PROCEEDINGS OF THE SOCIETY FOR EXPERIMENTAL BIOLOGY AND MEDICINE 157, 390–392 (1978)

The Distribution of Blood Flow Along the Small Intestine of The Dog (40060)

MICHAEL N. EADE AND RODNEY W. GINN

Department of Physiology, School of Medicine, Auckland University, Auckland, New Zealand

The presence of a blood-flow gradient along the small intestine is disputed. Geber (1), using electromagnetic flowmeters in dogs, and Steiner and Mueller (2) using the indicator fractionation technique in rats demonstrated that blood flow per unit weight was highest in the duodenum and then decreased progressively along the jejunum, ileum, and colon. On the other hand, Grim and Lindseth (3) using direct collection of venous outflow isolated loops of intestine in the dog, and Delaney and Custer (4) using the indicator fractionation technique in dogs did not observe a blood flow gradient. The negative view has also been supported by a more recent study of Goodhead (5) using the indicator fractionation technique in the dog.

This paper presents evidence that a blood flow gradient does exist in the small intestine of the dog when it is studied under basal conditions of anesthesia.

Materials and methods. Eighteen mongrel dogs weighting 15–30 kg were given water but no food for 24 hr in the preparation period. General anesthesia was then induced and maintained with intravenous pentobarbitone sodium (30 mg/kg). Blood pressure and heart rate were monitored from a femoral artery catheter and body temperature was kept at 37.5°. Care was taken to perform all blood flow measurements when these functions were stable.

Intestinal blood flow was measured by the indicator–fractionation technique with ^{42}K (15 μCi/kg) as the indicator. The ^{42}K was injected into the inferior vena cava and tissue ^{42}K content 100 sec after the injection was used for all blood flow calculations (5–8). The cardiac output was measured by the conventional dye dilution technique (9) immediately prior to the injection of the ^{42}K. Cardiac arrest was produced by a rapid injection of saturated magnesium sulphate into the inferior vena cava and this enabled removal of 3–5 cm sleeves of intestine for ^{42}K assay from the third part of the duodenum, the jejunum (10 cm distal to the ligament of Trietz), and the distal ileum (30 cm proximal to the ileo-caecal valve). Additional 3–5 cm sleeves of intestine were also taken from the jejuno-ileum in eight of these dogs. The mesentery and excess fat were removed, the intestine tissue weighed and then ^{42}K was measured in a Baird atomic γ-well counter.

All animals were studied under anesthesia with no attempt to vary the intestinal blood flow. Seven dogs were studied without prior laparotomy but eleven dogs had a midline laparotomy to enable identification of intestinal regions before the blood flow measurements were made. In these dogs, the midline incision was held closed by metal clips to permit rapid removal of intestinal tissue following cardiac arrest.

Results. Table I shows the blood flow per 100 g tissue in the intestine of the 18 dogs studied. On a two-way analysis of variance there was a significant difference of blood flow in the duodenal, jejunal and distal ileal sites ($P < 0.01$), and on Scheffé multiple comparison tests the mean blood flow in the distal ileum was significantly lower than in the duodenal site ($P < 0.05$) or jejunal site ($P < 0.05$). There was no significant difference of blood flow between the duodenal and jejunal sites. In the 8 studies in which jejuno-ileal blood flow was also measured, the mean blood flow in the distal ileum was significantly lower than in the jejuno-ileal site ($P < 0.01$). Blood flow in the jejuno-ileal site was lower than in either the duodenal or jejunal sites but this difference was not significant ($P > 0.05$).

In the 18 studies the mean intestinal blood flow to all sites was significantly higher ($P < 0.05$) in those with cardiac output > 10 ml/min per 100 g. This is reflected by a generally higher blood flow to specific intestinal regions in the seven dogs without laparotomy since the cardiac output was somewhat higher in these animals (14.1 ml/min per 100 g, s.d. 3.2 ml) than in the 11 with

0037-9727/78/1573-0390$01.00/0

TABLE I. INTESTINAL BLOOD FLOW MEASURED BY THE INDICATOR FRACTIONATION TECHNIQUE IN ANESTHETIZED DOGS (ml/min per 100 g INTESTINAL TISSUE).

Dog No.	Cardiac output (ml/min per 100 g body wt)	Duodenum	Jejunum	Jejuno-ileum	Distal-ileum
		No laparotomy prior ^{42}K injection			
1	11.0	58	59		30
2	9.6	60	59		42
3	14.3	68	72		47
4	13.5	71	70		48
5[a]	18.8	78	80		175
6	16.6	92	92		64
7	15.0	99	93		47
Dogs 1–7 Mean (s.d.)	14.1 (3.2)	75 (16)	75 (14)		65 (49)
Dog 5[a] excluded: Mean (s.d.)	13.3 (2.6)	75 (17)	74 (15)		46 (11)
		Laparotomy prior to ^{42}K injection			
8	7.1	36	36	25	21
9	7.6	39	35	33	31
10	9.2	41	43	44	37
11	7.5	46	48		32
12	6.5	47	45	44	35
13	8.0	53	61	57	34
14	6.6	56	50	45	38
15	11.8	56	73		38
16	10.7	64	75	57	42
17	11.8	78	76	71	42
18	15.0	103	110		52
Dogs 8–18 Mean (s.d.)	9.3 (2.7)	56 (20)	59 (23)	47 (14)	37 (8)

[a] Ileal sample heavily bile stained (see text).

laparotomy (9.3 ml/min per 100 g, s.d. 2.7 ml).

In these studies only one animal (Dog 5) had a large amount of bile in the distal ileum, and this was the only animal in which blood flow in the distal ileum was greater than in either the duodenal or jejunal sites. If this animal was excluded from analysis, then the difference between blood flow in the distal ileal site and the duodenal or jejunal sites was even more significant ($P < 0.001$).

Discussion. The experiments show that when intestinal blood flow is measured under basal conditions in the dog there is a definite gradient of blood flow down the intestine. Flow is highest in the duodenum and jejunum, and diminishes progressively in the jejuno-ileum and distal ileum. In the distal ileum the mean flow is only 65% of that in the duodenum or jejunum. This gradient was observed whether or not the abdomen had been opened prior to the measurement. In one dog the blood flow gradient was reversed, the distal ileum having more than twice the blood flow (per unit weight) of the duodenum and jejunum. In this study, bile was observed in the lumen of the distal ileum, and since bile salts are absorbed in this region by a highly specific, energy dependent, active transport mechanism (10) it is possible to speculate that bile salts may stimulate blood flow in this region.

In the seven studies in which laparotomy was not performed, the duodenal and jejunal blood flow averaged 75 ml (s.d. 14) per min for 100 g tissue. This is very similar to the figure of 72 ml/min reported by Delaney (11) in dogs and the 68 ml/min noted by Ross (12) in cats. In the 11 basal studies in which laparotomy had been performed, the duodenal and jejunal blood flows averaged 58 ml (s.d. 21) per min for 100 g tissue. This reduction in intestinal blood flow is of the same magnitude as the reduction in gastric blood flow noted by Delaney and Grim (13) as an effect of laparotomy. The blood flow figure of 58 ml/min per 100 g when the abdomen had been opened is very similar to the figure of 60 ml/min per 100 g noted by Grim (14) using a direct bleed-out technique in isolated loops of intestine in the dog.

In previous studies several authors (3–5)

have not observed a blood flow gradient down the intestine when measurements were made under basal conditions. However, these papers are a little misleading, since Goodhead (5) did observe differences but was not able to demonstrate statistical significance because his measurements showed a s.d. of 50%. In the paper by Delaney and Custer (4) the blood flow was measured in only two sites, the duodenum and the rest of the small intestine as a whole; in these sites the blood flow figures of 70 ml and 72 ml/min per 100 g tissue were not significantly different. Since blood flow in the jejunum, jejuno-ileum and distal ileum was not measured separately, the differences which we report might well have been obscured. Finally, the study of Grim and Lindseth (3) measured jejunal and ileal blood flow by direct collection of venous outflow from isolated loops of intestine. The operative manipulations involved in preparing an isolated loop, and in particular the cannulation of blood vessels may have modified blood flow and thus prevented differences from being observed.

Whatever the problems may have been in these earlier studies, the data presented in this current paper clearly support the observation of Geber (1) and Steiner and Mueller (2) that under basal conditions there is a blood flow gradient down the intestine, with blood flow (per unit weight) highest in the duodenum and lowest in the distal ileum.

This work has been supported by grants from the Medical Research Council of New Zealand and the Golden Kiwi Medical Distribution Committee. We should also like to thank Miss Lynnette L. Gilmore, Biostatistician, for assistance with the statistical analyses.

1. Geber, W. F., Amer. J. Physiol. **198,** 985 (1960).
2. Steiner, S. H., and Mueller, G. C. E., Circ. Res. **9,** 99 (1961).
3. Grim, E., and Lindseth, E. O., Med. Bull. Univ. Minnesota **30,** 138 (1958).
4. Delaney, J. P., and Custer, J., Circ. Res. **17,** 394 (1965).
5. Goodhead, B., Amer. J. Physiol. **217,** 835 (1969).
6. Sapirstein, L. A., Amer. J. Physiol. **193,** 161 (1958).
7. Sapirstein, L. A., Gastroenterology **52,** 365 (1967).
8. Mendell, P. L., and Hollenberg, N. K., Amer. J. Physiol. **221,** 1617 (1971).
9. Williams, J. C. P., O'Donovan, T. P. B., and Wood, E. H., J. Appl. Physiol. **21,** 695 (1966).
10. Tyor, M. P., Garbutt, J. T., and Lack, L., Amer. J. Med. **51,** 614 (1971).
11. Delaney, J. P., Surgery **62,** 155 (1967).
12. Ross, G., Proc. Soc. Exp. Biol. Med. **137,** 921 (1971).
13. Delaney, J. P., and Grim, E., Amer. J. Physiol. **207,** 1195 (1964).
14. Grim, E., in "Handbook of Physiology" (W. Hamilton and P. Dow, eds.), Sect. 2, Vol. 2, p. 1439, American Physiological Society, Washington, D.C. (1963).

Received July 25, 1977. P.S.E.B.M. 1978, Vol. 157.