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Venous Circulatory Changes in the Abdomen and Lower Extremities Attending Intestinal Distention.

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Scott and Wangensteen[1,2] observed that loss of blood into the infarcted gut in strangulating obstructions constituted an important factor in causing shock. It appeared equally significant to determine whether intestinal distention *per se* affects the circulation. To this end, the effect of intestinal distention upon the venous pressure in the lower extremities, the circulation time, the inferior vena cava, and the portal venous pressures was determined.

Method. (a) The first group of experiments was performed on healthy adult dogs under intravenous pentobarbital sodium (35 mg/kg) anesthesia, maintained by intermittent intramuscular administration. A small water-filled rubber balloon with a negligible pressure of its own was placed in the peritoneal space and connected to an external water manometer for recording of intraperitoneal pressure. The abdomen was then sutured closed. The sural vein to carotid circulation time was determined at intervals by the sodium cyanid method (Loevenhart, et al[3]). Air was injected per rectum in 5 and through the esophagus in 2 animals through a cervical esophagostomy. In this series no record was kept of the amount of air injected or of the intraluminal pressure.

(b) In a second series of animals, lateral venous pressures in the femoral or sural vein were determined by dividing the vessel and connecting the 2 segments to a small paraffined T-tube (Burton-Opitz[4]) which communicated with a saline manometer. The intraluminal pressure was measured by a manometer placed in the air injection system. Carotid blood pressure was obtained in the usual manner. Circulation times and intraperitoneal pressures were determined as in (a).

(c) In a third series of dogs, lateral pressure in the inferior

1 Scott, H. G., and Wangensteen, O. H., Proc. Soc. Exp. Biol. and Med., 1932, **29**, 744.

2 Scott, H. G., *Arch. Surg.*, 1938, **36**, 816.

3 Loevenhart, A. S., Lorenz, W. F., Martin, H. G., and Malone, J. Y., *Arch. Int. Med.*, 1918, **21**, 109.

4 Burton-Opitz, R., *Am. J. Physiol.*, 1903, **9**, 198.

vena cava was determined by cannulation of the renal vein after nephrectomy, establishing connection with a saline manometer. This method was supplanted in later experiments by insertion of a No. 10 F or No. 12 F urethral catheter through the femoral vein up into the inferior vena cava, the catheter then being connected to the manometer. Carotid or femoral arterial blood pressures were obtained. Lateral portal venous pressure was observed by either (a) cannulating the divided splenic vein (Bayliss and Starling[5]), (b) cannulating the divided inferior mesenteric vein, or (c) insertion of a paraffined T-tube between the segments of the divided portal vein itself, the cannula in any case being connected to a saline manometer. The intraluminal, intraperitoneal, and saphenous (or femoral vein) pressures were recorded. In some experiments the intraluminal pressure was steadily increased; in others, the pressures were maintained at a predetermined level by a constant pressure (Perusse[6]) bottle. The duration of the experiments varied from 2 to 8 hours.

(d) To determine the effect of increased intestinal pressure on the mesenteric venous pressure itself, a small dog was anesthetized with intravenous pentobarbital sodium. The upper jejunum was divided and the distal stoma cannulated and connected to a water manometer and air injection system; the terminal ileum was ligated. Venous pressures were determined in different veins of the mesentery with each increase of intraluminal pressure.

(e) The ankle venous pressure using the method of Griffith, Chamberlain, and Kitchell[7] and the circulation time from an ankle vein to the carotid were determined in 5 cases of clinical intestinal obstruction on admission to the hospital.

(f) The effect of opening the abdomen on the intraluminal pressure of distended bowel was studied in rabbits anesthetized with intravenous pentobarbital sodium. The terminal ileum was ligated, the duodenum cannulated and connected to the air injection system with a water manometer, and the abdomen sutured closed. The gut was then distended and the incision opened gradually, noting the pressures. The effects on the pressure of injecting or aspirating small quantities of air were recorded.

Results. (a) In the first series of dogs (Table I) distention was continued until respiration was almost entirely prevented and

[5] Bayliss, W. M., and Starling, E. H., *J. Physiol.*, 1894, **16**, 159.

[6] Perusse, G. L., *Surg., Gynec., and Obst.*, 1932, **54**, 770.

[7] Griffith, G. C., Chamberlain, C. T., and Kitchell, J. R., *Am. J. Med. Sci.*, 1934, **187**, 371.

TABLE I.
Effects of Experimental Intestinal Distention on Sural Vein to Carotid Body Circulation Time (Sodium Cyanid) and on Intraperitoneal Pressure.

Dog	Circulation time (seconds) Initial	Final	Increase	Intraperitoneal pressure increase (cm water)	Route of air injection
1	14	33	19	8 ↔ 13	Rectum
2	42	48	6	6 ↔ 19	ʼʼ
3	11	15	4	11 ↔ 14	ʼʼ
4	11	19	8	2	ʼʼ
5	17	135	118	6 ↔ 16	ʼʼ
6	10	23	13	1 ↔ 2	Esophagus
7	13	87	74	14	ʼʼ

cyanosis was present. An increase of circulation time from the lower extremity and an increase of intraperitoneal pressure was a constant accompaniment of the distention.

(b) In the second series of dogs (Table II) death occurred in each case from shock, being attended by dyspnea and cyanosis. In dog No. 4, shock appeared 6 hours after the distention was started. Elevation of the caudal extremity in steep Trendelenburg (45° downward tilt of the head) and transfusion with 500 cc of freshly drawn citrated blood revived the animal. It was sacrificed, however, and the bowel found to be badly discolored and engorged with blood, frank blood being found free in the peritoneal space. The venous pressure in the lower extremities steadily increased with increased intraluminal tension, a corresponding lengthening of circulation time being observed. In each animal a temporary rise of arterial blood pressure occurred with beginning distention.

(c) In the third series of dogs (Table III) the same rise of venous pressure in the lower extremities was found to accompany the increased intraperitoneal pressure attending the increased intraluminal pressure. Although no significant variation in inferior vena cava pressure was observed, the portal venous pressure underwent an early rise followed by a fall to a constant level. A temporary rise in arterial blood pressure corresponding to the temporary elevation in portal pressure was also observed, a chart of a sample experiment (dog No. 4, Table III) being shown in Figure 1.

(d) From Table IV it may be seen that a drop of mesenteric venous pressure accompanies increases of intraluminal pressure. When, however, the intraluminal pressure is increased from 50 to 100 cm water there is no change in the mesenteric venous pressure.

(e) In cases Nos. 2 and 3 of the clinical intestinal obstructions (Table V) the venous flow from the lower extremity was so retarded that the typical respiratory response to sodium cyanid could

TABLE II.

Effects of Experimental Intestinal Distention on Sural Vein to Carotid Body Circulation Time (Sodium Cyanid), Intraperitoneal Pressure, Carotid Blood Pressure and Venous Pressure in the Lower Extremities.

Dog	Duration of experiment	Intraluminal pressure increase (cm water)	Intraperitoneal pressure increase (cm water)	Initial consecutive arterial blood pressure (mm Hg)*	Initial and final venous pressure (cm water)	Circulation times consecutive determinations (seconds)
1	3 hr	30	36	(a) 105 (b) 125	2 47	
2	39 min	106	19 ↔ 24	(a) 135 (b) 150	3 17	(a) 15 (b) 24 (c) No typical response
3	35 min	130	16	(a) 120 (b) 170	3 11 (4.5 after deflation of bowel)	(a) 14 (b) 39 (c) 43
4	7 hr	180	35	(a) 140 (b) 180	4 58+	(a) 27 (b) 37 (c) 2 min after placing in steep Trendelenburg

* Consecutive 10- to 20-min determinations.

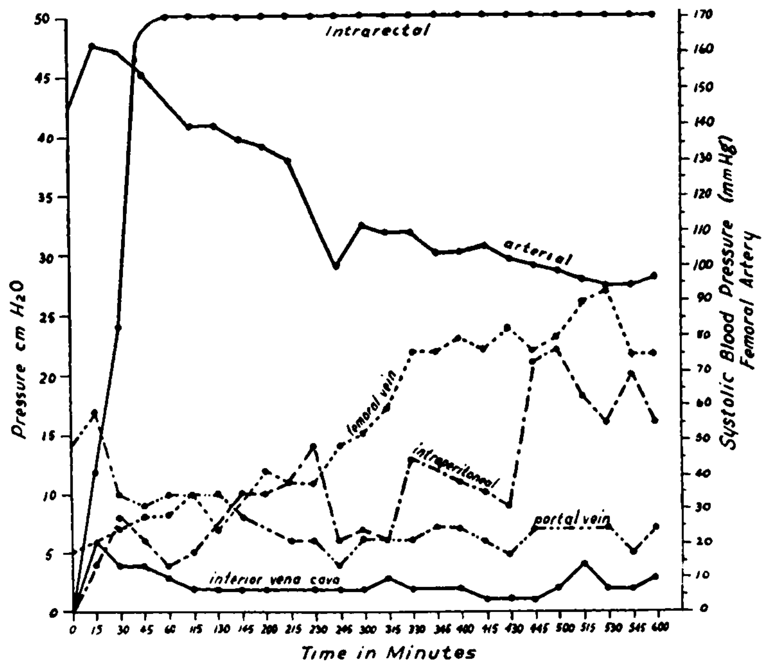

FIG. 1.
Intraintestinal Air Insufflation. Relation between arterial blood pressure, femoral venous pressure, inferior vena cava pressure, intraperitoneal pressure, and portal venous pressure. Intrajejunal pressure 50 cm water. (Table III, dog 4.)

only be elicited by placing the patient in the Trendelenburg position after injection into the ankle vein. The normal venous pressure and circulation time in case No. 4 is explained by the relatively small amount of distention found at operation.

(f) In a distended rabbit, when the intraluminal pressure was elevated to 104 cm water, opening the incision caused the pressure to fall to 84 cm water with rupture of the gut. In another animal the pressure was raised to 83 cm water, the tension dropping to 66 cm water when the abdomen was opened. In a third rabbit, aspiration and re-injection of 5 cc quantities of air into the distended bowel gave corresponding decreases and increases of intraluminal pressure of about 5 cc water. When the incision was opened 4 cm the intraluminal pressure dropped, additional pressure drops being noted when the incision was opened more. Exteriorization of bowel segments caused the intraluminal pressure to fall, exteriorization of

TABLE III.
Relation between Intraluminal, Intraperitoneal, Femoral Vein (or saphenous), Inferior Vena Cava, Carotid Artery (or femoral artery), and Portal Vein Pressures in Distended Dogs (bowel inflated with air).

Dog	Duration of experiment	Amount of air injected, cc	Arterial blood pressure, mm Hg*	Intra-luminal in gut, cm water	Intra-peritoneal, cm water	Femoral or saphenous vein,† cm water	Inferior vena cava, cm water	Portal vein pressure, cm water*
1	1 hr 55 min	2600	(a) 120 (b) Fall	0 100	0 10	3 43	8 (Through divided renal vein)	—
2	2 hr 25 min	3200	(a) 100 (b) Fall	0 202	0 18	10 31+	4 2 0 (Through divided renal vein)	—
3	6 hr	—	(a) 135 (b) 155 (c) Fall	100	0 10	7 21+	3 8 (Through catheter in femoral vein)	—
4	6 hr	—	(a) 144 (b) 162 (c) Fall	50	0	5 22	2 (Through catheter in femoral vein)	(a) 14 (b) 17 (c) 7 (Through divided inferior mesenteric vein)
5	8 hr 30 min	2250	(a) 110 (b) 115 (c) Fall	0 30	0 9	10 15	7 (Through catheter in femoral vein)	(a) 18 (b) 22 (c) 4 (Through divided splenic vein)
6	8 hr 15 min	—	(a) 110 (b) Fall	50	3 4	5 11	6 (Through catheter in femoral vein)	(a) 17 (b) 26 (c) 8 (T-tube in portal vein)

* Consecutive 10- to 20-min determinations.
† Initial and final readings.

TABLE IV.
Relation of Intraluminal Pressure in Bowel of Dogs to Mesenteric Venous Pressure Attending Inflation of Gut with Air.

Intraluminal pressure (cm water)	Mesenteric venous pressure (cm water)
0	13
10	12
20	12
30	12
40	10
50	6
60	5.5
70	5
80	5
90	6
100	6

longer bowel segments giving additional pressure drops. This was confirmed in a fourth animal.

In the main, the experimental intraluminal pressures employed in this study exceeded considerably those occurring spontaneously in the course of the distention accompanying acute clinical intestinal obstructions. Observations made previously during the course of intestinal obstruction occurring in man, as well as in obstructions established experimentally in dogs, suggest that the ordinary range of sustained intraluminal pressures for the small bowel varies from 4 to 18 cm of water, 10 to 14 cm being usual. In acute obstructions of the colon in man, however, higher intraluminal pressures are the rule and pressures in excess of 20 are observed not uncommonly; on one occasion a pressure as high as 52 cm occurred (Sperling, Paine and Wangensteen[8]). The temporary increase of portal venous pressure and arterial blood pressure early in distention may be due to the sudden increased volume of blood forced from the intestinal vessels into the portal system, though a reflex vasomotor mechanism can not be excluded. The shock that occurs late in clinical intestinal obstructions and in the experimental distentions is due partly to the stasis in the vessels between the mesenteric arteries and the portal vein and partly to a mechanical impediment to the return of blood from the lower extremities. The increased pressure in the veins of the lower extremity and the lengthened circulation time in the experimental distentions are in accord with such a thesis. The circulatory stasis in the lower extremities and mesenteric area attending intestinal distention may interfere with the volume of circulating blood sufficiently to provoke shock unless relieved early by con-

[8] Sperling, L., Paine, J. R., and Wangensteen, O. H., PROC. SOC. EXP. BIOL. AND MED., 1935, **32**, 1504.

TABLE V.
Venous Pressure (Ankle Vein) and Circulation Time (Ankle Vein to Carotid Sinus by Sodium Cyanid Method) in Patients with Clinical Intestinal Distention.

Case		Venous pressure ankle (cm water)	Circulation time (seconds)	
			Cubital to carotid	Ankle vein to carotid
1	(Carcinoma of pelvic colon with acute obstruction; pressure at operation 20 cm water; 1800 cc gas aspirated)	12	20	52
2	(Carcinoma of pelvic colon; pressure at operation 15 cm water; 1500 cc gas aspirated)	15.5	19	No response in horizontal. 22" in 30° Trendelenburg*
3	(Carcinoma of stomach with distention owing to metastases)	17.5	18	No response in horizontal. 15" in 30° Trendelenburg*
4	(Mass in terminal ileum treated conservatively by suction; 5 days later ileostomy; intraluminal pressure 14 cm water; 600 cc gas and fluid aspirated at operation)	3	22	35
5	(Abdominal injury with marked intestinal distention treated conservatively by suction applied to indwelling duodenal tube)	29	12	49

* Downward inclination.

servative decompression (Wangensteen[9]). The Trendelenburg posture would appear to be an effective agency in interrupting the impediment to venous return from the lower extremities occasioned by abdominal distention.

Summary. 1. Experimental intestinal distention of anesthetized dogs produces an elevation of intraperitoneal pressure which, however, does not increase at the same rate as the intraluminal pressure. 2. Venous pressure in the lower extremities of experimentally distended, anesthetized dogs increases with increasing intraperitoneal pressure. At the same time, the rate of blood flow from the lower extremities to the carotid is slower. 3. Shock, eventually produced by prolonged intestinal distention, is relieved by deflation, blood transfusion and the steep Trendelenburg position. 4. Intestinal distention is attended by diminished respiratory movements, stasis of abdominal and peripheral venous blood, and extravascular loss of whole blood and plasma. 5. Pressure in the inferior vena cava is not observed to be altered in experimental intestinal distentions in which the intraintestinal pressures reached 50 cm of water—a pressure in excess of the upper limit of sustained intraluminal pressure observed clinically. 6. Following a temporary initial rise in portal venous pressure, a gradual fall to a constant low level is noted with continued experimental intestinal distention. 7. Early in intestinal distention, a temporary rise in arterial blood pressure is present. 8. With the abdomen open, increase of intraluminal pressure in the anesthetized dog results in a fall of mesenteric venous pressure to a constant level. 9. In clinical intestinal obstructions, there is an increase of venous pressure in and a delay in return of blood from the lower extremities. 10. Addition or aspiration of small quantities of air from the distended rabbit intestine causes corresponding increases or decreases of intraluminal pressure. Opening the abdomen or exteriorization of segments of bowel in such an animal causes fall in intraluminal pressure.

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[9] Wangensteen, O. H., *The Therapeutic Problem in Bowel Obstructions*, Springfield, Ill., 1937, Charles C. Thomas.