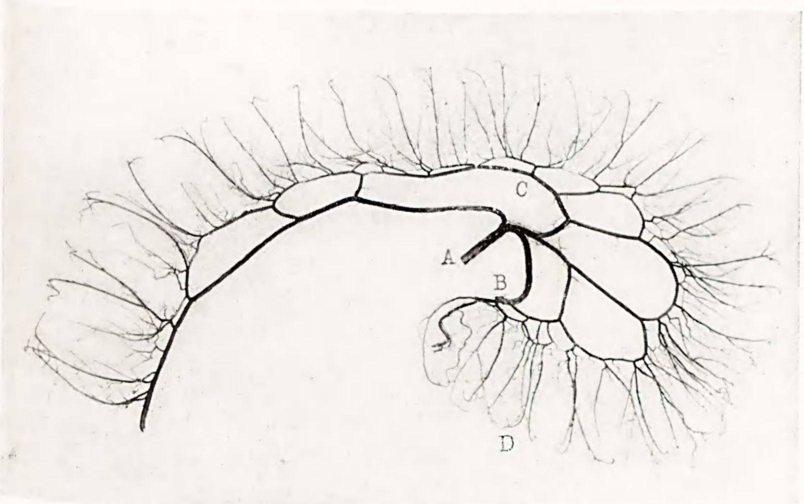

Fig. 8.—Celloidin cast of the inferior mesenteric artery supplying a portion of descending and pelvic colon, from the same case as Fig. 1.

Shows (A) The inferior mesenteric artery trunk becoming

(B) The superior rectal artery.

(C) The main branches of the inferior mesenteric artery with a well-marked marginal vessel and arcades in the pelvic mesocolon.

(D) The vasa recta longa with infrequent anti-colic anastomoses.

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(2) coming off a common trunk of variable length and branching to the same side of the colon, or (3) to opposite sides. There is only an imperfect system of anastomoses between these vasa recta on the gut wall—constituting the "tertiary" arcades mentioned before. Anastomoses across the anti-mesocolic border between vasa longa of opposite sides do exist, but they are infrequent. Fig. 8 illustrates these points. The contrast to the small intestine is very marked. It is clearly evident that the colon cannot withstand distension as the small intestine can; hence the presence of "stercoral ulcers" associated with colonic obstruction. The cæcum, in particular, is avascular compared with the small

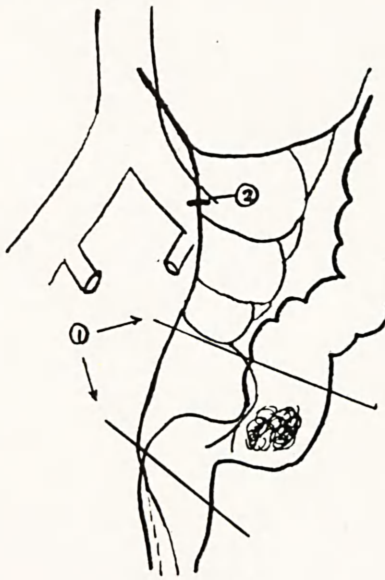

FIG. 7.

(1) Ligation and division of superior rectal artery distal to the point of emergence of the sigmoidal arteries and the segment to be removed (after Dixon).

(2) Ligation of inferior mesenteric vessels at level of common iliac bifurcation. Thus, virtually all sigmoidal vessels and their arcades are preserved and sufficient viable bowel is assured (after Bacon).

intestine; and Cameron (1938) has drawn attention to this as a possible ætiological factor in solitary cæcal ulcer.

The vasa recta run on a straight or sinuous course on the colon wall, flagged by the appendices epiploicæ, and they pierce the circular muscle coat gradually, passing deep to the anti-mesenteric (lateral) tæniæ coli (see Fig. 9). Their course is of considerable surgical interest. The point of entry into the intestinal wall constitutes a weak area, and this is the place where a diverticulum arises, as Hamilton Drummond clearly pointed out (1917).

On their way round the intestine these vessels take a curve, or sometimes a wide U-shaped bend in the subserous fat at the base of the appendices epiploicæ; this is to make allowances for the expansion of the colon when full. Jean Meillère (1927) described an actual loop taken by the vasa recta 5 to 10 mm. or even more from the intestine wall. A recent review of the anatomy and pathology of the appendices epiploicæ (Ross, 1950) though not disproving these views has shown that a true loop formation must be very rare. Surgical removal of appendices epiploicæ by ligation can be considered therefore quite safe, and does not endanger the blood supply of the colon wall. It is a reasonable precaution, however, as Sir John Fraser (1938) pointed out, to avoid being unduly radical when excising them, and in particular to avoid pulling the appendix away from the bowel before severance.

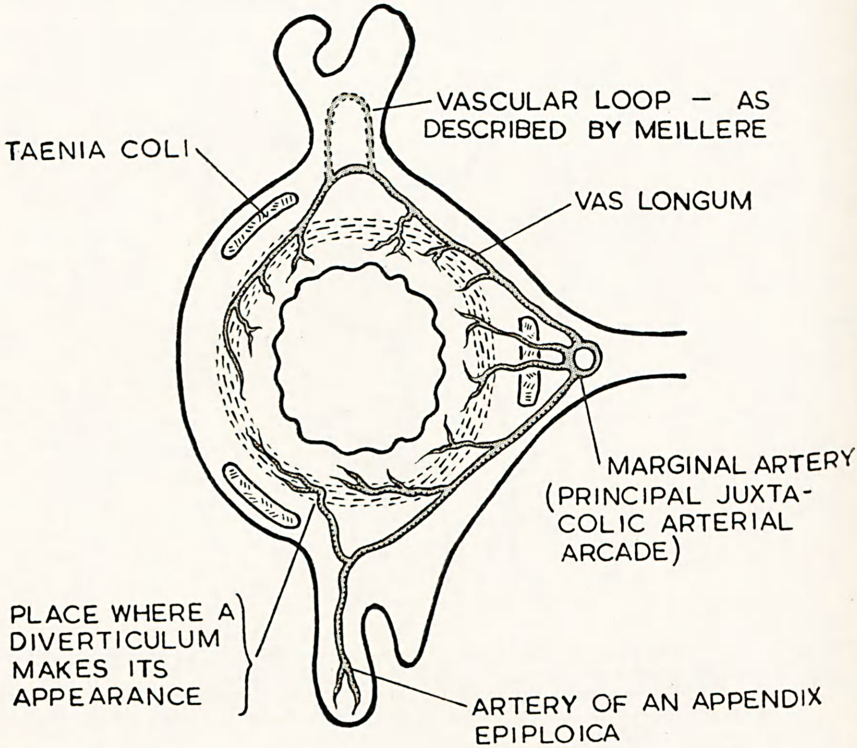

FIG. 9.—Diagram to illustrate the course of a vas longum on the colon wall.

The vessels of the appendices epiploicæ themselves are usually one, or less often two arteries which run as end arteries to the tip of the appendix. In certain circumstances an appendix epiploica may undergo torsion, and the vessels become obstructed or obliterated. Necrosis of the appendix epiploica then ensues, and it may become free and fall into the peritoneal cavity, thus producing one variety of those surgical curiosities, peritoneal loose bodies (Ross and McQueen, 1948).

It will be seen, then, that the vascular patterns of the intestines are of surgical importance, whether the main vessels or the smaller arterial radicles are considered.

In conclusion I would like to thank Professor Brash for his help and interest in the researches which form the basis of the present review. I must thank Mr John Borthwick for the photographs in Figs. 1, 2, 3, 4, and 8; Drs J. B. King, G. G. Allan, J. G. Kininmonth and W. MacLeod for the X-rays illustrating the different variteies of colons; and Dr Nora Campbell of the Medical Illustration Department for the diagram in Fig. 9.

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