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MICRORADIOGRAPHIC ANATOMY OF THE EXPLANTED RAT COLON

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Abstract

The colon of 32 healthy Sprague-Dawley rats was studied microradiographically. The colonic arterial distribution of 18 rats was examined after injecting barium sulfate into the isolated aorta. The mucosal surface in 9 rats was studied using double-contrast technique after colon explantation. In 5 animals arterial and mucosal studies were carried out simultaneously. The radiographic thickness of the colonic wall was measured using a comparative microscope. The specimens were observed, photographed and examined histologically. Unlike the cecum and distal colon which, when insufflated, do not have mucosal folds, the proximal colon exhibits folds in an oblique direction corresponding to that of the arteries, and the colonic wall in this region is thicker. Comparison between arterial and mucosal microradiographic anatomy and wall thickness enables the proposition of a simple nontopographic division of the rat colon into cecum, proximal colon and distal colon.

Key words: Rat colon, anatomy; —, microradiography; —, experimental investigation.

The rat is widely used as a laboratory animal for the study of experimental colitis models (1, 6–11). The anatomy and topography of the rat colon have been described on the basis of macroscopic (2–4) and radiologic observations (5) on the whole animal.

Radiology is useful for studying normal arterial and mucosal anatomy of the explanted rat colon. The description of the normal microradiologic anatomy is an indispensable premise for the identification of arterial and mucosal alterations in experimental colitis.

Proposals have been made for distinguishing subdivisions of the rat colon resembling those used for human anatomy (2, 3). Based on microradiologic analysis of the arterial distribution, mucosal surface and wall thickness of the explanted rat colon, we propose a simpler partitioning of the large intestine.

Material and Methods

Thirty-two Sprague-Dawley rats weighing on average 370 g were kept in a 20°C constant-temperature environment, 2 animals per cage, with free access to water and standard food. Colonic arterial distribution was studied in 18 rats after barium sulfate injection. The colonic mucosal surface was studied in 9 animals using double-contrast technique. In 5 rats the arterial and mucosal studies were carried out simultaneously.

In order to study the arterial branching the aorta was isolated on the operating table. Using an optical microscope the renal and ileal arteries were tied to obtain a more effective barium sulfate injection pressure in the intestinal arteries. The colon was lifted from its splanchnic lodging and freed from the ligaments. A 1.2- to 0.9-mm needle was inserted into the abdominal aorta with the needle tip placed at the origin of the mesenteric artery. The aorta was tied at the level of the celiac trunk. The vessels were cleared of blood with 200 ml physiologic saline perfusion to prevent artifacts in the microradiographic images. The portal vein was kept open during the first 5 min of perfusion and then tied to promote colonic venous outflow via the inferior vena cava. Approximately 20 ml of 50% w/v micronized barium sulfate was then injected through the same needle using an infusion pump with a flux of 1.65 ml/min. The barium suspension was injected until it became visible in the distal artery branches under the serosa (Fig. 1). Finally the superior and caudal mesenteric arteries and the 2 colic extremities were clamped for explantation and microradiologic investigation of the specimen.

Double-contrast microradiologic investigation also re-

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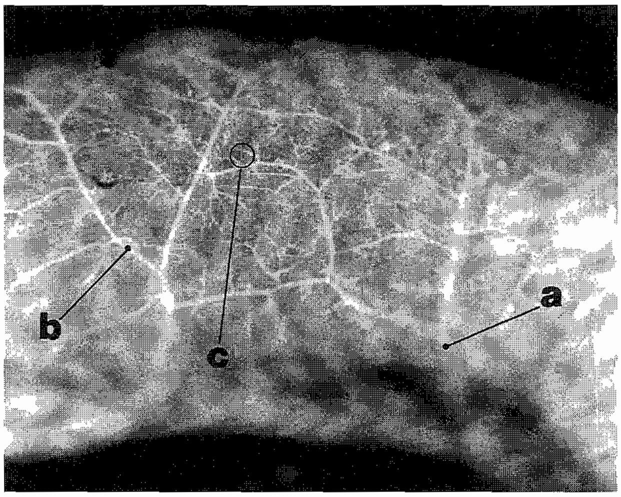

Fig. 1. Distal colon of a rat. Optical image: main arteries and their ramifications are visible through the serosa. a) Rectilinear artery; b) collateral artery; c) terminal arteriolae.

quired explantation of the colon, which was clamped at the level of the distal ileum and rectum. Ten ml of 50% w/v micronized barium sulfate and 20 to 50 ml of air were injected through a 1.7-mm catheter until the entire colon was filled. The colon was repeatedly turned to obtain a thin radiopaque film on the mucosal surface.

The microradiologic examination of the specimen was carried out using a focal spot of 0.3 mm, a focus–film distance of 70 cm and high-definition contact films (vacuum-compressed Kodalith ortho type 3 without screens). Microradiography (Gilardoni Radiolight, 0.3 mm, FFD 70 cm, 18–22 kV, 5 mA, exposure time 1–2 min) was carried out on colons which were either insufflated or cut open along the antimesenteric border and then placed directly on the film with the mucosal surface down.

The thickness of the colonic wall was measured using an optical microscope with 2 orthogonal axes in the eyepiece and equipped with a comparator. The specimen was observed, the mucosal and serosal sides were photographed, and the specimen was placed in a 10% formalin solution for histologic examination with hematoxylin and eosin staining.

Results

Microradiographic arterial anatomy. The colonic arterial supply is derived from the superior and caudal mesenteric arteries which belong to the main branches of the abdominal aorta. The superior mesenteric artery supplies the small intestine, cecum and almost all of the colon. The caudal mesenteric artery supplies the lower colon and the rectum. The mesenterial arteries arise from the mesenteric artery and run along the lesser curvature of the cecum; rectilinear arteries arise from the mesenterial artery and fan out along the lower axis of the cecum towards the greater curvature. About halfway between the 2 curvatures these rectilinear

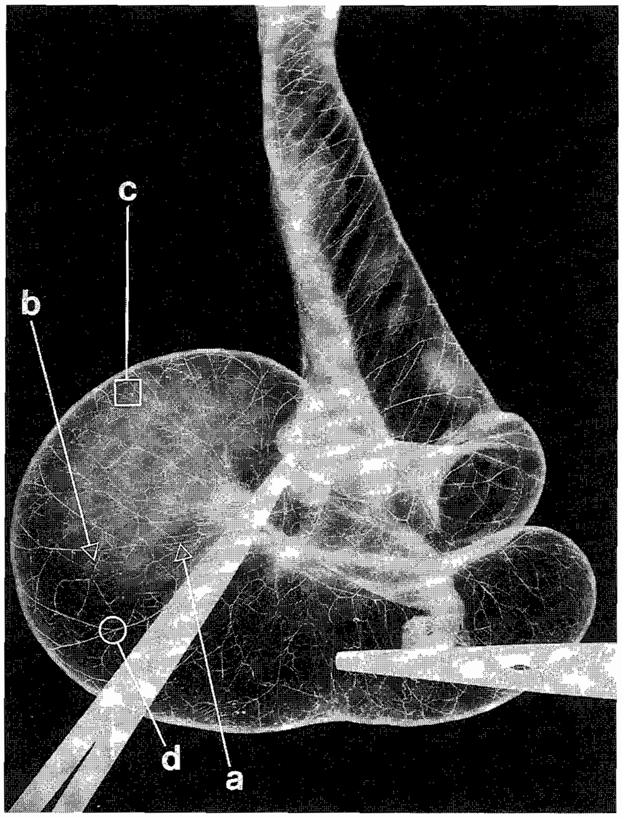

Fig. 2. Rat cecum. Microradiograph of the arteries. a) Rectilinear artery; b) collateral artery; c) terminal arteriolae; d) dichotomy.

arteries divide dichotomously, forming an acute angle towards the greater curvature. The dichotomous branches give rise to minute collaterals: some create anastomotic networks, others produce new dichotomous subdivisions closer to the greater curvature, in turn dividing into non-anastomosed arteriolae (Fig. 2).

From the mesenterial artery in the proximal colon, rectilinear collateral arteries arise at an acute angle towards the cecum or at almost right angles. Rectilinear arteries are united by collateral arteries in an oblique direction, thus creating a characteristic rhomboid arterial pattern for the first 7.5 to 9 cm of the colon. The rectilinear arteries can be followed to the antimesenteric border and end with non-anastomosed terminal arteriolae (Fig. 3).

The arterial supply of the proximal 2/3 of the distal colon arises from the superior mesenteric artery, while the supply of the remaining portion rises from the caudal mesenteric artery, also supplying the rectum. The superior and caudal mesenteric arteries divide close to the intestinal wall into mesenterial arteries, run close to it, to fully fuse into each other. Rectilinear collaterals originate from the mesenterial arteries at almost right angles and soon after their appearance give rise to collateral branches at both acute and right angles to the antimesenteric border. These collaterals form a network and provide communication between contiguous rectilinear arteries. The terminal arteriolae close to the antimesenteric border do not appear to be anastomosed (Fig. 4).

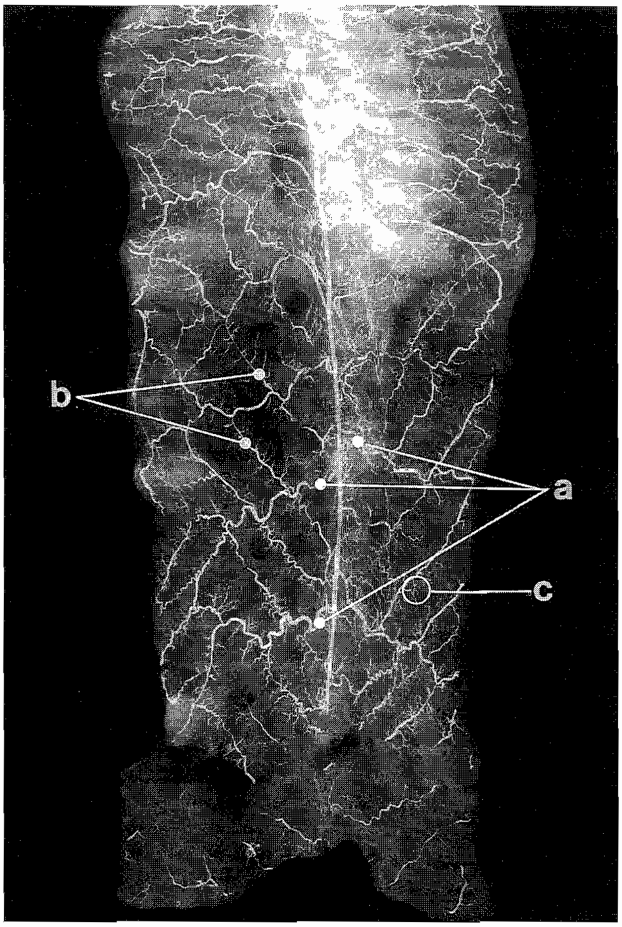

Fig. 3. Proximal colon of a rat opened along the antimesenteric border. Microradiograph of the arteries. a) Slightly serpiginous rectilinear arteries in a partially relaxed organ; b) collateral arteries with oblique direction; c) terminal arteriolae. Crossings of rectilinear and collateral arteries form a rhomboid pattern.

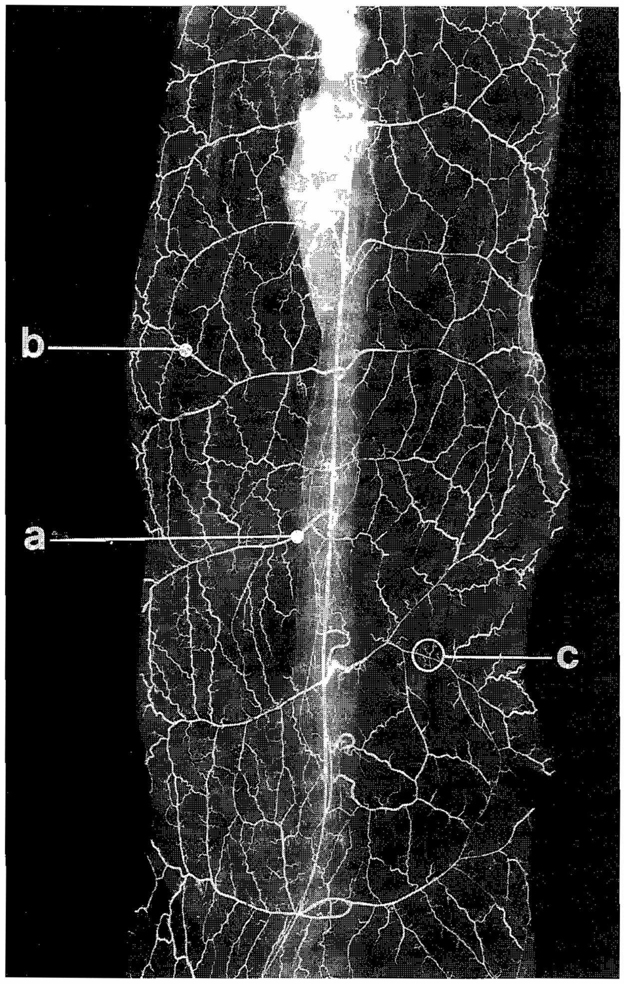

Fig. 4. Rat distal colon opened along the antimesenteric border. Microradiograph of the arteries. a) Right-angled rectilinear artery; b) collateral artery; c) terminal arteriolae.

Microradiographic mucosal anatomy. On double-contrast examination the mucosal surface of the live rat presents the typical palm-leaf appearance of the folds of the proximal colon. Spots of contrast medium accumulation, particularly in the distal colon, correspond to lymphoid plaques (5). The insufflated cecum does not present mucosal folds. The average radiologic thickness of its walls is 391 μ. As described in *in vivo* studies (5), also in the isolated organ only the part of the colon which is immediately downstream from the cecum presents typically oblique folds (Figs 5, 6). These oblique folds are arched and converge at acute angles both on the mesenteric and the antimesenteric side. The acute angle is thus open towards the rectum with a colon dissected on the antimesenteric border and open towards the cecum with a colon dissected on the mesenteric border. The folds are visible both in the insufflated and the relaxed organ.

The average wall thickness of the proximal colon is 478 μ, which is significantly larger than that of the cecum ($p = 0.004$) and distal colon ($p = 0.001$). The insufflated distal portion of the colon and the rectum do not present folds;

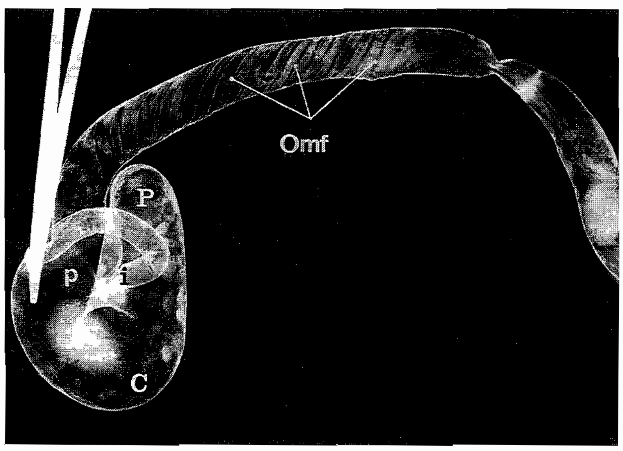

Fig. 5. Isolated rat colon. Double-contrast microradiograph of the mucosa. Oblique mucosal folds (Omf) are present only in the proximal colon. Colonic flexures are barely evident; (i) distal ileum; (C) cecum; (P) proximal pole of cecum; (p) distal pole of cecum and beginning of tubular colon.

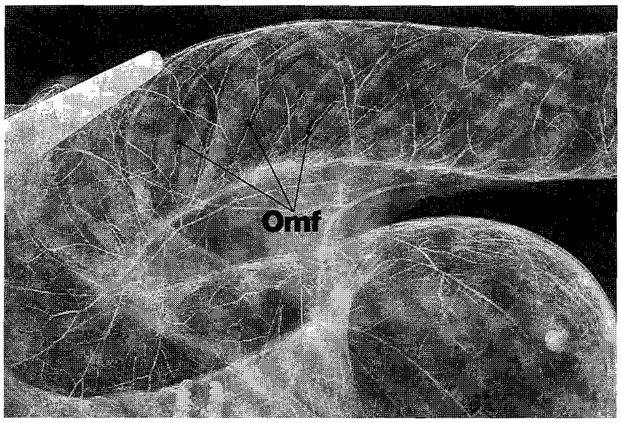

Fig 6. Isolated proximal colon of a rat. Microradiograph of the arterial distribution and of the mucosal surface. Collateral arteries run inside the oblique mucosal folds (Omf).

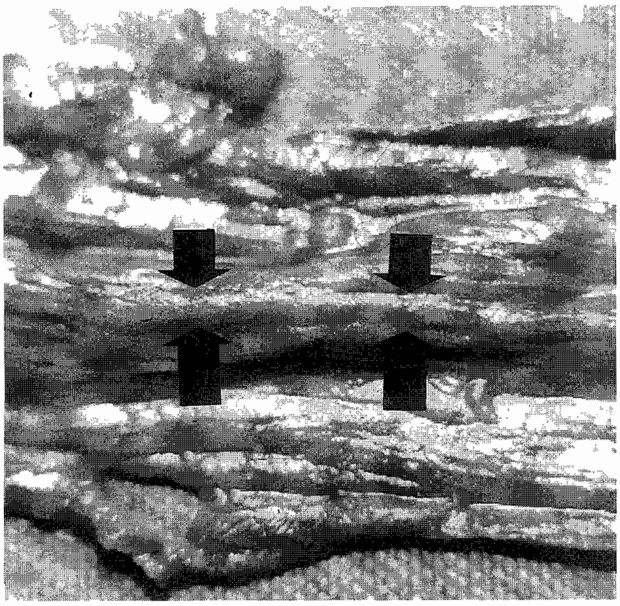

Fig. 7. Distal colon of a rat. Optical image. In the relaxed colon the mucosal surface ascends in 5 to 6 similar longitudinal folds (→).

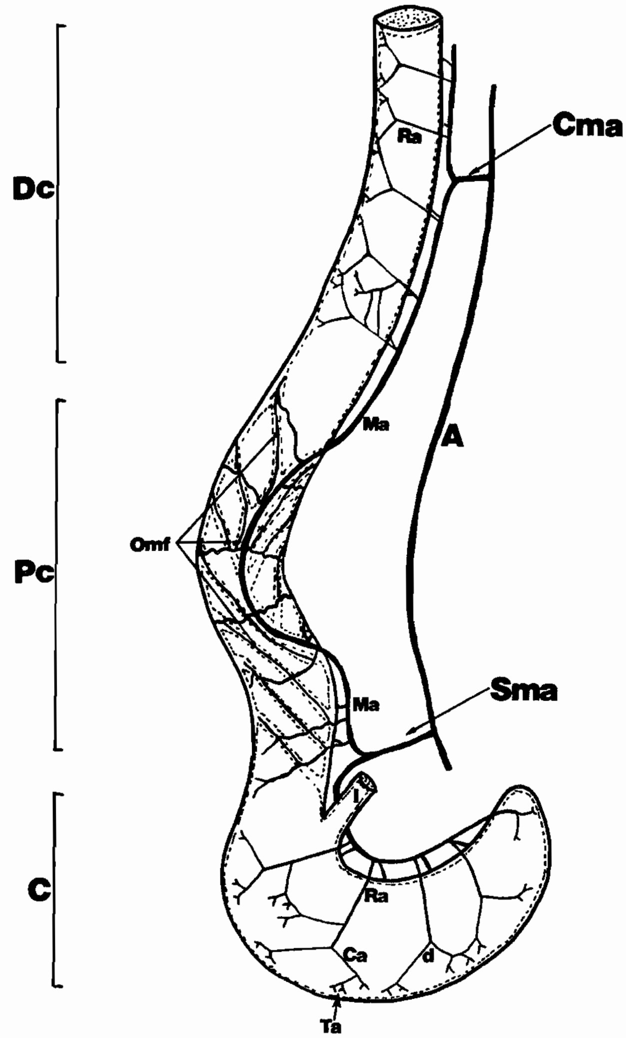

Fig. 8. Schematic drawing of an isolated rat colon. (A) Aorta; (Cma) Caudal mesenteric artery; (Sma) superior mesenteric artery; (Ma) mesenterial arteries; (Ra) rectilinear arteries; (d) dichotomy; (Ca) collateral arteries; (Ta) terminal arteriolae; (I) ileum; (C) cecum; (Pc) proximal colon; (Dc) distal colon; (Omf) oblique mucosal folds with collateral branches of rectilinear arteries.

but when the organ is relaxed the wall ascends into 3 to 4 longitudinal folds separated by furrows (Fig. 7). The average thickness of the distal colon wall is 371 μ.

Discussion

The comparison of arterial and mucosal morphology of the isolated rat colon prompts a simple subdivision of the large intestine into cecum, proximal colon and distal colon (Fig. 8). This comparison highlights the correspondence between arterial and mucosal structures. In addition, a radiologic measurement of the colonic wall thickness substantiates a subdivision of the colon into 3 parts.

Cecum. The cecum of the rat is 5 to 8 cm long; it is the largest part of the colon (5), sack-shaped (3) and has 2 poles: proximal and distal, and 2 curvatures: the lesser and the greater. The distance between the 2 poles is the longer axis which measures 4 to 7 cm, while the distance between the 2 curvatures is the shorter axis and measures 2 to 3 cm. The cecum does not have a vermiform appendix (3–5). The outlet of the distal ileum is in the lesser cecal curvature and, next to it, at the level of the distal cecal pole, the colon assumes a tubular morphology. In the cecum the emergence of rectilinear arteries from the mesenterial artery is at right angles. Rectilinear arteries then fan out towards the greater curvature. The mucosal surface of the insufflated cecum does not present folds.

Proximal colon. From its cecal origin the proximal colon is 7.5 to 9 cm long. Our anatomic description differs from that of others (2, 3, 5) because in the isolated organ the colonic inflexions (denoted smaller and major flexures) (5) are much less evident (Figs 5–8). In the proximal colon rectilinear arteries emerge from the mesenterial artery either at an acute angle or at almost right angles and are united by transversal collateral arteries. These collateral arteries are inside the mucosal folds, which are also obliquely orientated. Thus, a correspondence exists between the mucosal and arterial topography (Figs 6–8). Mucosal folds persist in the insufflated colon. The proximal colonic wall is thicker than other parts of the colon.

Distal colon. The distal colon in the rat is 5 to 7 cm long and runs straight down to the rectum, which presents similar characteristics (5). The rectilinear arteries originate from mesenterial arteries at almost right angles. The mucosal surface of the insufflated colon is devoid of folds in this segment.

Since our subdivision of the rat colon was nontopographic and only concerned with the microradiologic, mucosal and arterial anatomy of the isolated colon, it constitutes a simplification of subdivisions presented by others (2–5), who have emphasized inconstant structures such as the smaller flexure, or have differentiated portions of the colon presenting similar characteristics, such as the distal colon and rectum. The subdivision of the colon proposed by us is relatively similar to DUMAS' macroscopic observations (4) jynd is justified by the microradiographic agreement between mucosal and arterial characteristics and by the thickness of various portions of the colon wall.

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