Lipid Metabolism during Pregnancy and Lactation

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Placental transfer of fatty acids

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Information derived from animal investigations using labelled fatty acid infusions and measurements of the fatty acid concentrations found in the various fractions in maternal and foetal umbilical artery and venous blood and tissues have shown that the net flux of fatty acid from mother to foetus across the placenta varies greatly from species to species. In general, in those species with maternal as well as foetal layers in the placenta, e.g. sheep, pig and cat, fatty acid transfer is small, and the profile of fatty acids in the foetal circulation does not match that in the maternal circulation (Elphick et al., 1979, 1980; Leat & Harrison, 1980; Elphick & Hull, 1985), whereas in those species with only foetal layers in the placenta, e.g. rabbits, rats and guinea pigs, the net flux can be high and the fatty acid mixture entering the foetal circulation from the placenta reflects maternal free fatty acid concentrations of the various fatty acids (Elphick & Hull, 1977; Hummel et al., 1975; Hershfield & Nemeth, 1968; Thomas & Lowy, 1982). Arachidonic acid is a common exception.

The human placenta like the rabbit placenta does not have maternal layers. The human foetus, in contrast to other species, lays down sizeable stores of fat in white adipose tissue in the last trimester of pregnancy. In the guinea pig and rabbit the fat is mainly found in brown adipose tissue. Fatty acids have been shown to cross from the maternal spaces into the foetal vessels of the isolated perfused human placenta and the fatty acids appear to cross in an unselected manner (Booth et al., 1981). However, during the brief period when this preparation is viable, arachidonic acid leaves the placenta into both the maternal and foetal compartments. So human placental tissue is permeable to fatty acids.

Measurement of fatty acid mixtures in the various plasma compartments in umbilical cord artery and vein blood taken easily and simultaneously during elective Caesarean section at term is the closest we have come to obtaining data which reflect the physiological state in man (Hendrickse et al., 1985). Even so the anaesthesia and surgery provoked a rise in maternal circulating free fatty acid concentrations and no doubt handling the cord affected placental perfusion.

Fatty acid concentrations in the human maternal circulation, umbilical vein, umbilical artery and the umbilical venous-arterial difference are shown in Fig. 1. There was a significant flow of fatty acids to the foetus. In Fig. 1. Plasma concentrations of individual fatty acids in the free fatty acid fractions of human (a) maternal blood, (b) umbilical cord vein [○] and artery [□] and (c) the umbilical venous-arterial concentration difference

Results are mean ± S.E.M. of 33 observations. Umbilical venous and arterial concentrations of each fatty acid were compared by using paired t-tests; significant differences are given in (c): *P < 0.05; **P < 0.01; ***P < 0.001.
general the free fatty acids in the foetal circulation were similar to those in the maternal free fatty acid compartment. However, the cord venous–arterial difference was interesting in that whilst palmitic (16:0), palmitoleic (16:1), stearic (18:0) and linoleic (18:2) acids entered the foetal circulation in similar proportions to those in the maternal circulation, arachidonic (20:4) and oleic (18:1) acids did not.

In contrast with the other fatty acids arachidonic acid is often present in higher concentrations in the foetal than the maternal circulation. When the concentration of maternal arachidonic acid was plotted against the umbilical venous–arterial difference, the net flux of arachidonic acid was from the foetus to the placenta at high concentrations and vice versa at low concentrations.

Likewise for oleic acid; at high foetal levels oleic acid tended to leave the foetal circulation as it passed through the placenta. However, even at low foetal free fatty acid concentrations the net flow of oleic acid to the foetus was not as great as non-selective flow from the maternal free fatty acid compartment would imply.

Clearly the foetus only gets those fatty acids which are 'on offer' in the maternal circulation. If these are changed, for example if pregnant rabbits 2 days before term are fed on a corn oil-rich diet, more of the fed fatty acid enters the foetal fat stores, which with corn oil was linoleic acid (18:2) (Stammers et al., 1983). Infants born to mothers who prefer foods containing unsaturated to saturated fatty acids did not.

Hormonal control of energy metabolism in pregnancy

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Metabolic adaptations to pregnancy are directed towards (1) ensuring satisfactory growth and development of the foetus in utero, (2) equipping the foetus with a store of energy to see it through the immediate neonatal period, and (3) establishing an adequate maternal bank of energy to secure survival, not only of the foetus and neonate, but also of the infant by means of lactation, in the event of the supply of dietary energy being inadequate at any point during and after the pregnancy. At any one time the demands of the first two objectives are competing with that of the third for the available energy. Yet to ensure successful reproduction all three must be met.

When access to food is unrestricted pregnancy is above all an anabolic event in which appetite and food intake are increased, activity is diminished and, in the human, an average of 3.5 kg of maternal fat is deposited and 900 g of new protein is synthesized in the product of conception and in maternal reproductive tissues (Hyttten, 1980). The overall energy cost of human reproduction is of the order of 75,000 kcal (313,800 kJ). This is equivalent to an additional daily consumption of 300 kcal (1255 kJ) throughout the pregnancy and the recommended dietary allowances for pregnancy are based on this value. It is, however, well documented that many women eat considerably less than the recommended allowances and yet put on weight, produce a normal baby, and lactate satisfactorily (Whitehead & Paul, 1962). Moreover, experiments involving pregnant rats have consistently produced data showing that complete fasting for 2 days in the second half of pregnancy has surprisingly little effect on foetal weight (Fain & Scow, 1966; Girard et al., 1977; Shambough et al., 1977). Therefore a successful pregnancy is clearly not totally dependent on an 'appropriate' increase in energy intake throughout pregnancy. Thus the concept has evolved in which the metabolic adaptation to pregnancy is seen as being primarily designed to safeguard against variable and restricted energy intake. This is achieved in two ways: (1) by a reduction in energy expenditure, due to decreased activity combined with increased metabolic efficiency, and (2) by phased metabolic activity.

Little is known about metabolic efficiency in pregnancy but the indication that increased efficiency exists is for example, serial studies of energy balance in pregnant women living in Cambridge and Gambia have shown no increase in energy intake, no detectable change in activity, normal maternal weight gain, and normal infant birthweight (Whitehead, 1983). It was concluded that although subtle changes in activity may have contributed to a reduction in energy expenditure, the increased metabolic requirements of pregnancy must have been met mainly by enhanced metabolic efficiency. This was apparently greater in women in the Gambia than in the U.K.

The phenomenon of phased metabolic activity in pregnancy is well recognized (Hyttten, 1980), with deposition of maternal fat stores dominating the first half of pregnancy and foetal growth the second. This spreads the energy cost and protein requirement of pregnancy over the whole of gestation, which may be vital when food supplies are variable and restricted. The precise mechanism is less well defined, but we believe that it is programmed by the placental steroid balance, which is not affected by environmental factors such as diet, but rather determined by placental growth. Briefly the concept is that progesterone, which dominates the first half of pregnancy, is mainly responsible, via insulin, for conserving energy in early pregnancy, the state designated by Freinkel (Freinkel...