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MAMMARY BLOOD FLOW AND VENOUS DRAINAGE IN COWS*

By
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KJÆRSGAARD, PER: *Mammary blood flow and venous drainage in cows*. Acta vet. scand. 1974, 15, 179—187. — The mammary blood flow and the udder drainage in vivo evaluated using the antipyrine absorption method has been compared with the anatomical findings in the udder after slaughtering of the experimental cows (Table 1).

Because of the orientation of the valves in the perineal veins and blood samples taken in vivo it must be assumed that the perineal veins lead blood toward the veins at the udder base.

It is concluded that the drainage of the udder in standing cows will primarily be through the milk veins, eventually there will be a flow of non-mammary venous blood down the external pudic veins at the udder base, as in the case of the perineal veins.

blood flow; udder; mammae; antipyrine absorption; venous drainage; cow.

It seems possible by a simple experimental technique to measure the mammary blood flow in cows using the antipyrine absorption method (*Rasmussen* 1965).

The aim of the present work was partly to examine the venous drainage of the cows udder in vivo and correlate this with the anatomical findings after slaughtering, and partly to measure the mammary blood flow.

MATERIALS AND METHODS

The experimental procedure and calculation of the mammary blood flow was performed as described by *Rasmussen* (1965), who found that the absorption of antipyrine (phenazonum, NFN**) after intramammary application was a first-order reac-

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** NFN = Nordisk Farmakopé Nævn.

tion. A solution of 6 g of antipyrine dissolved in 120 ml of sterile water was infused into the udder through the teat canal (1.5 g equivalent to 30 ml of the solution into each quarter), after the milk in the udder had been removed by "milking out" the cow. The udder was massaged for 30 sec. after infusion of the antipyrine. When periods of 15, 20, 25, 30, 35, and 40 min. had elapsed after the infusion of antipyrine, blood samples were collected simultaneously from the 2 milk veins (v. subcutanea abdominis dexter et sinister, N.A.V.*) and from the jugular vein (v. jugularis externa, N.A.V.). An intravenous injection of 10 i.u. oxytocin usually 45—50 min. after the application of antipyrine facilitated removal of residual milk from the udder. The volume of milk from each udder quarter was measured, and the concentration of antipyrine in the milk from each quarter was determined. Knowing the injected amount of antipyrine as well as the amount which was left back in the udder after a certain number of minutes, the amount of antipyrine absorbed was determined. The absorption of antipyrine is a first-order reaction so it is possible to calculate the amount of antipyrine which is absorbed during a specific time. The arterio-venous difference is also known, because *Rasmussen* has shown that the concentrations of antipyrine in the external pudic artery (a. pudenda externa, N.A.V.) and in the jugular vein are identical. A blood flow through the external pudic vein was prevented by manual clamping of the vein during every second sampling of blood. There were 5 experiments performed on each of 8 cows. In the first experiment antipyrine was infused in all 4 quarters, and then with a few days' interval, 4 experiments were performed where 6 g antipyrine was applied alternately into each quarter.

In order to prevent damage to the wall of the veins and haematomas, Braunüle 2R® was used for the blood collection. The canula was introduced in the vein by incising the overlying skin after local analgesia of the skin, using inj. lidocaini noradrenalini 1 % DAK**. Between the blood samplings the canula was filled with heparine-saline to prevent blood clotting.

In 2 cows the concentration of antipyrine in blood samples from the perineal vein (v. labialis caudalis et mammaria, N.A.V.) was measured. Blood samples were collected from canulas in

* N.A.V. = Nomina Anatomica Veterinaria, 1968.

** DAK = Danmarks Apotekerforenings Kontrollaboratorium.

this vein simultaneously with blood samples from the jugular vein and the milk veins.

The absorption of antipyrine from each quarter of the cows was calculated. It followed a half-life curve, showing that the absorption was a first-order reaction. So the experimental cows fulfilled the condition for measuring the mammary blood flow using the antipyrine absorption method (*Rasmussen*).

Antipyrine was determined according to the method of *Brodie et al.* (1949).

After slaughtering the cows, the venous system of the udders was dissected and examined. The position of the valves in the veins and their capability of preventing back flow of the blood was examined by water pressure in the unopened vein (*Rasmussen*). The veins were then opened longitudinally and the valves examined macroscopically. Besides in the cows given in Table 1, the valves in the perineal veins were examined in further 8 cows after slaughtering.

The experimental animals were older Jersey cows, which on a clinical examination were found to have a normal mammary organ.

RESULTS

In Table 1 to the left, the mammary blood flow with and without manual clamping of the external pudic veins is shown in the experiments where antipyrine was infused simultaneously into all 4 quarters. The results are used to conclude whether the valves in the external pudic veins were competent or incompetent.

The following columns to the right show the results of application of antipyrine into a single quarter where the concentration of antipyrine in the venous blood from the udder could indicate the venous drainage, i.e. the presence of anastomoses between the 2 milk veins. The last but one column states the conclusion concerning the *in vivo* experiments, and in the last column the post-mortem findings are shown. Furthermore, the post-mortem examination showed that all the valves in the milk veins and in the external pudic veins directed the blood away from the udder, while the valves in the mammary veins would tend to direct the blood towards the external pudic veins.

The valves in the mammary veins were incompetent in nearly all the cases. The few findings of competent valves were in trans-mediane anastomoses of small diameter. Only in 1 case (no. 5)

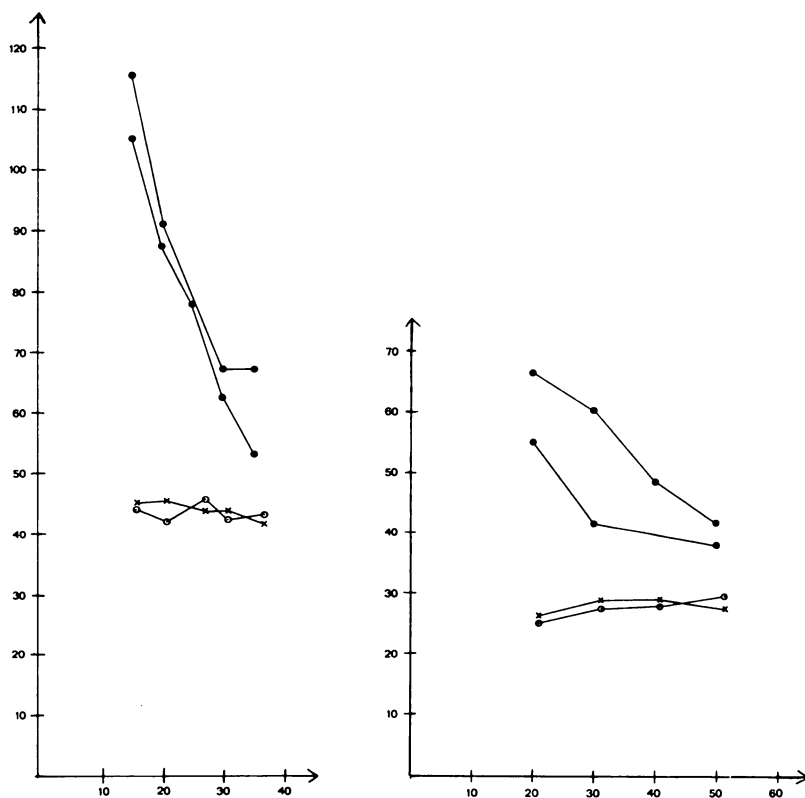
Table 1. Udder blood flow and anatomical findings.

Cow no.	Body weight kg	Udder weight kg	Milk yield kg/day	Udder blood flow (l/min.)		Antipyrine in the opposite milk vein after application in			Conclusion*	Section*
				with clamping/without clamping of the external pudic veins	with clamping/without clamping of the external pudic veins	LF	LH	RF		
1	400	10.2	4.0	1.8	2.2	yes	yes	no	yes	1, 2, 3
2	340	5.2	2.0	1.4	1.6	yes	yes	no	no	1, 2, 4
3	400	12.0	10.5	5.4	5.8	no	no	-	varies	1, 2, 3
4	430	9.2	3.8	3.2	2.7	yes	no	no	yes	1, 2, 4
5	290	6.5	3.0	3.9	4.1	no	no	yes	yes	1, 2, 4
6	390	10.2	6.5	2.5	3.4	no	no	no	yes	2, 3
7	300	6.5	4.0	2.7	4.8	no	no	no	yes	2, 3
8	370	11.4	9.0	7.9	8.2	no	yes	no	no	2, 4

- * 1. Transmedian venous anastomoses cranial in the udder.
 2. Transmedian venous anastomoses caudal in the udder.
 3. Incompetent valves in the external pudic veins.
 4. Competent valves in the external pudic veins.

a competent valve was found between the fore- and the hind quarter of the udder.

In 2 cows (nos. 6 and 8) blood samples from the perineal veins were taken simultaneously with blood samples from the jugular and milk veins after application of antipyrine into the 4 udder quarters. The concentration of antipyrine in the blood in those veins are shown in Figs. 1 and 2, which show that the concentration of antipyrine in the perineal vein was low and identical to that of the jugular vein, while the concentration in both milk veins was high.



Figures 1 and 2. The concentration of antipyrine in the perineal, milk and jugular veins in cows nos. 6 and 8.

- × — × perineal veins
- ⊗ — ⊗ milk vein
- — ○ jugular vein

Ordinate: concentration of antipyrine ($\mu\text{g/ml}$ blood)

Abscissa: Time after application of antipyrine (min.)

The examination post mortem of the udder from no.6 revealed 2 perineal veins with incompetent valves orientated toward the udder, while no. 8 had 1 perineal vein with competent valves orientated toward the udder, too. In the other experimental cows and in the above-mentioned additional 8 cows the post-mortem examination showed valves which were also orientated towards the udder, in other words allowing blood flow toward the udder. In 9 of those cows the valves were competent, while they were incompetent in either the left or right or both the perineal veins in 5 cows.

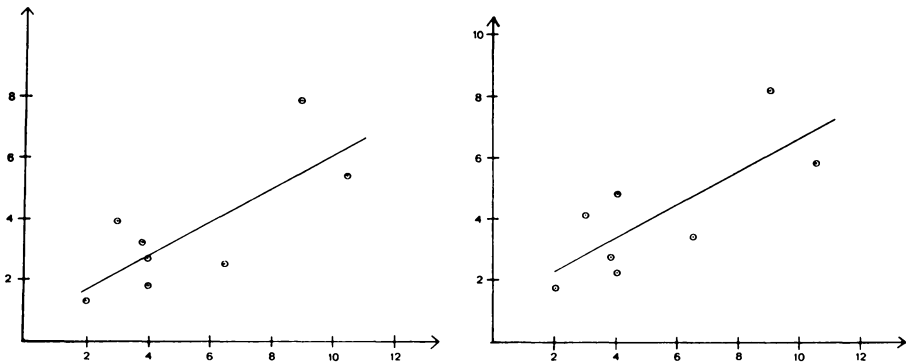


Figure 3. Udder blood flow with manual clamping of the external pudic veins.

Ordinate: blood flow (l/min.)

Abscissa: milk yield (kg/day)

$$y = 0.663 + 0.547 x$$

Figure 4. Udder blood flow without manual clamping of the external pudic veins.

Ordinate: blood flow (l/min.)

Abscissa: milk yield (kg/day)

$$y = 1.206 + 0.543 x$$

DISCUSSION

Presuming a heart minute volume in cows to be 110 ml/kg body weight (Doyle *et al.* 1960, Fischer & Dalton 1961) the mammary blood flow in the experiments will average 8 % (3—19 %) of this. Usually (i.e. Kolb 1960) the udder blood flow per min. is assumed to be 20—30 % of the minute volumen of the heart in lactating cows. The experimental animals were all older cows which had been sent for slaughter, so the milk yield was low (average 5 kg daily) and the mammary blood flow, too.

In Figs. 3 and 4 the mammary blood flow with (Fig. 3) and without (Fig. 4) manual clamping of the external pudic veins is plotted against the daily milk yield. In 7 of the 8 cows the blood flow fell during clamping of the external pudic veins, but the lowering is not significant ($P > 0.05$). The values for the mammary blood flow agree with findings in cows of *Rasmussen* (1965) and *Kronfeld et al.* (1968) who also used the antipyrine absorption method, while *Linzell* (1970) found lower values for the mammary blood flow using the thermodilution method. Similar differences between the methods have been reported in goats (*Reynolds et al.* 1968).

In 3 animals (nos. 1, 6, 7) the clamping of the external pudic veins has changed the mammary blood flow more than 10 % below the mean. The post-mortem examination of these cows showed that they had incompetent valves in the external pudic veins. Of the remainder 5 cows 3 were found to have competent valves in the external pudic veins, while 2 (nos. 3 and 8) had incompetent valves. So measurement of the mammary blood flow with and without clamping of the external pudic veins has given probable information concerning the valves in these veins in 6 of the 8 cows.

Application of antipyrine in single quarters has in all cases given correct information concerning transmedian venous anastomoses between the udder halves.

The finding of valves in the perineal veins which were directed toward the udder agrees with findings of *Becker* (1937), *Swett* (1941), *Becker & Arnold* (1942), *Swett & Matthews* (1949), *Gracev & Ivanov* (1955), *Linzell* (1960), *Lebedawa* (1960), *Vau* (1960), and *Vollmerhaus* (1964). So presumably the perineal veins do not drain blood away from the udder, but toward the veins at the base of the udder. This is supported in the experiments where blood samples were taken simultaneously from the perineal, jugular and milk veins, where the concentration of antipyrine in the perineal and jugular veins were identical, and only approximately the half of the concentration in the milk veins (Figs. 1 and 2). So it must be stated that the venous drainage of the cow's udder depends upon the milk veins and the external pudic veins.

As seen from Table 1 there was an increase in the mammary blood flow during clamping in only 1 cow (no. 4), while all the other cows showed no change or a lowering of the blood flow.

The decrease could be due to a flow of blood having a high concentration of antipyrine away from the udder through the external pudic veins. It could also indicate a flow of venous blood through the external pudic veins toward the veins at the base of the udder, which seems most probable due to the incompetence of the valves in veins.

So it ought to be assumed that the venous drainage in standing cows is primarily through the milk veins, and eventually there will be a non-mammary blood flow down rather than up in the external pudic veins, even the orientation of the valves should prevent such a flow. *Linzell & Rasmussen* (1972) mention that in 35 % of the animals (goats and cows in their second or subsequent lactation) there is a contamination of the blood in the milk vein with non-mammary blood.

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SAMMENDRAG

Yverets blodgennemstrømning og dets venøse afløb.

Yverets blodgennemstrømning og venøse blodafløb *in vivo* (bestemt ved hjælp af antipyrin-absorptionsmetoden) er blevet sammenholdt med de fundne anatomiske forhold i yverets venøse karsystem efter slagting af forsøgskøerne (tabel 1).

På grundlag af veneklappernes orientering i vv. perinei samt blodprøver udtaget *in vivo* (fig. 1 og 2) må det antages, at vv. perinei fører venøst blod til yverets venøse afløbssystem.

Det konkluderes, at yverets venøse afløb hos stående køer sandsynligvis udelukkende sker gennem vv. subcutaneae abdominis; eventuelt kan der gennem vv. pudendae externae flyde venøst blod ned til venerne i yverets basis, i lighed med vv. perinei.

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