BRIEF COMMUNICATION

The nature of the microcirculation in the mammary gland of the lactating rat

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The secretory cells of the mammary gland depend upon the blood supply to provide nutrients and endocrine signals to regulate milk output. The relationship of blood flow to the mammary gland and milk yield has been well described, at least in ruminants (Linzell, 1974). However, the nature and regulation of blood flow in capillaries has not been studied previously in mammary tissue, yet it is the level of perfusion through capillaries or capillary beds which potentially plays the major role in both acute and long-term regulation of milk synthesis. Further, the flow through capillaries may or may not be reflected in gross arterial blood flow if there are 'non-nutritive' channels (for example, arterio-venous shunts) by-passing the capillary beds.

The following study required the development of a technique for *in vivo* microscopy of mammary tissue in lactating rats. Briefly, rats around peak lactation (days 10-12) were anaesthetized with sodium pentobarbitone (50 mg/kg, IP) and a catheter placed in a jugular vein. The skin above the surface of an inguinal gland was reflected to expose approximately 1 cm^2 of the mammary surface. This area was covered with a coverslip mounted on a perforated glass slide and the rat placed on a heated (37 °C) platform on an inverted microscope.

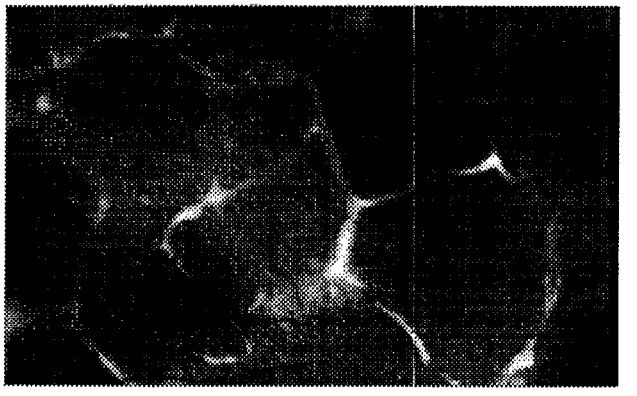
Illumination was provided by a fibre-optic, cold light source or by endogenous fluorescence following intravascular injection of fluoroscein isothiocyanate-dextran (Ave molecular weight 150,000; Sigma Chemical Co., St Louis, Mo. USA). Capillaries were visualized easily with x20 and x40 objectives and the image recorded via a video camera onto VHS tape.

Blood flow through capillaries supplying individual, superficial alveoli of the mammary gland of the lactating rat were observed by light microscopy for several hours. The density of capillaries on the alveolar surface was approximately 1 per 50 microns. Each alveolus was encircled by a ring of capillaries, with up to one-third of alveoli showing capillaries crossing the alveolar surface. The latter, in particular, showed intermittent flow, movement of red blood cells and plasma ceasing, commonly for periods of up to a minute although longer periods of stasis were not unusual (Plate 1).

Oxytocin (oxytocin-S, Intervet Pty Ltd, Lane Cove, NSW, Australia) injection at a physiological dose via the jugular vein (2 m IU) caused milk ejection, during which blood flow through capillaries ceased for 1-3 min., while flow through major vessels continued. Preliminary data indicated that, following injection of oxytocin at pharmacological doses (5 IU subcutaneously) into mice, the duration of capillary closure was greatly extended.

Oxytocin administration increases blood flow in the mammary artery, at least in ruminants (see Linzell, 1974). However, the present study shows that capillary flow is abolished during milk ejection. This observation explains the marked fall in pO_2 observed in rat mammary tissue during milk ejection (Silver, 1956). Further, the deleterious effect of pharmacological doses of oxytocin on tight junction patency between epithelial cells (Linzell, 1967) may be caused by the local anoxia induced by capillary closure.

PLATE 1: View of alveoli of lactating rat at day 10 of lactation (x20 objective) showing stationary red blood cells in some capillaries. Exposure time was 3 sec. Capillaries were viewed by fluorescence microscopy following injection of 20 mg FITC-dextran into a jugular vein.



Intermittent and/or variable flow through individual alveolar capillaries may be controlled by differential pressures in the capillary network or by capillary sphincters. Control of capillary flow by smooth muscle cells in sphincters would imply that such cells play a pivotal role in regulating milk output through control of the supply of hormones and nutrients to individual alveoli. However, currently there is no direct evidence for capillary sphincters in mammary tissue.

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There is evidence that the distribution of blood perfusion in the mammary gland may be controlled at the lobular rather than the alveolar level. This evidence stems from gene expression studies where changes in gene expression are usually seen in whole lobules rather than individual alveoli (Molenaar *et al.*, 1992).

REFERENCES

Linzell, J.L. 1974. Mammary blood flow and methods of identifying and measuring precursors of milk. In 'Lactation: A Comprehensive Treatise' Eds B.L. Larson; V.R. Smith. Academic Press, New York.

Linzell, J.L. 1967. The effect of very frequent milking and oxytocin on the yield and composition of milk in fed and fasted goats. Journal of physiology 190: 333-346.

Molenaar, A.J. ; Davis, S.R.; Wilkins, R.J. 1992. Expression of a-lactalbumin, α-s_1-casein and lactoferrin genes is heterogeneous in sheep and cattle mammary tissue. Journal of histochemistry and cytochemistry 40: 611-618.

Silver, I.A. 1956. Vascular changes in the mammary gland during engorgement with milk. Journal of physiology Lond. 133: 65P-66P.