BLOOD SUPPLY TO FORE-, MID- AND HINDGUT IN CASE OF NON-ROTATION OF 2nd STAGE ASSOCIATED WITH ABNORMAL DUODENUM AND ABUNDANT SPLENIC TISSUE

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Although many cases of arrest of intestinal rotation in the 2nd stage have been recorded,[1] Bleloch[2] rightly points out that the associated vascular arrangements have been described in comparatively few of these. The present report describes the arrangement of the bowel and its blood supply in an instance of complete second-stage non-rotation of the midgut loop found in a White female aged 79 years, dissected during 1963 in our laboratories. The associated abnormal arrangement of the duodenum and pancreas and the presence of an unusual volume of splenic tissue in this individual form the subject of other papers.

DISPOSITION OF BOWEL AND PERITONEAL ATTACHMENTS (*Fig.* 1)

In the thorax the oesophagus, after passing behind the arch of the aorta, lay in the midline to the right of and anterior to the descending aorta. The cardia, embraced by the loops of the diaphragmatic crura, lay anterior to the beginning of the abdominal aorta in the midline at the level of the 12th thoracic vertebra, the inferior vena cava being closely related to its right border (Fig. 2). The stomach was normal in all respects.

The small intestine joined the pylorus 2·5 cm. to the LEFT of the midline at the level of the 2nd lumbar vertebra. Its proximal 13·3 cm. formed a freely mobile peritoneal-covered U loop with its concavity upwards, which was related to the head, neck and part of the body of the pancreas. Following this U loop was a 10-cm. vertical limb of bowel anchored to the posterior body wall in relation to the inferior vena cava; from this a further 10-cm. loop of small bowel proceeded to the right, its concavity facing downwards. Peritoneum covered the inferior, anterior, superior and part of the posterior aspects of this last loop, so that a deep peritoneal fossa was formed between it and the lower pole of the right kidney. The exact site of the duodeno-jejunal junction defies anatomical definition.

The ensuing coils of small bowel, measuring 2·43 m. in total length, and also the caecum and proximal 20 cm. of colon, occupied the free border of the mesentery. The root of the mesentery, 20 cm. in length, began at the lower pole of the right kidney, 10 cm. from the midline, and extended from the right upper to the left lower quadrant of the abdomen, skirting the brim of the pelvis to end to the left of the midline at the level of the promontory of the sacrum just short of the left sacro-iliac joint. The right leaf of the mesentery became continuous with the attenuated pelvic mesocolon, whereas the left leaf continued to anchor an ascending limb of colon to the posterior body wall in the left half of the abdominal cavity.

The mobile caecum (Fig. 3), 8·75 cm. in width by 5·23 cm. in depth above the ileocolic valve, lay slightly to the left of the midline at the pelvic brim; the terminal ileum entered it from the right side and the 2·5-cm. appendix projected upwards and to the right from its superior aspect. The proximal 20 cm. of colon, leading from the caecum, was also supported by the mesentery; it formed a mobile knuckle of bowel dipping into the pelvis and closely related to the relatively immobile pelvic colon. From this pelvic loop, a tortuous ascending limb of colon, 20 cm. long, ran up the posterior body wall behind the peritoneum and reached the tail of the abbreviated pancreas behind the stomach. Here it continued by a sharp flexure into a descending, vertical, retroperitoneal limb measuring 13·75 cm., which lay to the left of the ascending

Fig. 1. Photograph of exposed abdominal viscera. I=inferior vena cava. K = kidney. P = pancreas. D = duodenum. S=spleen. Note the left-sided coils of small bowel and right-sided large bowel.

limb. At the brim of the pelvis the descending colon flexed sharply to form a hairpin-loop directed upwards and supported by a mesocolon measuring 7·5 cm. from root to apex and 3·75 cm. wide at the base. This hairpin-loop which measured 27·5 cm., occupied the left paracolic gutter and was related to splenic tissue; distally it became continuous with 12 cm. of pelvic colon. The rectum was normal in all respects.

The lesser omentum, including structures in its right free border, was normal in all respects.

The greater omentum lay entirely to the left of the midline and was adherent to the coils of large intestine found in the left half of the abdomen, especially to the part demarcated by its blood supply as transverse colon.

Peritoneal Attachments

The arrangement of the mesenteries in this case appear to differ from those in the majority of previously reported cases. In these the usual findings were: (1) a narrow, transversely-disposed universal mesentery attached at the duodenocolic isthmus and related mainly to the superior mesenteric vessels, and therefore liable to predispose to

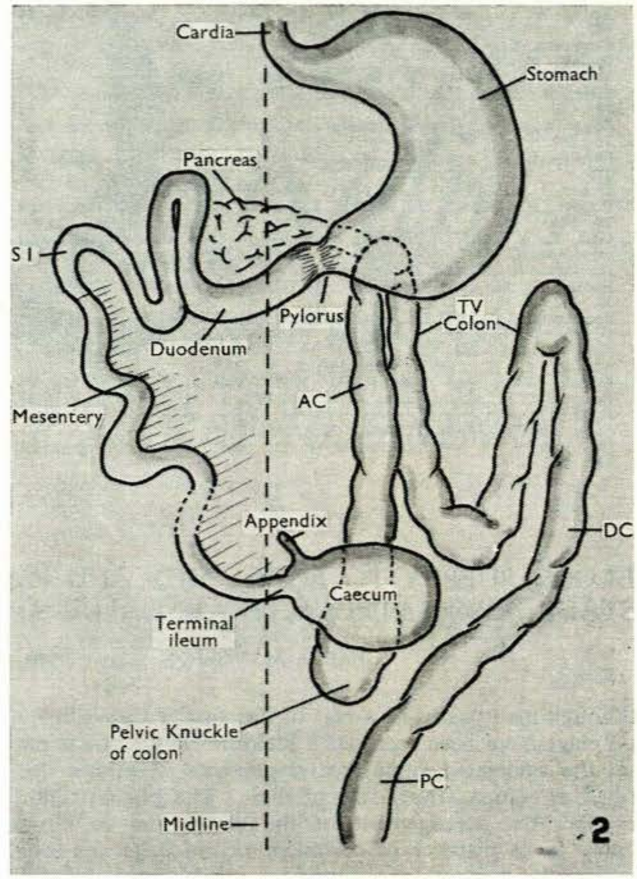

Fig. 2. General scheme of abnormality—diagrammatic. TV=transverse (colon). DC=descending colon. PC=pelvic colon. AC=ascending colon. SI=small intestine.

volvulus; (2) a short attachment of the mesentery either in the midline or on the right psoas muscle; and (3) mesenteries enclosing redundant loops of large bowel. Associated with these anomalies of fixation, obstructing peritoneal bands especially related to the duodenum are common; they were first clearly depicted by Ladd.[3]

In our case we have a main mesentery supporting jejunum, ileum, caecum, appendix, and proximal colon, with its broad root placed obliquely at right-angles to the line of the normal mesenteric attachment and a narrow tongue of mesentery supporting the distal part of the transverse and descending colon. In addition, the short U loop of duodenum, suspended in a short mesoduodenum, is firmly tethered at each end and no abnormal peritoneal bands were found.

These attachments thus protected this woman from the complications requiring surgery so adequately described and reviewed by many authors.[3-10] If an error of rotation is destined to cause symptoms, it usually does so during the early years of life, frequently within the neonatal period, symptoms of duodenal obstruction being the commonest mode of presentation; Zimmerman and Laufman, in 1953, were able to collect only 12 cases occurring in adults over a 1-year period in a 3,500-bed hospital.[11]

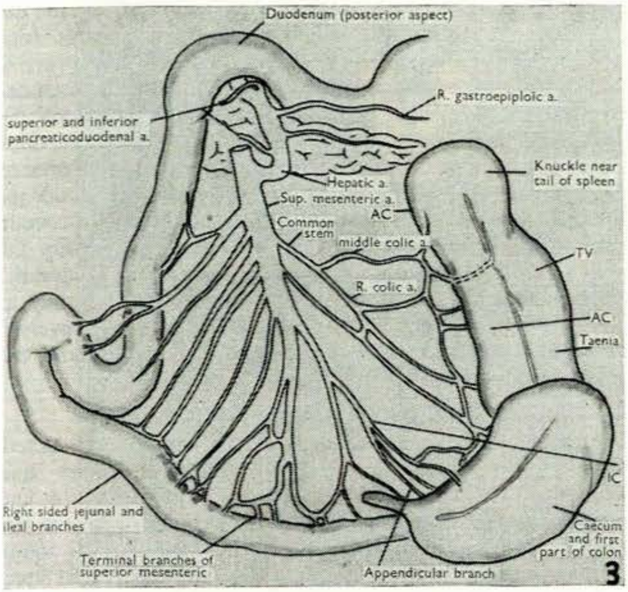

Fig. 3. Blood supply of gut. AC=ascending colon. TV=transverse colon. IC=ileocolic artery from left.

BLOOD SUPPLY

Foregut

The *coeliac* trunk, arising from the abdominal aorta as it emerged beneath the median arcuate ligament, divided into two branches only: (*a*) the *left gastric* artery, from which sprang an unusually large accessory hepatic artery, and (*b*) the remarkably tortuous *splenic* artery, giving numerous branches to the pancreas, the multiple spleens and spleniculi, and the greater curve of the stomach.

The true *hepatic* artery arose in common with the *superior mesenteric* artery behind the pancreas by a common stem 0·625 cm. long. From the division of this hepatomesenteric trunk, the hepatic artery ran downwards and forwards, insinuating itself between the lower border of the pancreas and the upper border of the U-shaped loop of duodenum close to the lowest part of the U. Thence it ran upwards on the anterior surface of the pancreas with the common bile duct on its right; this normal relationship of these two structures is considered to establish the identity of the artery as the true hepatic artery and not merely an accessory hepatic artery.[12] As these structures reached the upper border of the pancreas, the portal vein joined them from behind it, and all three then entered the right free border of the lesser omentum.

The foregut branches of the hepatic artery were given off (Fig. 3) from its left side mainly behind the pancreas; these were (*a*) an *inferior pancreatic* artery, from which arose an *accessory gastro-epiploic* branch; (*b*) a *right gastric-epiploic* artery; (*c*) a *superior pancreatico-duodenal* artery, giving branches to the duodenum and pancreas proximal to the opening of the common bile duct and pancreatic duct; and (*d*) a *small right gastric* branch. Anterior to the pancreas only a few arterioles to pancreas and duodenum arose from the right side of the hepatic artery.

Midgut

(a) *Branches from the hepatic artery.* The superior pancreaticoduodenal artery terminated as a T-shaped branch lying to the right of the hepatic artery and supplied a large part of the U loop of duodenum distal to the duodenal papilla. It was joined by two *inferior pancreatico-duodenal* branches springing from the right side of the hepatic artery close to its origin. Anterior to the pancreas a few small duodenal arterioles were given off from the right side of the hepatic artery.

(b) *Branches from the superior mesenteric artery* (Fig. 3). From the right side of the superior mesenteric artery seven main jejunal and ileal trunks, dividing and forming arcades, could be identified, as well as many smaller branches. The terminal part of the superior mesenteric divided into two branches, one whose ramifications linked with the lowest ileal branches on the right, and one which formed a U loop of anastomosis with the *ileo-colic branch.* This last artery, which sprang from low down on the LEFT side of the superior mesenteric artery, supplied the terminal ileum, caecum and appendix and anastomosed freely in the left side of the abdomen with the branch supplying the first part of the colon.

An artery that arose more proximally from the LEFT side of the superior mesenteric divided into two branches for the supply of the ascending and transverse colon (Fig. 4). The branch for the first part of the colon, which would, if rotation had taken place, have been the *right colic* branch, ran downwards and laterally, supplying the

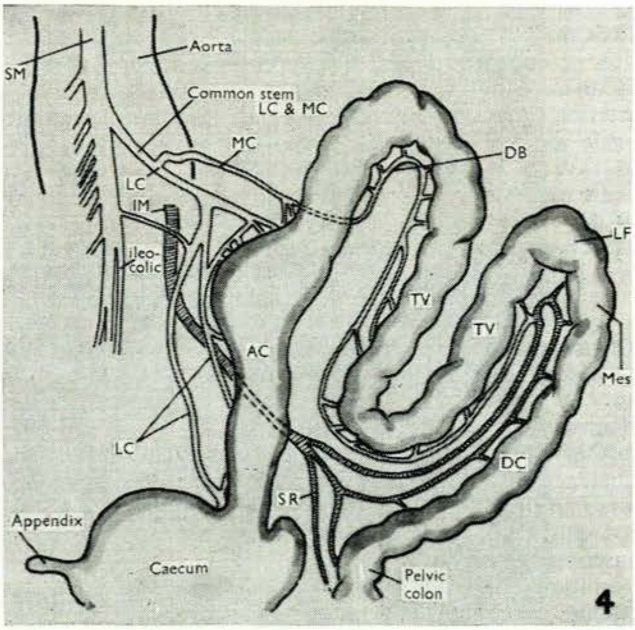

Fig. 4. Blood supply of large intestine. SM=superior mesenteric artery. MC=middle colic artery. LC=left colic artery. IM=inferior mesenteric artery. SR=superior rectal artery. DB=deep branch of middle colic artery feeding transverse colon. LF=left flexure of colon. AC=ascending colon. TV=transverse colon. DC=descending colon. Mes=loop enclosed in mesocolon.

proximal pelvic knuckle of colon and the whole of the tortuous ascending limb. It anastomosed proximally with the ileocolic artery, and distally with the second branch, which may be termed *middle colic*. This artery gave branches to the 'pancreatic' flexure, and then passing *behind* the ascending limb of colon formed an arcade that supplied the descending limb, the lower flexure and the ascending limb of the hairpin-loop before anastomosing with the ascending left colic branch of the inferior mesenteric artery. The parts of the colon supplied by this artery may be considered equivalent to the transverse colon of normal anatomy. The distal portion of this 'transverse' colon shared a mesentery with the part equivalent to the descending colon. The mesenteric veins bore their usual relationship to the arteries.

Hindgut

The *inferior mesenteric artery* appeared essentially normal, left colic and sigmoid branches passing to the left to supply the descending colon and pelvic colon, and the continuing trunk, the superior rectal, descending into the pelvis to supply the rectum.

ASSOCIATED ANOMALIES

Schultz *et al.*[13] have drawn attention to the appreciable incidence of associated congenital anomalies in cases with abnormalities of rotation of the bowel; 27% of their series were so afflicted, the anomalies being mainly confined to the cardiovascular system.

The most obvious anomaly in the present case is the origin of the main hepatic artery in common with the superior mesenteric. Whereas in about 20% of cases the right hepatic artery is an offshoot of the superior mesenteric artery,[14] it is very unusual for the main hepatic artery to arise in this manner. This anomaly is explained on the basis that the hepatic diverticulum arising from the junction of the fore- and midgut loops is entitled to draw its blood supply from either coeliac or superior mesenteric arteries. The small valvular opening of a patent foramen ovale was discovered in the heart; it seems very unlikely to have been of physiological significance, although the heart was enlarged. There was also a curious displacement of the brachiocephalic artery and its branches, which may have been either congenital or acquired; this is discussed in a separate study by Dr. J. F. Jarvis.[22]

DISCUSSION

The mechanism of malrotation of the midgut loop based on an understanding of the normal process of rotation worked out by pioneers like Treves,[15] Keibel,[16] Keith,[17] and Frazer and Robins,[18] and crystallized by Dott,[1] has been further elucidated by the more recent work of Snyder and Chaffin[19] and Kanagasuntheram.[20] The former investigators find that during the 1st stage of rotation (5-10 weeks) not only does the 90° counterclockwise twist of pre- and postarterial segments occur but, in addition, there is migration of the duodenojejunal junction to the left of the midline behind the superior mesenteric vessels; this event was clearly and repeatedly demonstrated at about 7 weeks (25 mm.), before the 2nd stage (with the return of the midgut loop to the abdominal cavity) began at about 10 weeks (40 mm.). Kanagasuntheram[20] has postulated that this move on the part of the terminal duodenum is the essential prerequisite for normal 2nd-stage rotation, and should it fail to take place arrested rotation of the midgut loop, as exemplified by our case, may ensue.

Snyder and Chaffin[19] have suggested a new classification for 2nd-stage anomalies based on the final position of the duodenojejunal and ileocolic loops in relation to the superior mesenteric vessels. Their system defines four groups, as follows: Group I corresponds to 'reversed' rotation, a rare anomaly. Group II is the commoner arrested rotation, also termed non-rotation, in which the duodenojejunal loop lies to the right of the superior mesenteric and the ileocolic to its left, as in the present case. Group III comprises cases in which the duodenojejunal loop is in its normal position and the ileocolic loop lies mainly to the left of the midline. Group IV embraces those cases now labelled 'undescended caecum'. On balance this classification does not seem as handy as the older one, in which cases not clearly showing reversed or arrested rotation can be termed malrotated and the exact details of the anomaly then defined.

SUMMARY

Typical features of 2nd-stage arrested rotation are noted, accompanied by additional anomalies of the fore- and hindgut. The oesophagus retains its midline position and the pylorus and first inch of the duodenum lie to the left of the midline because the stomach has failed to rotate completely. Failed migration of the duodenojejunal junction, partial persistence of the mesoduodenum, and peritoneal adhesions, account for the complicated arrangement of the proximal small bowel and possibly for the mainly right-sided position of the small bowel and left-sided position of the large bowel. Persistence of part of the universal mesentery has produced the mobile loops of large bowel in unusual sites. The vascular arrangement in general corresponded with the altered disposition of the bowel, as is usual in these cases of arrested rotation and is unlike the case encountered last year[21] in this Department, in which the blood vessels lay in their correct positions and supplied the bowel found in these regions; presumably this was because in the latter case the error in rotation occurred at a much later stage.

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