ESTIMATION OF RATE OF PORTAL BLOOD FLOW IN RUMINANTS: EFFECT OF FEEDING, FASTING, AND ANESTHESIA

The direct estimation of the total amounts of metabolites absorbed from the gastrointestinal tract involving arterio-portal differences in concentrations requires estimates of the portal blood flow rate, to convert portal concentrations into the absolute quantities absorbed. In using this approach to estimate the amounts of volatile fatty acids (VFA's) absorbed, Anison et al. (2) employed the average rate of portal blood flow of 37 ml/min/kg of body weight derived by Schambye (11, 12). Conrad et al. (4) used the average blood flow values obtained with anesthetized animals to estimate the extent of the absorption of VFA's from the forestomachs of calves. Aside from Schambye's (12) portal blood flow determinations, the only other measurements in unanesthetized ruminants are the ones reported recently by Fries and Conner (9) and Waldern et al. (14).

In these experiments the times at which the blood flow determinations were conducted did not seem to be related to the times of feeding. Fegler and Hill (8) measured portal blood flow rate in anesthetized sheep and correlated it to cardiac output. Ambo and Umezu (1) estimated the ratio of portal blood flow rate to hepatic arterial blood flow rate in anesthetized goats. To our knowledge, in all direct absorption experiments reported to date, a constant portal blood flow value was assumed and, furthermore, this value was not obtained with the same experimental animals from which blood samples were taken for the estimation of the concentration of metabolites. It is difficult to conceive that the flow rate of portal blood is constant in light of the work of Herrick et al. (10), which points to variations in the blood flow rate in other vessels (in the dog) at intervals after feeding and which, therefore, infers the possibility of a similar occurrence in the portal vein.

The present study had, as one of its objectives, that of testing the preceding hypothesis as well as that of determining the effect of anesthesia on the portal blood flow rate. The data reported here constitute a portion of the results obtained in absorption studies in which serial measurements of the portal blood flow rate and concurrent serial samplings of the portal and carotid blood were taken during the same experimental periods from the same animal, for the determination of certain metabolites.

EXPERIMENTAL METHODS

Animals and rations. Western white-faced sheep equipped with an exteriorized carotid loop and a rubber rumen cannula were fed the same diets for a period of at least a month. The animals were fed once daily and received, respectively: Sheep 1, 1.0 kg of finely ground hay; Sheep 2, 1.0 kg of chopped hay; Sheep 4, 1.3 kg of hay pellets; and Sheep 6, 0.5 kg of chopped hay.

Blood flow measurement. The blood flow technique used is the thermodilution technique developed by Fegler (6, 7) and Fegler and Hill (8). This method is based on the indicator-dilution procedure of Stewart (13). A small amount of saline of known temperature, but cooler than the circulating blood, was injected into the anterior mesenteric vein and the changes in temperatures were recorded downstream in the portal vein. The blood flow rate was then calculated from the recorded thermodilution curve. Schambye (11) has given good evidence to support the view that indicator substances infused in a peripheral portal branch are well mixed by the time they reach the portal vein. As pointed out by Fegler (7), there is no problem of the accumulation of a foreign substance in the circulation when saline is used and, therefore, a large number of measurements can be made at intervals of a few minutes. Certain modifications were made in the original method: the temperature changes were measured by a 100,000 ohm thermistor with a time constant of 1 sec and Sanborn recording equipment was used for continuous recordings.

Surgical preparation for blood flow measurement and blood sampling. One week before the experimental day, except when indicated otherwise, the surgery necessary for blood flow measurements and blood sampling was performed. The animals were starved for 18 hr prior to the surgical operations to facilitate removal of rumen contents, using a vacuum pump. This emptying of the rumen was an essential step in providing an easier approach to the portal region.

The abdomen was opened by a paracostal incision 1-inch lateral, and parallel, to the last right rib. The jejunum was exposed, and a branch of the anterior mesenteric vein was cannulated with No. 260 polyethylene tubing. The catheter was gently inserted in the aforementioned vein until it reached the portal vein. Due to the anatomical disposition of the gastro-splenic-portal junction (Figure 1), the tip of the tubing often enters the gastro-splenic vein. The exact position of the tubing tip can be assessed by palpation of the portal vein. This catheter was used during the experimental period as a means of inserting a temperaturesensing unit. A catheter for cold saline injection was introduced into another branch of the anterior mesenteric vein, with its tip in the...
main trunk of the mesenteric vein. The two catheters were held in place by suturing surgical sponge rings fitting snugly the catheters to the mesentery.

The sampling catheter was introduced directly into the portal vein as shown in Figure 1. A purse-string suture was first made in the wall of the portal vein at the level of the hepatic lymph node. Three of four stitches of nylon (no. 000) gave satisfactory results. The blood flow in the vein was then shut off by gently constricting the vein between two fingers. An opening in the vein wall was then made, and polyethylene tubing (No. 200, 2-mm internal diameter) with a small flange at its tip was introduced into the vein. The suture was completed and the tubing pulled slowly until the flange rested against the vein wall.

The three catheters were sutured to the skin at the point where they passed through the body wall. To control infection at the point of exit of the tubings, a mixture of penicillin and streptomycin was injected under the skin for the first five days following the operation. In addition, the skin around the stab wounds was everted and snugly tied around the catheters. When the latter precautions were taken, a preparation relatively free of infection for periods of 3 to 4 wk or more was obtained. At the end of the operation, 1,000 IU of heparin per kg of body weight were given intravenously and an additional 15,000 IU were administered every 6 hr thereafter. Even with the precautionary method of flushing the catheters every 6 hr, they could not be maintained patent for a period longer than 5 wk.

Volatile fatty acid analysis. Total VFA concentrations were determined by steam-distillation (3).

RESULTS AND DISCUSSION

In each experiment an attempt was made to obtain as many individual portal flow measurements as possible. A blood flow pattern with individual measurements is given for Sheep 1 in Figure 2. Results obtained for each sheep were averaged for consecutive periods of 2-hr duration after feeding in Table 1. In all cases there was a definite increase in portal blood flow within 3 and 7 hr after feeding. The maximum average increase during any 2-hr period over the prefeeding levels for Sheeps 1, 2, 4, and 6, respectively, were: 82, 56, 169, and 73%. Herrick et al. (10), working with dogs, reported an increased blood flow after feeding in the superior mesenteric artery of 61% over the prefeeding level. In the experiments of Herrick et al., increases in blood flow due to feeding were also observed in the femoral artery, the carotid artery, and the jugular vein.

The effect of anesthesia and fasting on portal blood flow were studied with one sheep. Just after surgery was completed on Sheep 6, the animal was kept under anesthesia and the portal blood flow measured. The average blood flow rate for six observations during a period of 3 hr was 0.81 ± .08 liter/min. Two days later, the portal blood flow was measured in the same animal in the conscious, fasted state. The average blood flow rate for seven determinations during an experimental period of 6 hr was 1.3 ± .14 liters/min. Seven days after the surgery, the average portal blood flow rate between 3 and 5 hr after being fed a meal of 500 g of chopped hay was 1.82 liters/min. A similar decrease in the flow of portal blood due to both laparotomy and nembutal anesthesia has been reported by Schambuye (12), Fries and Conner (9), and Fegler and Hill (8). Another interesting observation made in this experiment, and in the experiments conducted with the other animals, is the reasonably small standard deviations associated with the mean portal blood flows measured over short periods, in which the animal is in a relatively constant physiological state. This suggests that a reasonably accurate estimate of blood flow can be
TABLE 1
Average portal blood flow rates during 2-hr intervals after feeding

<table>
<thead>
<tr>
<th>Hours after feeding</th>
<th>-1 to 1</th>
<th>1 to 3</th>
<th>3 to 5</th>
<th>5 to 7</th>
<th>7 to 9</th>
<th>9 to 11</th>
<th>11 to 13</th>
<th>13 to 15</th>
<th>15 to 17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sheep 1</td>
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<td></td>
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<tr>
<td>Portal flow (liters/min)</td>
<td>0.60</td>
<td>0.55</td>
<td>0.55</td>
<td>1.09</td>
<td>0.71</td>
<td>0.71</td>
<td>0.64</td>
<td>0.73</td>
<td>0.55</td>
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<tr>
<td>Observations</td>
<td>2</td>
<td>3</td>
<td>10</td>
<td>11</td>
<td>11</td>
<td>10</td>
<td>12</td>
<td>4</td>
<td>1</td>
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<tr>
<td>Sheep 2</td>
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<tr>
<td>Portal flow (liters/min)</td>
<td>1.31</td>
<td>1.35</td>
<td>1.86</td>
<td>2.04</td>
<td>1.59</td>
<td>1.36</td>
<td>1.32</td>
<td>1.05</td>
<td>0.80</td>
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<tr>
<td>Observations</td>
<td>5</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>5</td>
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<td>Sheep 6</td>
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<tr>
<td>Portal flow (liters/min)</td>
<td>......</td>
<td>0.88</td>
<td>1.20</td>
<td>2.37</td>
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<td></td>
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<tr>
<td>Observations</td>
<td>......</td>
<td>4</td>
<td>5</td>
<td>4</td>
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<td>Sheep 6</td>
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<tr>
<td>Portal flow (liters/min)</td>
<td>1.05</td>
<td>......</td>
<td>1.82</td>
<td>1.66</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Observations</td>
<td>2</td>
<td>......</td>
<td>2</td>
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</table>

obtained from only a few determinations during a given 2-hr period.

The authors do not yet have a good explanation for the increase in portal blood flow after the ingestion of feeds in ruminants. Dobson and Phillipson (5) reported an increased portal flow in anesthetized sheep after increasing the rumen VFA concentrations. These findings prompted a study of the correlation between rumen VFA concentrations and portal blood flow. The correlation between portal VFA concentrations and portal blood flow was also studied. Although rumen VFA concentration curves and portal blood flow patterns showed similar trends (Figure 3) the correlation coefficients were not significant (Table 2).

Results obtained in this study indicate that the rate of portal blood flow may be subject to a number of physiological variations. Some of these are associated with feeding. The flow rate is low in the fasted ruminant but, after feeding, it increases markedly and reaches a maximum between 3 and 7 hr after feeding.

The rate of portal blood flow in the unconscious ruminant is considerably lower than that in the fasted, conscious animal. These data demonstrate that very misleading results can be obtained in absorption studies in which a single or an average portal blood flow value is employed to represent that during a 24-hr period. Also, it is expected that the level of metabolites absorbed by conscious animals would be greatly underestimated when the blood flow-rate value employed is determined in the unconscious animal.

ACKNOWLEDGEMENT
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REFERENCES


ESTIMATES OF HERITABILITY OF FLY SUSCEPTIBILITY IN DAIRY CATTLE

The use of chemical materials for fly-control purposes is definitely limited by excretion of insecticides or their breakdown products in milk, change in the resistance of insects to insecticides, and the short period of activity of repellents. Therefore, new approaches to fly control should be considered, along with improvement of methods in present use.

Several investigators [Pearson, Wilson, and Richardson (3), Pearson (4), and Fryer et al. (1)], working with fly repellent and insecticides on dairy cattle, have concluded that differences among cows were a primary reason for variations of fly susceptibility in their results. Data from tests at the Oklahoma Experiment Station suggested that these differences might be heritable. Therefore, a study was made in which the resemblances in fly susceptibility between dairy cows of known relationships were measured, thus estimating heritabilities.

SOURCE OF DATA

The data available for study were counts of the house fly, Musca domestica (Linn.), the stable fly, Stomoxys calcitrans (Linn.), and the horn fly, Haematobia irritans (Linn.), taken on lactating cows during 1953, 1954, 1957, 1958, 1959, and 1960. The number of counts varied from nine to 32 within different breeds and years. Yearly average counts were used as a measure of normal fly susceptibility of individual cows. Breeds represented were Ayrshire, Guernsey, Holstein, and Jersey. Counts of the three fly species were made on the whole body area of the cow, excluding the head and udder. These counts were recorded for an entire breed within a 1-hr period, thus tending to eliminate large variations due to fluctuating fly population levels. Counts were taken under a wide range of environmental conditions; therefore, each individual cow's performance was measured in different environments.

Two hundred and five paternal half-sibs representing 23 sires, and 89 dam-daughter pairs representing 25 sires, were obtained from pedigrees of cows for which fly count data were available. To take advantage of larger numbers, heritability estimates were made for combined as well as the individual breeds.

ANALYSIS OF DATA

Heritabilities were obtained by two methods. One was the paternal half-sib method in which...