Inside the Lactating Breast: The Latest Anatomy Research

Donna T. Geddes, PhD

Although it is well recognized that a thorough understanding of the anatomy of an organ is essential to enable assessment of any abnormalities in that organ, there has been little investigation of the anatomy of the normal lactating breast since Sir Astley Cooper performed detailed dissections of the anatomy of the breast more than 160 years ago. Many mothers recognize that breast milk provides the ultimate nutrition and protection for the infant; however, a significant proportion of women experience difficulties breastfeeding, some of which lead to weaning the infant. Recently, a small number of studies have focused on the gross anatomy of the breast, and have found that the ductal system is comprised of fewer numbers of main ducts than previously thought. In addition, the ducts are compressible and do not contain large amounts of milk, the amount of fatty tissue in the breast is variable, and a proportion is situated within the glandular tissue. These findings add to our understanding of both the physiology and pathology of the lactating breast. J Midwifery Womens Health 2007;52:556–563 © 2007 by the American College of Nurse-Midwives.

**keywords:** anatomy, breast, breastfeeding, lactation, mammary gland

INTRODUCTION

The human breast reaches its full functional capacity during lactation with the production of breast milk. In order to diagnose and treat breastfeeding problems and pathologies that arise during lactation, it is essential to have an extensive understanding of the normal anatomy and physiology of the breast. This review details the development of the breast and the most recent findings in breast anatomy. The effect breast anatomy has upon clinical practice as well as the importance of milk ejection is reviewed.

DEVELOPMENT OF THE BREAST

While it is undisputed that breast milk provides the optimal nutrition for the developing infant, breast milk also contains unique protective factors for the mother. It has been hypothesized that the mammary gland first evolved from the innate immune system as an inflammatory response to provide protection to the young, and that nutritional factors developed later. To date, nutrition has assumed a position of dominance over the protective factors in considerations of the physiology of human lactation.

The human breast is a dynamic organ that does not go through all developmental stages unless a woman experiences pregnancy and childbirth. The course of breast development can be described in distinct phases beginning with the fetal phase and progressing through the neonatal/prepubertal and postpubertal phases. Development of the breast can then proceed through a number of lactation cycles (pregnancy, lactogenesis I, lactogenesis II, and involution; (see review by Kent on page 564).

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BREAST DEVELOPMENT

Fetal Development

The human breast develops from a thickened ectodermal ridge (milk line) situated longitudinally along the anterior body wall from the groin to the axilla at about 6 weeks’ gestation. Regression of the ridge occurs except for the pectoral region (2nd–6th rib), which forms the mammary gland. Supernumerary glands may develop anywhere along the ectodermal ridges, and in 2% to 6% of women, these glands either mature into mammary glands or remain as accessory nipples.

During the 7th and 8th weeks of gestation, the mammary parenchyma invades the stroma, which appears as a raised portion called the mammary disc. Between the 10th and 12th weeks, epithelial buds form; parenchymal branching occurs during the 13th through 20th weeks. Between the 12th and 16th weeks of gestation, the smooth musculature of the areola and nipple are formed, and at approximately 20 weeks’ gestation, between 15 and 25 solid cords form in the subcutaneous tissue. Branching continues, and canalization of the cords occurs, forming the primary milk ducts by 32 weeks’ gestation. At 32 weeks’ gestation the ducts open onto the area, which develops into the nipple. The adipose tissue of the mammary gland develops from connective tissue that has lost its capacity to form fibres, and it is considered necessary to further growth of the parenchyma.

Shortly after birth, colostrum can be expressed from the infant’s mammary glands. This is attributed to the pro-lactation hormones present in the fetal circulation at birth. Regression of the mammary gland usually occurs by 4 weeks postpartum and coincides with a decrease in the secretion of prolactin from the anterior pituitary gland of the infant.

Neonatal and Prepubertal Development

The ducts in the newborn breast are rudimentary and have small, club-like ends that regress soon after birth.

Address correspondence to Donna T. Geddes, PhD, Department of Biochemistry and Molecular Biology, School of Biomedical, Biomolecular and Chemical Sciences, Faculty of Life and Physical Sciences, M310–The University of Western Australia, 35 Stirling Highway, Crawley WA 6009 Australia. E-mail: donna.geddes@uwa.edu.au
Before puberty, the growth of the breast is isometric. Allometric growth of both the stroma and epithelium begins with the onset of puberty (8–12 years of age). Although the impact of obesity on breast development at this stage is unknown, it is of interest that ruminants fed a diet that is higher than their energy requirements have impaired mammary development and subsequent impaired lactation performance.\textsuperscript{8,9}

**Puberty**

At puberty, the increase in breast size is mainly caused by the increased deposition of adipose tissue within the gland. However, progressive elongation and branching of the ducts creates a more extensive ductal network.\textsuperscript{10} The major site of growth is the bud-like structures at the end of the ducts, and these form the terminal duct lobular units or acini.\textsuperscript{11} Although knowledge of the hormonal regulation of mammary growth during puberty is not extensive, these maturational changes are associated with increased plasma concentrations of oestrogen, prolactin, luteinizing hormone, follicle stimulating hormone, and growth hormone.\textsuperscript{12,13}

**Menstrual Cycle Changes**

During the follicular phase of the menstrual cycle, the lobules are small, with few alveoli, and there is low mitotic activity. During the luteal phase, the lobules and alveoli develop with open lumens and mitotic activity is at its greatest.\textsuperscript{14} From day 27 to menstruation, these changes regress. However, the degeneration of the epithelial growth is not complete,\textsuperscript{15} and some of the follicular growth remains until the next cycle. With increasing years, there is a relative decrease in mitotic activity until about 35 years of age, when breast development plateaus.\textsuperscript{4}

**GROSS ANATOMY OF THE NON-LACTATING BREAST**

For the past 160 years, the descriptions of the anatomy of the breast have changed little since Sir Astley Cooper’s\textsuperscript{16} meticulous dissections of breasts of women who were lactating when they died (Figure 1).

The breast is composed of glandular (secretory) and adipose (fatty) tissue, and is supported by a loose framework of fibrous connective tissue called Cooper’s ligaments. Traditional descriptions of breast anatomy describe the glandular tissue as consisting of 15 to 20 lobes that are comprised of lobules containing between 10 and 100 alveoli that are approximately 0.12 mm in diameter\textsuperscript{17} (Figure 2). The size of each lobe is extremely variable, and some lobes may differ by 20-to 30-fold.\textsuperscript{18}

Although it is generally thought that each lobe is a single entity, a recent study that created three-dimensional reconstructions of the entire ductal system (16 lobes) of a mastectomized breast of a 69-year-old female was able to demonstrate two connections between lobes.\textsuperscript{19} It is generally believed that 15 to 25 ducts drain the alveoli and merge into larger ducts that eventually converge into one main milk duct which dilates slightly to form the lactiferous sinus before narrowing as it passes through the nipple and opens onto the nipple surface (Figure 2). Recent histologic sections of mastectomy nipples have shown more than 17 ducts on average\textsuperscript{18,20}; however, it is not known whether these are all patent, and others suggest the average number of ducts is lower (5–9).\textsuperscript{21}

The diameters of the main ducts in the non-lactating breast as measured by ultrasound are between 1.2 mm and 2.5 mm in diameter. Dilated ducts in the non-lactating breast may be caused by conditions such as polycystic ovarian disease\textsuperscript{22} or ductal ectasia. The nipple pores are 0.4 mm to 0.7 mm in diameter and are surrounded by circular muscle fibres.\textsuperscript{4,5}

The heterogeneous distribution of glandular and adipose tissue in the breast has hindered measurement of these tissues. However, the ratio of glandular to adipose tissue estimated by mammography is 1:1 on average, and it is well documented that the proportion of glandular tissue declines with both advancing age\textsuperscript{23} and increasing breast size.\textsuperscript{24}

**Arterial Supply**

The blood supply to the breast is provided mainly by the anterior and posterior medial branches of the internal
mammary artery (60%) and the lateral mammary branch of the lateral thoracic artery (30%).\textsuperscript{25} Smaller sources of arterial blood include the posterior intercostal arteries and the pectoral branch of the thoracoacromial artery.\textsuperscript{5} There is wide variation in the proportion of blood supplied by each artery between women,\textsuperscript{26} and little evidence of symmetry between breasts. Moreover, the course of the arteries does not appear to be associated with the ductal system of the breast.\textsuperscript{4}

Venous Drainage

The venous drainage of the breast is divided into the deep and superficial systems which are joined by short connecting veins. Both systems drain into the internal thoracic, axillary, and cephalic veins. The deep veins are assumed to follow the corresponding mammary arteries, while the superficial plexus consists of subareolar veins that arise radially from the nipple and drain into the periareolar vein, which circles the nipple and connects the superficial and deep plexus. Symmetry of the superficial venous plexus is not apparent.\textsuperscript{25}

Innervation

Cooper\textsuperscript{16} showed that the 2nd to 6th intercostal nerves supply the breast. The distribution and course of these nerves are complex and variable. The anterior nerves take a superficial course in the subcutaneous tissues, while the lateral nerves travel a deep course through the breast. The nipple and areola are supplied by the anterior and lateral cutaneous branches of the 3rd to 5th intercostal nerves most commonly the 4th intercostal nerve.\textsuperscript{27}

Lymphatic Drainage

The drainage of lymph from the breast has been extensively investigated with particular reference to breast carcinoma, and there are two main pathways by which lymph is drained from the breast. The first is to the axillary nodes; the second is to the internal mammary nodes. The majority of the lymph from both the medial and lateral portions of the breast is drained to the axillary nodes (75%), whereas the internal mammary nodes receive lymph from the deep portion of the breast. However, as expected, there is a wide variation in the drainage of lymph from the breast, and less common pathways have been demonstrated.\textsuperscript{5}

PREGNANCY

During the first half of pregnancy, extension and branching of the ductal system occurs, along with intensified lobular–alveolar growth (mammogenesis). 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,\textsuperscript{28,29} and parathyroid hormone–related protein.\textsuperscript{30} Growth of the glandular tissue is believed to occur by invasion of the adipose tissue.\textsuperscript{4} By mid-pregnancy, there is some secretory development, with colostrum present in the alveoli and milk ducts. In the last trimester, there is a further increase in lobular size.

While these changes typically lead to a marked 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.
While the major increase in breast size is usually completed by week 22 of pregnancy, significant breast growth occurs during the last trimester of pregnancy in some women, and some women undergo significant breast growth postpartum. At the end of pregnancy, the volume of breast tissue had increased by 145 ± 19 ml (mean ± standard error of the mean; n = 13; range, 12–227 ml), with a further increase to 211 ± 16 ml (n = 12; range, 129–320 ml) by 1 month of lactation. The rate of growth of the mother’s breast during pregnancy is correlated with the increase in the concentration of human placental lactogen in the mother’s blood, which suggests that this hormone stimulates breast growth in women.31

During pregnancy, mammary blood flow approximately doubles in volume. This increased blood flow is concomitant with both the increased metabolic activity and temperature of the breast. This elevation in blood flow persists during lactation and appears to decline to prepregnancy levels about 2 weeks after weaning.32

GROSS ANATOMY OF THE LACTATING BREAST

The breast reaches its full functional capacity at lactation, and as a result, several internal and external changes occur. During pregnancy, the areola darkens in colour, and the Montgomery glands, which are a combination of sebaceous glands and mammary milk glands, increase in size. The secretions of these glands, which number between 1 and 15,33 are thought to provide maternal protection from both the mechanical stress of sucking and pathogenic invasion. In addition, it is also suspected the secretion may act as a means of communication with the infant via odor. In this connection, a recent study demonstrated that increased numbers of Montgomery glands is associated with increased infant weight gain in the first 3 days after birth, infant breastfeeding behaviour (increased latching speed and sucking activity), and decreased time to onset of lactation in primiparous mothers,33 suggesting that there is indeed a functional role of the Montgomery glands during lactation.

The standard descriptions of the human breast are based on Cooper’s16 magnificent cadaver dissections of breasts of women who were lactating at the time of death. Although imaging modalities have become more sophisticated, research has focused extensively on abnormalities of the non-lactating breast. Mammography of the lactating breast is limited because of the increase in glandular tissue and the secretion of breast milk, which causes an increase in radiodensity, making images of the breast difficult to interpret.34

Galactography (the injection of radio-opaque contrast media into the duct orifice at the nipple and subsequent radiography) has illustrated only a portion of the ductal system, and few studies have examined lactating women. Of those that have looked at lactating breasts, some have described the milk ducts as being significantly larger compared to those of the non-lactating breast. In contrast, Cardenosa and Eklund35 have reported that the ducts do not enlarge during lactation.

To date, both computed tomography and magnetic resonance imaging have had little to offer in elucidating mammary anatomy. However, in two recent studies that used magnetic resonance imaging to image the breast, one study was able to identify some central ducts in the breasts of lactating women,36 and another attempted to quantify fatty and glandular tissue volumes in the breasts of non-lactating women.37 These findings suggest that this modality may offer some new insights into the anatomy of the breast in future.

Our laboratory has recently reinvestigated the anatomy of the lactating breast using high-resolution ultrasound.38 Ultrasound is non-invasive and allows the structures of the breast to be examined without distortion. Compared with the quoted 15 to 25 ducts of conventional texts,4,5 fewer ducts were imaged with ultrasound (mean, 9; range, 4–8), which concurs with both Love and Bar- sky’s,21 observations of lactating women expressing milk with a breast pump (mean, 5; range, 1–17) and Going and Moffatt’s39 dissection of a nipple (4 patent ducts) from a woman who was lactating. Interestingly, these are in agreement with Cooper,16 who found 7 to 12 patent ducts in cadaver dissections of breast from a woman who was lactating before death, although he could cannulate up to 22 ducts.

Ultrasound imaging has also elucidated other characteristics of the milk ducts, in that they are small (mean, 2 mm), superficial, and easily compressed. In addition, they do not display the typical sac like appearance of the “lactiferous sinus” originally thought to exist (Figure 3). Instead, branches drain glandular tissue located directly beneath the nipple and often merge into the main collecting duct very close to the nipple38 (Figure 3). Furthermore, the milk ducts increase in diameter at milk ejection,40 leading to the conclusion that it is likely that the main function of the ducts is the transport rather than storage of milk. In addition, the actual course of the ducts from the nipple into the breast is erratic, and they are intertwined much like the roots of a tree38 (Figure 1), making them difficult to separate surgically.5

It is widely believed that the lactating breast is predominantly composed of glandular tissue during lactation. Using a semi-quantitative ultrasound measurement of the glandular and adipose tissues in the breast, we have found there to be approximately twice as much glandular tissue as adipose tissue in the lactating breast. However, there is great variability, and in some women, up to half of the breast is comprised of adipose tissue. In addition, the amount of fat situated between the glandular tissues is highly variable. At this stage, no relationship between the amount of glandular tissue in the breast and
either the storage capacity of the breast or milk production has been demonstrated.38

Nerve fibres have been identified in association with the major duct system in the lactating breast; however, they are sparse in the region of the smaller ducts, areola, and nipple.41 Although these nerves are sensory, apart from a marked increase in areola and nipple sensitivity within the first 24 hours postpartum,42 women tend not to be particularly sensitive to breast changes associated with some abnormal conditions. For example, women with mastitis often experience influenza-like symptoms before becoming aware of breast tenderness or the presence of a blocked duct. In addition, the absence of motor innervation of the lactocyte and glandular tissue further supports that the production of milk is independent of neural stimulation.53 It should be noted, however, that as with the gross anatomy of the breast, the nerve supply of the breast has not been extensively investigated recently.

These new findings with regard to breast anatomy have several clinical implications (Table 1). For example, abnormalities of the lactating breast have not been extensively investigated in comparison to the pathological, non-lactating breast. Although ultrasound imaging is only semi-quantitative and can be subjective, it may provide information on the proportion of glandular tissue in mothers with very low milk supply, breast hypoplasia (too little glandular tissue), or hyperplasia (overgrowth of glandular tissue). With rising rates of obesity, there is some concern about the effect of obesity on lactation, particularly with increasing reports that obese women are experiencing breastfeeding difficulties (see review by Jevitt et al. on page 606). Only a few studies have been carried out to investigate the effect of obesity on lactation, and they have been difficult to perform because of known confounding factors such as the mode of delivery and parity. These studies show that pregnant women with a high body mass index are more likely to experience delayed lactogenesis II.44 While the cause of delayed lactation is not clear, hormonal influences on milk production, increased difficulty attaining a successful infant latch to the breast, and socio-cultural factors have been suggested.45

Knowledge of the normal features of the ductal system is integral to diagnosing ductal abnormalities such as galactoceles and blocked ducts. A palpable lump and ultrasonic features of non-compressible ducts is indicative of a blocked duct and should not be considered “normal” for the lactating breast. Furthermore, the ultrasound scan may identify the level of the blockage, providing useful information for treatment with therapeutic ultrasound.

Mothers of premature and sick infants rely on breast pumps to initiate and maintain lactation. Clinically, it has been observed that larger shield sizes may optimize milk removal for some mothers. It is therefore feasible that compression of superficial ducts within the breast by the shield may indeed compromise milk flow. Further research is required to determine the effect of ductal anatomy on pumping performance in women.

Many women who have breast reduction surgery may be able to partially breastfeed their infant, but relatively few are able to exclusively breastfeed.52 This is likely because of the codistribution of glandular and fatty tissue within both the lactating38 and non-lactating breast,53 making it difficult to preferentially remove fatty tissue. In addition, milk outflow is probably disrupted, because there are fewer numbers of ducts than previously thought.21,38 Furthermore, it is possible that the milk ejection reflex may be inhibited if the nerve supply to the nipple is disturbed.

The absence of lactiferous sinuses or milk reservoirs leads one to reconsider the mechanism by which the infant removes milk from the breast. Generally, it is believed that the predominant action involved in removing milk from the breast is peristalsis or a stripping action.54 We have found that milk flows into the infant’s mouth when its tongue is lowered and vacuum is applied to the breast. This finding suggests that the vacuum applied by the breastfeeding infant is a major component of milk removal.55 Indeed, it is evident that correct positioning and attachment of the infant to the breast is
important for successful breastfeeding; however, the mechanism should be fully understood in order to diagnose and manage infants with sucking abnormalities. Finally, the absence of the lactiferous sinuses further emphasizes the critical nature of milk ejection for successful breastfeeding, because only small amounts of milk are available before the stimulation of milk ejection.40,46

MILK EJECTION

Milk ejection is critical for successful lactation, because only small volumes of milk (1–10 mL) can be either expressed46 or removed by the breastfeeding infant40 before milk ejection. Failure to remove sufficient quantities of milk results in a decrease in milk production because of local control mechanisms.47 Stimulation of the nipple initiates milk ejection via initiation of nervous impulses to the hypothalamus, which stimulates the posterior pituitary gland to release oxytocin into the bloodstream.48 Oxytocin causes the myoepithelial cells surrounding the alveoli to contract, forcing milk into the ducts. This results in increased intraductal pressure,49 duct dilation40,50 (measured by ultrasound), and consequently increased milk flow rate50 (measured by continuous weigh balance during breast expression). Multiple milk ejections almost always occur during breastfeeding40 (mean, 2.5; range, 0–9) and breast expression50 (mean, 3–6 for 15-minute expression period), and although many women are able to sense the first milk ejection, few are able to sense subsequent ones.

While it is well known that stress can influence milk ejection—resulting in diminished amounts of milk removed by both the infant48 and breast pump51—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. Another factor that may influence milk ejection and milk removal is the ductal anatomy of the breast. In a study of mothers expressing with an electric breast pump, ultrasound was used to image duct dilation in the breast that was not pumped. It was found that mothers with larger ducts expressed more milk during milk ejection and had longer milk ejections than mothers with smaller ducts.50 Therefore, the rate of milk removal for a mother may be influenced in part by her ductal anatomy.

CONCLUSION

New anatomy research has shown that the milk ducts of the breast are small, compressible, superficial, and closely intertwined. They do not display typical dilated “sinuses” and do not typically store large amounts of milk. In addition, the amount of adipose tissue in the breast is highly variable, particularly between the glandular tissue. This fundamental knowledge of the anatomy of the breast—particularly when it is fully functional—

Table 1. Summary of Some of the Common Breastfeeding Conditions and Symptoms and the Connection With Breast Anatomy

<table>
<thead>
<tr>
<th>Clinical Condition</th>
<th>Symptoms</th>
<th>Anatomical Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glandular anomaly</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypoplasia</td>
<td>Low milk production</td>
<td>Possible deficiency of glandular tissue</td>
</tr>
<tr>
<td>Hyperplasia</td>
<td>Excessive breast growth, lymphoderma, possible necrosis</td>
<td>Excess glandular tissue</td>
</tr>
<tr>
<td>Breast surgery</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reduction</td>
<td>Low milk production</td>
<td>Large volume of glandular tissue removed, severing milk ducts fewer in number than previously thought; possible nerve damage inhibiting milk ejection reflex</td>
</tr>
<tr>
<td>Mammaplasty</td>
<td>Low milk production</td>
<td>Possible compression of milk ducts by implant</td>
</tr>
<tr>
<td>Breast augmentation</td>
<td>Low milk production</td>
<td>Possible deficiency in volume of glandular tissue</td>
</tr>
<tr>
<td>Palpable mass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blocked duct</td>
<td>Mass (small or large) ± pain</td>
<td>Compression of ducts: possible cause of blocked duct; if large lobe affected a significant reduction in milk production may occur; identification of the level of duct obstruction by ultrasound ensures treatment of entire affected area</td>
</tr>
<tr>
<td>Galactocele</td>
<td>Mass (generally small)</td>
<td>Possible ductal abnormality</td>
</tr>
<tr>
<td>Benign mass (cyst, fibroadenoma)</td>
<td>Mass</td>
<td>Possible compression of ducts causing blocked duct; possible obstruction of milk flow in the area of attachment of the infant to the breast</td>
</tr>
<tr>
<td>Malignant mass</td>
<td>Palpable non-resolving mass</td>
<td>Irregular shaped mass that may be mistaken for a blocked duct or galactocele; ultrasound ± mammography needed for diagnosis</td>
</tr>
<tr>
<td>Infant sucking mechanism</td>
<td>Ineffective suck</td>
<td>Lack of milk sinuses and evidence that vacuum plays a major role in milk removal may alter intervention</td>
</tr>
<tr>
<td>Milk expression</td>
<td>Differences in efficiency of pumping</td>
<td>Theorized that women with large milk ducts or duct dilations at milk ejection express milk quickly</td>
</tr>
<tr>
<td>Milk ejection</td>
<td>Time of increased milk availability</td>
<td>Poor shield fit may result in compression of superficial ducts and inhibit milk flow</td>
</tr>
</tbody>
</table>

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allows one to begin to understand and the myriad of problems that are experienced by women during lactation. This knowledge will form a foundation for the development of appropriate treatments and interventions.

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REFERENCES


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