The anatomy of the lactating breast: Latest research and clinical implications

Knowledge of the anatomy of the lactating breast is fundamental to the understanding of its function. However, current textbook depictions of the anatomy of the lactating breast are largely based on research conducted over 150 years ago. This review examines the most recent literature in an effort to update the current knowledge of the anatomy of the lactating breast. These findings provide insight into breast function and the breastfeeding process and have significant clinical implications that will ultimately allow for improved support of the breastfeeding mother.

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Key points

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1. The latest evidence suggests that the anatomy of the lactating breast is different from current textbook descriptions.
2. The conventionally described lactiferous sinuses do not exist.
3. The ratio of glandular to fat tissue is 2:1, although both tissue types are intermingled and difficult to separate.
4. The main milk ducts in the breast are fewer than previously thought, can be small (2mm in diameter), superficial and easily compressed and are not uniformly distributed throughout the breast.
5. Clinically, this data is important for women undergoing breast surgery and those seeking breastfeeding advice.

It is well established that breast milk provides the infant with optimal nutritional and developmental factors. Organisations such as the American Academy of Pediatrics recommend breastfeeding (or the provision of mother's own milk) for all infants, including high risk and premature infants[1]. Indeed, many mothers, physicians and other health professionals recognise this, however, many women still experience a variety of breastfeeding problems resulting in low percentages exclusively breastfeeding at six months postpartum[2,3], which is the current recommended duration for exclusive breastfeeding[4]. Unfortunately, these rates are even lower for those women who deliver prematurely, even though the premature infant stands to gain the most from the provision of mother's own milk[5,6]. This situation suggests that support for the breastfeeding mother (term and preterm) is currently inadequate and indicates a clear need to bridge scientific investigation of breast function and clinical application.

The knowledge of the anatomy of the lactating breast is fundamental to the understanding of its function. However, the current understanding of the anatomy of the lactating breast has largely been based on research conducted over 150 years ago with little work performed since[7]. This review will examine the most recent literature in an effort to update the current knowledge of the anatomy of the breast. These findings have provided insight in to breast function and the breastfeeding process and will ultimately allow for improved support of the breastfeeding mother.

Anatomy and pregnancy

Two stages of breast growth occur during pregnancy. During the first half of pregnancy there is intense lobular-alveolar growth (mammogenesis), resulting in both increased number and size of alveoli and extension and branching of the ductal system occurs[8]. The growth of the mammary gland is influenced by a number of hormones including oestrogen, progesterone, prolactin, growth hormone, epidermal growth factor, fibroblast growth factor, insulin-like growth factor[9,10] and more recently parathyroid hormone-related protein[11].

Montgomery glands, which are a combination of sebaceous glands and mammary milk glands, increase in size and secretion during pregnancy, ranging in number from 1 to 15. It is believed the secretions protect the nipple from both the mechanical stress of sucking and pathogenic invasion[12]. There is also speculation that the odour of the secretion may act as a means of communication with the infant. It is of interest that a recent study has shown that increased numbers of Montgomery glands are associated with increased infant weight gain in the first three days after birth, increased infant latching speed and sucking activity and decreased time to onset of lactation in primiparous mothers[12], suggesting a functional role of the Montgomery glands during lactation.

Proliferation of the glandular tissue is believed to occur by invasion of the adipose tissue[13]. By mid-pregnancy there is some secretory development with colostrum present in the alveoli and milk ducts and this increases throughout the second half of pregnancy. Branching of the ductal system continues during this time but this is less marked than the first half of pregnancy[8]. It is of interest that this is the stage that mothers who deliver preterm infants are required to initiate their lactation. It is therefore possible that development of the breast is interrupted prematurely and this may impact on milk production[14].

While development of the breast typically leads to an increase in breast size during pregnancy, the proportion of growth varies greatly between women ranging from little or no increase to a considerable increase in size. Although the major increase in breast size is usually completed by week 22 of pregnancy, it is clear that for some women significant breast growth occurs during the last trimester of pregnancy and some women can undergo significant growth post-partum[15]. The increase in size of the mother's breast during pregnancy is positively correlated with the increase in the concentration of human placental lactogen in the mother's blood suggesting that this hormone may be integral in stimulating breast growth in women[15]. However, breast growth during pregnancy should not necessarily be used as a proxy of future lactation success as, while Cox and colleagues showed great variability in breast growth between women, all successfully breastfed for at least 12 months[15].

Anatomy and lactation

Descriptions of the anatomy of the lactating breast have changed little since Sir Astley Cooper's meticulous dissections of the breasts of women who had died during lactation (**FIGURE 1**) were published over 160 years ago[7]. As a result of this work it is well accepted that the breast is composed of glandular and adipose tissue, supported by a loose framework of fibrous connective tissue called Cooper's ligaments. Descriptions of the breast describe the glandular tissue as consisting of 15-20 lobes, themselves comprised of lobules, each containing 10-100 alveoli that are approximately 0.12mm in diameter[16]. The alveoli are the sites of milk synthesis and storage. The smallest elements of the alveoli are the secretory cells. These epithelial cells are arranged in a single layer around a lumen, thus giving form to the alveolus. Each alveolus is surrounded by a network of starlike, branching myoepithelial cells responsible for contracting (under the action of oxytocin) and ejecting the milk from the alveoli lumen into the ductules leading from each alveolus[16].

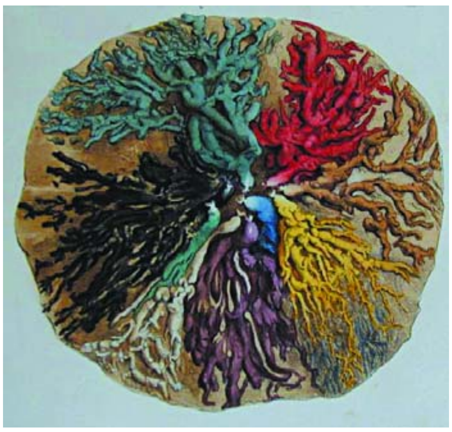

FIGURE 1 Artist's representation of the ductal system of a cadaver injected with coloured wax (Cooper, 1840).

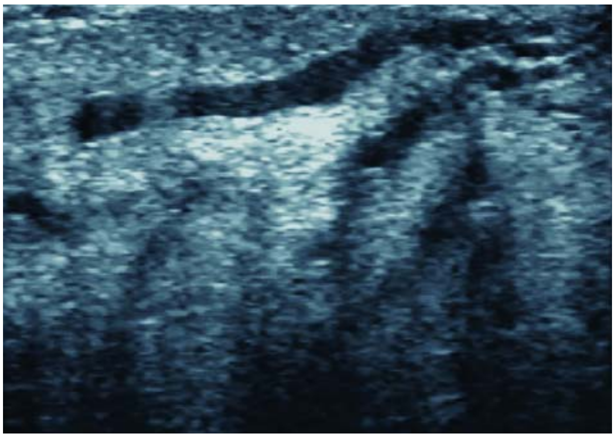

FIGURE 2 Ultrasound image of the lactating breast showing milk ducts (dark, hypoechoic) within the breast, under the areola. Note the superficiality of the duct, the early branching and the lack of a sinus.

Research methodology issues

Investigation of the lactating breast since Cooper has been slow, mainly due to limitations of imaging techniques. For example, mammography of the lactating breast is hindered due to a marked increase in glandular tissue causing a subsequent increase in radio-density thus making the images of the breast difficult to interpret[17]. Galactography (the injection of radio-opaque contrast media into the duct orifice at the nipple and subsequent radiography) is not ideal in the lactating woman as it is limited to imaging one ductal system (that may not be outlined completely) and the risk of introduced infection is increased. Computed tomography (CT) and magnetic resonance imaging (MRI) are promising modalities that may, in the future, provide more information regarding mammary gland anatomy. Two recent studies have used MRI to image the breast – one was able to identify some central ducts in the breasts of lactating women[18], whilst another attempted to quantify fatty and glandular tissue volumes in the breasts of non-lactating women[19]. Ramsay et al recently re-investigated the anatomy of the lactating breast using high resolution ultrasound[20]. High resolution ultrasound is able to delineate very small structures of the breast with the added advantage of being non-invasive, thus allowing the breast to be examined without distortion. (**FIGURE 2**).

Anatomy of the lactating breast

It is widely believed that the predominant tissue in the lactating breast is glandular. Ramsay et al. found there to be approximately twice as much glandular tissue as fatty tissue in the lactating breast[20]. However, the proportion of tissues varied greatly between women with some women having up to half of the breast comprised of fatty tissue and conversely others up to 80% of the breast comprised of glandular tissue. In addition, the glandular tissue was not evenly distributed throughout the breast with the vast majority (over 66%) being found within a radius of 30mm from the base of the nipple. The fatty tissue was also not evenly distributed with fatty tissue being found within the glandular tissue (intraglandular), at the back of the breast (retromammary) and subcutaneously. Indeed, the amount of fat intermingled with the glandular tissue (intraglandular fat) was highly variable, similar to that observed in the non-lactating breast[21]. Furthermore, most of the fatty tissue in the breast was subcutaneous (approximately two thirds) and was also not uniformly distributed, with little subcutaneous fat found at the base of the nipple and areola.

Ultrasound imaging has also provided further information on the ductal anatomy of the lactating breast. It is commonly quoted that the glandular tissue is drained by 15-20 ducts[22] and is based on Cooper's original work[7]. It is however possible that not all ducts emanating from glandular

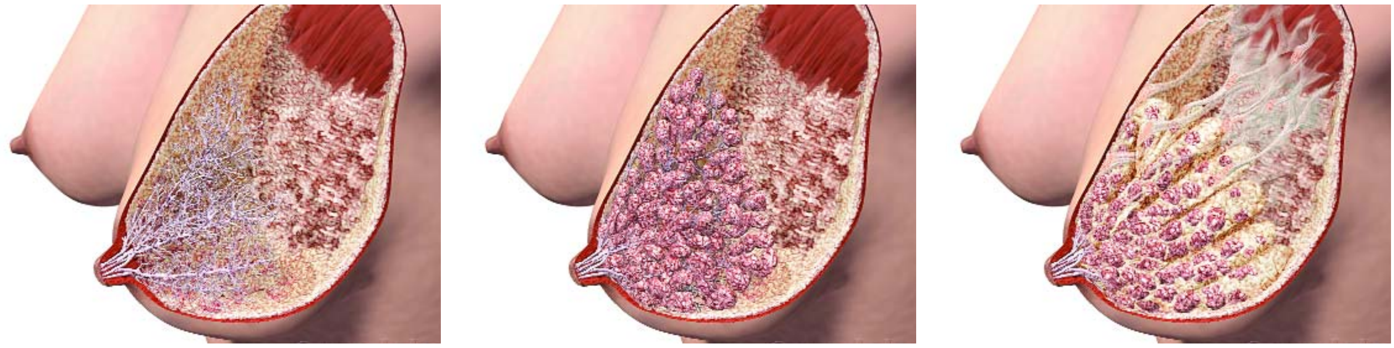

FIGURE 3 3D representations of the tissues of the lactating breast based on the ultrasound findings of Ramsay et al[20]. A) Ductal network, B) Distribution of glandular tissue and C) Complete 3D representation of all tissues. *Copyright Medela AG, 2006. Used with permission.*

tissue open on to the nipple or *vice versa*[23]. Love and Barsky observed an average of five nipple openings (range 1-17), most frequently in the central portion of the nipple, in a group of 219 expressing women[23]. Similarly, 10 mastectomy (non-lactating) nipples in the same study showed 5-7 patent ducts. Going and Moffatt's dissection of one lactating nipple showed only four patent ducts[24]. Ramsay and coworkers, using ultrasound to examine the lactating breast, have also shown lower numbers of main milk ducts (mean 9; range 4-18) than the 15-20 commonly reported[20]. Importantly the results of these recent studies compare favourably with Cooper who, although he stated finding 15-20 openings at the nipple, also wrote that he could usually only cannulate 7-12 patent ducts[7]. Furthermore, both Going and Moffat[24] and Love and Barsky[23] found no evidence of ductal communication between the lobes of the breast (non-lactating) in contrast to Ohtake who demonstrated two connections between lobes in the mastectomised breast of a 69 year old woman[25]. Whilst these results were obtained from studies on non-lactating breasts they agree with Cooper's observations that each glandular lobe exited the breast from its own duct.

Ramsay and coworkers have also shown that the milk ducts in the lactating breast are small (mean 2mm in diameter), superficial and easily compressed[20]. In addition they do not display the typical sac like appearance of the 'lactiferous sinus' (**FIGURE 2**). Instead branches drain glandular tissue located immediately below the nipple and often merge into the main collecting duct very close to the nipple[20] (**FIGURE 2**). Furthermore, ultrasound studies have demonstrated that the milk ducts increase in diameter at milk ejection leading to the conclusion that the main function of the ducts is likely to be the transport of milk rather than storage[26]. This is in agreement with Cardenosa and Eklund who concluded that the ducts are not, in general, enlarged during lactation[27]. In addition the paths of the ducts from the nipple into the breast are erratic and they are intertwined much like the roots of a tree[20] (**FIGURE 1**) making them difficult to separate surgically[22].

Clinical implications

The new findings with regard to the anatomy of the breast have allowed for the development of new anatomical diagrams (**FIGURE 3**) and have many clinical implications for lactating women. Of most importance is that they have provided the clinician with a better understanding of the normal function of the breast and, at the same time, greater insight to the 'abnormal' function of the breast. Indeed, these anatomical findings may help in providing physiological explanations for often observed clinical phenomena.

Breast surgery

The number of women electing to have breast surgery is increasing annually. In the UK, anecdotal reports suggest that breast augmentation in 2005 increased by 51 percent from 2004[28]. Alarmingly, studies have shown that as many as 50 percent of women who have undergone breast augmentation may experience low milk production[29,30]. Moreover, periareolar incisions were associated with an increased likelihood of lactation insufficiency[29,31]. It is reasonable to assume that the severing of ducts and glandular tissue will diminish the amount of milk producing tissue that is able to drain freely through the nipple, especially since the breast has a lower number of patent ducts than previously thought[20,23]. In addition, the pressure of an implant upon the glandular tissue may cause compression of the ducts thus raising the possibility of obstruction of milk flow.

Similarly, reduction mammoplasty can impact on lactation with 0-82% of women able to breastfeed (at least partially) depending on the surgical technique used[32,33]. A possible explanation of why these mothers may have low milk production includes the obvious removal of large quantities of glandular tissue. Unfortunately the co-distribution of glandular and fatty tissue demonstrated within both the lactating[20] and non-lactating breast[21] would make it difficult to preferentially remove fatty tissue during this procedure. Furthermore, it is possible that the reduction surgery may impair the outflow of milk, perhaps more severely than augmentation, given that the breast has fewer patent ducts than previously quoted[20,23].

Low milk production

Whilst there is little information regarding the incidence of verified low milk supply, it is certainly recognised as a significant problem for mothers of preterm infants who must express their milk in order to feed their baby and maintain lactation[34]. Clinically, pharmacological intervention (metoclopramide, domperidome) to increase prolactin levels and boost milk production may be trialled. This usually occurs without prior measurement of maternal serum or milk prolactin levels and not unexpectedly, provides varying success. Another reason for low milk production may be insufficient glandular tissue. Ramsay and coworkers[20] showed that the ratio of glandular tissue to adipose tissue was 2:1 and quantification of the volume of glandular tissue in the breast (possibly by ultrasound, CT or MRI) of mothers experiencing milk supply problems would be valuable to exclude a maternal, physiological cause for low milk production. Further investigation could then be directed towards the effectiveness of milk removal by either the infant or breast pump (in the case of the mother expressing for the preterm infant) or the management of breastfeeding/expressing regimes. Finally, knowledge of the normal features of the ductal system is integral to diagnosing ductal abnormalities that may affect milk flow and drainage of the glandular tissue and manifest themselves as low milk production.

Milk ejection and milk removal

Milk ejection is critical for a successful lactation as only small volumes of milk (1-10mL) can be either expressed[35] or removed by the breastfeeding infant[36] prior to milk ejection. Stimulation of the nipple initiates milk ejection by conveying nervous impulses to the hypothalamus, which causes the posterior pituitary gland to release the hormone oxytocin into the bloodstream[37]. Oxytocin causes the myoepithelial cells surrounding the alveoli to contract thereby forcing (ejecting) milk into the ducts. This results in increased intra-ductal pressure[38], duct dilation[36,39] and increased milk flow rate[39]. Multiple milk ejections almost always occur during breastfeeding (mean 2.5; range 0-9)[36] and breast expression (mean 3-6 for a 15 minute expression period)[39] and although many women are able to sense the first milk ejection, few are able to sense subsequent milk ejections.

Effective milk removal from the breast by either the infant or breast pump is necessary to avoid the down regulation of milk synthesis by local control mechanisms and eventual weaning[40]. While it is well known that stress can influence milk ejection, resulting in diminished amounts of milk removed by both the infant[37] and breast pump[41], it is often the subtle stress which affects maternal confidence and subsequently milk ejection that is overlooked. Therefore it is important to provide positive support to the mother during both breastfeeding and pumping.

The effect of breast anatomy on the expression of milk is largely unexplored, however there is an indication that larger milk duct diameters are associated with longer milk ejection episodes and more available milk expressed during pumping[39]. It is possible to image the milk ducts in the nipple with ultrasound and marked differences in duct size between women have been observed[20,42]. Thus milk duct size or nipple integrity may indeed affect milk flow during expression or breastfeeding. These observations may explain the differences in pumping success experienced by different women. Also, since the ducts are superficial and compressible it may be possible that an ill fitting breast shield used to apply vacuum to the breast may compress some ducts and thereby compromise milk flow. This emphasises the need for the mother to use a correctly fitted breastshield.

The absence of lactiferous sinuses or milk reservoirs leads one to reconsider the mechanism by which the infant removes milk from the breast. It is evident that correct positioning and attachment of the infant to the breast is important for successful breastfeeding, however the rationale for this is not fully explained. Mechanistically, it is commonly believed that the infant uses a peristaltic motion of the tongue to strip milk from the nipple[43]. However, Ramsay et al, have recently shown that milk flow into the infant's mouth occurs when the tongue is lowered and vacuum in the mouth is increased[44]. In addition, the absence of the lactiferous sinuses further emphasises the critical nature of milk ejection for successful milk transfer as it is well documented that only small amounts of milk are available prior to the stimulation of milk ejection[35,36], thus suggesting that the main function of the ducts is the transport of milk, not storage. Finally, the mother using a breast pump should attempt to optimise milk removal during the initial milk ejection periods as milk ejection is a discrete event with as much as 45% of the removed milk being obtained during the first milk ejection[39].

Conclusion

To date, few studies have actively investigated the anatomy of the lactating breast despite the obvious importance a clear understanding of the lactating mammary gland has to both mother and infant. Perhaps this lack of information is a part of the greater reason why many women continue to experience breastfeeding problems. The latest studies outlined here have provided new information on the ductal structures in the breast (fewer numbers, increased branching close to the nipple, compressible, superficial with no lactiferous sinus) and the distribution of glandular tissue (significant glandular tissue close to the nipple, ratio of 2:1 between glandular and fatty tissue). Furthermore, they have provided new insights into the functional aspects of the lactating breast (e.g. effect of duct diameter on milk flow) as well as the clinical aspects (e.g. lower duct numbers, breast surgery and future lactation potential). Only when the physician and clinician alike have an accurate understanding of the anatomy of the 'normal' functioning mammary gland will they be able to address the 'abnormal'. This will lead to improved support of the breastfeeding mother and potentially help in increasing the number of breastfeeding mothers and the duration of breastfeeding.

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