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Physiology of lactation: How the breast works

Professor PE Hartmann, University of Western Australia

A common feature of mammals is the ability to be able to suckle their young. There are large variations between mammalian species in the duration of lactation and the composition of the milk they produce in order to meet the specific needs of each species young, providing both protective and nutritive factors. Lactation is an ancient reproductive trait that predates the origin of mammals. Although a variety of theories have been proposed to explain the origin of the mammary gland and its secretion, its functional and morphological origins remain speculative. The most recent theory suggests that lactation evolved from an inflammatory response to provide innate immune protection for the hatchling.

Functional development

The development of the fully functional lactating breast is normally, but not exclusively, associated with the hormonal changes that occur during pregnancy. It is possible, for at least some women (e.g. some adopting mothers), to bypass pregnancy and by just applying the suckling stimulus to the breast, develop a full lactation.

In women who deliver at term, the functional development of the breast occurs in two stages. Lactogenesis 1, now known as **secretory differentiation** where the mammary secretory epithelial cells differentiate into lactocytes that are capable of synthesizing the unique milk components such as lactose and milk protein. Secretory differentiation is difficult to measure in women, but it is reflected by the change from a viscous clear fluid that is present in the ducts of the non-lactating breast to a secretion with the appearance colostrum during pregnancy. Since the tight junctions between the lactocytes are not closed at this time lactose can pass from the alveolar lumen into the blood and is then excreted in the urine. Thus an increase in the excretion of lactose in the urine of pregnant women indicates of the time of secretory differentiation in pregnant women.

The second stage is **secretory activation** (previously lactogenesis 2) is the initiation of copious milk secretion with definitive changes in milk composition that occurs 30-40 hours after birth in breastfeeding mothers delivering at term. Milk components with the greatest changes from day 1 to 5 days post-partum include citrate, lactose, sodium and total protein and these are ideal markers of secretory activation.

Regulating Milk Supply

Understanding the control of milk synthesis during established lactation in women was initially gained from research in dairy and laboratory animals. However, dairy and laboratory animals generally are managed so that they are producing milk at near their physiological maximum capacity, women breastfeeding their babies normally have to down regulate their synthetic capacity so that their actual rate of milk production is similar to their infant's appetite. In the early 1970's it was discovered that the sucking stimulus evoked the release of prolactin during established lactation in women. It was assumed that the release of prolactin provided an explanation for the regulation of milk 'supply' by infant appetite ('demand') and that more frequent sucking released more prolactin, which stimulated an increase in milk production.

However, it is now clear that during normal lactation in women each breast independently regulates the short-term rate of milk synthesis by responding to the fullness of the breast through an autocrine feedback loop. However, women's breasts vary in their capacity to store milk and therefore inhibition of

synthesis occurs much sooner in women with breasts that have a small storage capacity (<100ml) than those with larger capacities (>200ml). The more a breast is emptied, the greater the rate of synthesis. Longer term regulation is hormonal, increasing cell proliferation to create more secretory tissue.

Mothers who deliver pre-term give birth at a time when secretory differintiation may be incomplete and may experience difficulty in establishing an adequate milk supply. Recent research has improved our understanding of the initiation and establishment of preterm lactation. It's practical practical application is discussed by Liz Jones (see page 4).

For further information readers are directed to the *Textbook of Human Lactation* edited by Thomas Hale and Peter Hartmann., www.ibreastfeeding.com

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The role of donor breastmilk in supporting lactation and breastfeeding

Gillian Weaver, Chair of UKAMB

Donor breastmilk is freely donated by a lactating mother to human milk banks which collect, screen, process, store and distribute the donor breastmilk. In the UK, donor breastmilk is almost exclusively used to feed premature babies and neonatal units are able to obtain donor milk from an in-house milk bank or from the nearest milk bank if it supplies other hospitals. (The United Kingdom Association for Milk Banking - UKAMB can give advice on availability of donor milk). Although not evenly distributed, there are 17 established milk banks in the UK. Most are locally funded by the NHS. Globally the banking of donated breastmilk is growing with more banks being established.

The availability of donor breastmilk enables infants to be enterally fed as dictated by their clinical condition even if the mother is not yet able to provide any or sufficient of her own colostrum or breastmilk. Audit information on the use of donor breastmilk at Queen Charlotte's and Chelsea hospital in West London during the period January to December 2006, shows that most infants receive the donor milk as an adjunct to their own mother's milk for less than 7 days and that only 4% received it for more than 4 weeks. It is important to ensure that the use of donor milk isn't seen as an easier option than supporting the baby's mother to establish or maintain her lactation. Heat treated donor milk is inferior to the mother's own fresh breastmilk because the pasteurisation process reduces the anti-infective properties of the milk. However the resultant heat treated donor milk retains some of these properties and so offers distinct advantages over formula.

There is currently no national service and so infants do not have equal access to donor milk – UKAMB is calling for the establishment of an appropriately regulated national service that will make donor milk available according to clinical need. In the absence of regulation, milk banks in the UK voluntarily follow guidelines published by UKAMB[1]. The guidelines cover justification for the use of donor milk, the selection and screening of donors including their serological testing and criteria for permanent or temporary exclusion together with guidance regarding the collection, storage, testing and pasteurisation of the breastmilk. In the UK all donor milk is pasteurised in purpose designed equipment and the milk is then tested for the presence of bacteria and strict criteria apply for its acceptance.

A systematic review published in 2007[2] carried out by Boyd et al of the National Perinatal Epidemiology Unit highlights evidence of benefit of donor milk for preterm infants when fed as the sole diet, identifying a lower risk of necrotising enterocolitis compared with infant formula. The review does state that the evidence for benefits is limited and calls for further research to confirm the findings as well as research to look at the use of fortified or supplemented donor breastmilk. The review is further discussed in an article by Williams et al[3]

References:

1. *Guidelines for the establishment and operation of human milk banks in the UK 2003* United Kingdom Association for Milk Banking, **www.ukamb.org**

2. *Donor breast milk versus infant formula for preterm infants; a systematic review and meta analysis* Boyd et al Arch. Dis. Child. Fetal Neonatal Ed. 2007 92

3. *Banking for the future: investing in human milk* Anthony F Williams, Camilla C Kingdon and Gillian Weaver Arch. Dis. Child. Fetal Neonatal Ed. 2007 92

Breastfeeding: A new perspective

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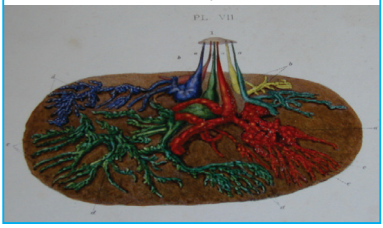
Renowned British surgeon Sir Astley Cooper was requested to write a text detailing the diseases of the breast in the early 1800's. In his attempt to fulfil this task he realised that no one could definitively describe the anatomy of the human breast. Cooper recognised that an extensive knowledge breast anatomy was essential to the diagnosis and effective treatment of breast disorders and disease and subsequently embarked on the most extensive investigation of the breast carried out to date. Cooper painstakingly dissected the breasts of women who had died during lactation to provide a comprehensive description of the gross anatomy, innervation, lymphatics and blood supply of the breast publishing in 1840.

Fig 1. Artists impression of the ductal system of the human breast (Cooper, 1840)

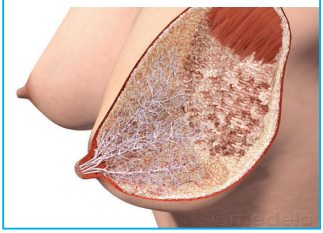


Amazingly few studies have been carried out since mainly due to the scarcity of cadavers, mastectomies and biopsies of lactating women. In addition ductography is invasive and CT and MRI are yet to be refined to produce good anatomical information regarding the breast. Ultrasound image resolution has improved rapidly in the past 20 years allowing the identification of very small structures'. In addition it has the advantage of being non-invasive thus not distorting the anatomy.

Recently we used ultrasound to image the anatomy of the breasts of fully breastfeeding women (1-6 months). The milk duct system was different to that depicted in standard anatomical textbooks. The main milk ducts were small (approx 2mm), superficial (4-5mm under the skin) and branched close to the nipple (within the areola radius). The expanded ducts under the areola (lactiferous sinuses) were not observed and the number of main ducts detected at the base of the nipple was less than the quoted 15-20 (9.4, range 4-18; Ramsay et al, 2005). These findings along with evidence that little milk is available prior to milk ejection (Kent et al, 2003) and that ducts dilate to accommodate milk at milk ejection suggests that the main function of the milk ducts is to transport rather than store large amounts of milk (Ramsay et al, 2004).

Both the absence of lactiferous sinuses and the small size of the milk ducts have led to the investigation of the sucking mechanism of the breastfeeding baby using simultaneous measurement of intra-oral vacuum and ultrasound imaging of tongue action. Interestingly term infants do not show a pronounced peristaltic action of the tongue, but rather lowering of the posterior tongue creates increased pressure resulting in an increase in nipple diameter, nipple duct opening and milk flow into the area between the nipple and soft palate. Thus intra-oral vacuum plays a predominant role in milk removal during breastfeeding.

Fig 2. Ductal system of the human lactating breast based on ultrasound findings (Ramsay et al, 2005)



Ultrasound imaging has provided new insights into the breast anatomy and breastfeeding. This knowledge is extremely valuable to the understanding of and development of successful clinical interventions for lactation difficulties.

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Supporting pre-term breastfeeding

Elizabeth Jones, Infant feeding adviser and research fellow

Breast milk is the preferred feed for preterm infants. Nutritionally it is highly bioavailable, provides immunological protection, improves developmental outcome and promotes maternal attachment behaviours. For the mother of a preterm baby, expressing breastmilk may be the one thing she can do for her baby in these early days.

Getting started

Following a pre-term delivery, breastfeeding becomes an important part of that babies care. Mothers need skilled advice and support to initiate lactation. At the beginning, the most valuable actions for the neonatal support team are to

- Emphasise the benefits of breast milk
- Teach effective milk expression techniques as a matter of urgency
- Encourage breast expression as soon as possible following delivery
- Use breast compression to stimulate milk flow
- Advise mothers to express early and express often (8 -10 times in 24 hours)
- Provide support and encouragement
- Encourage mothers to express in close proximity to baby
- Warn there may be a delay in establishing a milk supply

To sustain breast milk production

- Use massage to trigger milk ejection reflex ('let down')
- Double pump until milk flow ceases
- Empty the breasts as thoroughly as possible at each session
- Aim for a milk volume of >500 mL/d at two weeks
- Don't leave a gap longer than 6 hours overnight between expressions
- Practise kangaroo care (also called skin-to skin holding)

Problems Related to Milk Expression:

Sore Nipples:

- Centre milk expression shield
- Try a variety of shield sizes to better match nipple size
- Increase pump vacuum slowly until uncomfortable then reduce by 10%
- Stop pumping before removing shields
- Don't use plastic backed breast pads

Too little milk:

- Increase kangaroo care (skin-to-skin)
- Check frequency and duration of pumping
- Check shield funnel size (too small a funnel may cause ducts to collapse.
- Use breast compression during expression
- Increase frequency of expression sessions
- Check maternal medication
- Prolactin enhancers are only useful if serum prolactin levels are low
- Praise provision of expressed milk – no matter how small

Transition to Breast

- Provide optimal environment
- Assess baby's cues for interest in oral feeding
- Provide support, encouragement and expertise
- Kangaroo care during tube feeds helps build feeding associations
- Non Nutritive Suckling on an emptied breast shortens transition time
- Express before feed to trigger milk ejection reflex
- Instil a few drops of expressed breast milk to trigger suck / swallow reflex
- Use breast compression during breastfeed
- Assess attachment and positioning

Getting ready for home:

- Provide facilities for 'rooming in'
- Assess suck / swallow patterning - suckling bursts
- Help mother to recognise milk ejection reflex and degree of breast fullness before / after feeds
- Provide supplementation post-feed when needed
- Assess the need for post-feed milk expression
- Check infant excretion patterns
- Plan for (modified) demand feeding
- Provide post-discharge breastfeeding support

Reference:

Feeding and Nutrition in the Preterm Baby
Eds Jones and King, Elsevier 2005, Chapters 5 and 9.

Adequacy of human milk for preterm babies

Caroline King, Neonatal Dietitian

The nutritional composition of human milk varies between women; however in well nourished women, breast milk composition is remarkably well preserved, regardless of dietary variation. Differences in some breastmilk components in women delivering prematurely have been detected, however, these may have been an artefact of mechanical expression

Babies born at term or near term who are able to fully demand feed from the breast are likely to grow well with good support for lactation and breastfeeding. Those born preterm, particularly those <30 weeks gestation and <1.5kg birth weight have higher requirements of some nutrients than can be provided in breast milk – even when fed at high volumes. A key determinant of nutrient intake is volume. Babies on volumes of breast milk consistently less than 180ml / kg are at greatest risk of insufficient nutritional intake.

Minerals and vitamins

Due to high placental transfer in the last trimester many minerals and vitamins are needed in higher quantities than can be provided by breast milk e.g. sodium, calcium, phosphorus, zinc, vitamins A and D. Most preterm babies will need oral phosphorus and sodium supplements once parenteral nutrition has ceased and the baby is on breast milk alone.

Energy

Despite popular belief, energy intake may be sufficient, as breast expression often means a woman can empty her breast of the fat and energy rich hind milk at each expression, especially if double pumping. This is in contrast to healthy term baby feeding at the breast, where the may not empty the breast at each feed.

Protein

Breast milk protein levels are very variable between women and depend on both volume of milk expressed and stage of lactation. The highest levels being early on in lactation, in the lowest volumes expressed. As preterm babies don't grow any faster if given protein in excess of needs, there is no benefit to adding protein early on while breast milk levels are high. However, by 2-4 weeks levels have dropped towards mature milk (approx 1g/100ml). To satisfy protein requirements around 350ml / kg would need to be fed which is an impractical volume; an alternative is to provide additional protein added to the breast milk. Some clinicians will increase feed volumes to 200ml/kg others keep to around 160ml/kg- this obviously will affect nutritional intake.

At the moment there are no quick methods of analysing mothers' milk to assess protein adequacy so a surrogate measurement can be useful i.e. serial serum urea levels. In most babies urea declines over the first few weeks. In uncomplicated clinical situations this is likely to be due to reducing levels of protein in mothers milk; however other factors affecting urea levels should also be taken into consideration eg level of hydration, sepsis and use of some drugs. Once levels approach 2mmol / l, additional protein can be added as a multinutrient fortifier. These fortifiers contain minerals vitamins trace elements and protein so that sodium and phosphorus supplements can usually be dispensed with.

Fortifying breast milk

There are two camps when it comes to the use of fortifiers, one starting at a set volume of milk regardless of any indicators, others add fortifiers only when more protein is needed. However, possible detrimental effects of either approach remain largely theoretical. As there is no growth advantage to providing protein over recommended levels and addition of supplements to breast milk may adversely affect its protective properties, it seems best to delay adding fortifier until needed.

What are we aiming for?

Growth is not the only end point to be aiming for. In the future as new information becomes available on body composition and its implication for health in later life, it will be important to optimise both growth and body composition. It is thought that distribution of adipose tissue may influence endocrine effects. Initial studies have shown that adipose distribution is affected by other variables, not just nutrient intake.

Reference: *Feeding and Nutrition in the Preterm Baby* Eds Jones and King, Elsevier 2005, Chapter 3.

Feeding development and challenges

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The feeding reflexes of rooting, sucking, swallowing are practiced in utero towards the end of the first trimester of pregnancy. Airway protection by coughing is not fully developed at birth and the important protective gag reflex develops late in gestational age. Without Despite an anatomy designed to protect the airway the preterm infant is at risk from aspirating with oral feeding if fed without a good understanding of normal feeding development and how to support it.

Infants born preterm start to be able to co-ordinate sucking and swallowing with breathing from 32 weeks gestation and by 37 weeks most are mature. Immature sucking is characterized by short sucking bursts with breathing occurring in the pauses, this is an adapted pattern to cope with immature co-ordination. If they keep sucking in long busts they may not breathe and may then desaturate or have marked apneas with feeding.

Maturity of development depends on many factors including general health, weight, sex, race etc. By 36 weeks the majority of preterm infants are ready for home, but may still be mastering their feeding skills and have disorganized patterns of feeding that may need addressing as part of their discharge plan.

Feeding and prematurity

Preterm infants experience a range of medical interventions which can cause abnormal stimuli around their face, mouth and throat, disrupting normal sensation and feeding development.

- tapes and cannula on their face may interrupt the development of rooting
- indwelling gastric tubes may suppress the gag and swallow reflex.
- frequent or prolonged interventions may lead to structural abnormalities e.g. a high arched palate
- Gastro oesophageal reflux may cause desatu rations with feeding and the pain of oesophagitis can lead to feeding aversion.
- Infants with chronic lung disease may find the effort of breathing limits their endurance for feeding and causes problems co-ordinating swallowing with breathing. They also like to have their arms, head and neck in extension making positioning for feeding midline difficult.
- Infants who have abnormal reflexes or disrupted tone due to neurological impairment can have specific difficulties with sucking and swallowing.

Improving the feeding experience

Creating opportunities to experience and practice normal components of feeding can prevent problems and help infants go home early, feeding well.

- Skin to skin contact during tube feeds provides positive oro-facial touch, smell, handling and the opportunity for licking and tasting, linking oral stimulation with satiation.
- Non nutritive sucking provides relief for painful procedures and optimizes nasal CPAP. It also can help an infant accelerate the organization and efficiency of sucking. Often by 34 weeks, waking and being unsettled can be a hunger cue for the infant to go to the breast and non nutritive sucking should not be used. Demand feeding can now normalize feeding patterns.

Breastfeeding is the best oral feeding experience for preterm infants. Observing and reading an infants cues can guide the appropriate intervention and use of equipment.

- nipple shields may help the small preterm infant attach to a large or inverted nipple and seem to give more stimulation to help them to attach to the breast,
- a supplemental nursing system can provide a top up at the breast if the suck is weak or the milk supply not yet established..

Bottle feeding can present challenges as the milk flows without sucking, however, a number of techniques can help.

- The preterm infant's suck is slightly weak, and can benefit from jaw support to aid suction.
- Slow flow teats can make coordination of sucking and swallowing easier than fast-flow.
- Infants who can't stop sucking to pause and breathe, may be helped by taking the teat out to enforce pacing.
- Side lying positioning resembles breastfeeding and can help an infant feel supported and breathe more easily than in an upright position.
- Swaddling so a baby can be flexed in the midline with their hands near their face can help them organize the co-ordination needed for feeding.

Reference:

Feeding and Nutrition in the Preterm Baby
Eds Jones and King, Elsevier 2005, Chapter 9.