SURGICAL FOUNDATIONS

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Essentials of BREAST SURGERY

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Dedication

To my wonderful wife, Janeel, who was extremely understanding when family time needed to be compromised, and to my beautiful children, Alex and Madison, although they weren't quite as understanding. Also, to my parents, Steven and Rhoda, who through their love and patience got me to the point where I can hopefully make them proud.

Preface

The management of both benign and malignant breast disease represents a major portion of a surgeon's responsibility, yet often comprises only a minor portion of their training. The diagnostic workup and treatment of breast disease is constantly changing and increasingly complex, making it extremely challenging for the surgical trainee or practicing general surgeon to keep up with changes in the field. Surgeons will see an extremely high volume of patients with complaints related to the breast, and it is imperative that they allay fears, palliate symptoms, and not miss diagnosing malignant disease. Surgeons must also identify patients at high risk of developing breast cancer so that appropriate screening and prophylactic measures may be considered. The management of malignant breast disease is increasingly multifaceted. The days of the surgeon seeing the patient, completing surgical therapy, and then referring the patient to other specialists have passed; today the surgeon needs to work in concert with radiologists, pathologists, medical and radiation oncologists, plastic surgeons, and other medical professionals to formulate an appropriate diagnostic and therapeutic plan. Multidisciplinary management of the breast cancer patient is critical and often guided by the surgeon even though surgery may not be the first modality employed.

Any surgeon dealing with breast disease is in need of a strong grasp of not only the anatomy and physiology of the breast, but the potential and limitations of breast imaging, benign and malignant breast histology, genetics, cancer biology, and an understanding of all treatment modalities such as radiation and systemic therapies. However, most textbooks on breast disease are meant for clinicians and researchers from multiple disciplines, containing extremely thorough reviews of the research, the evolution of treatment, and the randomized trials that led us to this point. This can be too confusing and overwhelming for the surgeon in training or the practicing general surgeon who must also focus on diseases outside of the breast. *Surgical Foundations: Essentials of Breast Surgery* captures the true essentials of the management of breast disease in an easily readable and absorbable format. The principles of multimodality therapy (chemotherapy, radiation therapy, hormonal therapy) are explained from a surgical perspective, as are the basics of breast anatomy and physiology, the diagnostic workup and management of benign breast disease, and risk stratification and reduction. Our goal is a textbook that surgery residents, surgical oncology fellows, and breast surgery fellows can utilize in training (and beyond) and that practicing general surgeons can use to enhance their management of breast disease. Easy to read, with a list of key topics to help focus the reader and a liberal use of tables, boxes, and figures to reinforce the information in each chapter, this textbook will hopefully be a useful resource to any surgeon responsible for the management of diseases of the breast, particularly breast cancer.

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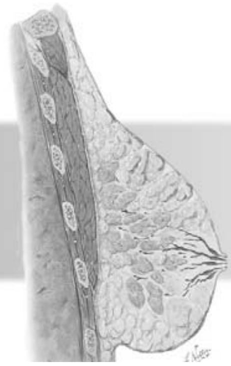

Anatomy and Physiology of the Breast

DEVELOPMENT OF THE BREAST
Embryology
Development during Puberty

ANATOMY OF THE ADULT BREAST
Muscular Anatomy of the Chest Wall
Fascia of the Breast and Chest Wall
Neural Anatomy of the Breast and Chest Wall
Vascular Anatomy
Lymphatic Anatomy
Anatomy of the Axilla

PHYSIOLOGY OF THE BREAST
Hormones Affecting the Breast
The Breast during the Menstrual Cycle
The Breast after Menopause
The Breast during Pregnancy
Lactation

Key Points

- Know the development of the breast from intrauterine development through puberty.
- Describe the anatomy of the breast and the relationship of the breast to the chest wall and axilla.
- Understand the segmental distribution of the ductal-lobular units and the pathway of milk from the lobules to the nipple
- Name the muscles of the chest wall and axilla, their blood supply and innervation, and the impact of a nerve injury.
- Understand the arterial supply and venous and lymphatic drainage of the breast and how this impacts breast pathology and surgery.
- Describe the anatomy of the axilla, the boundaries of the "axillary pyramid," and the groupings of the lymph nodes in the axilla.
- Understand the hormones that can affect breast physiology and how lactation occurs.
- Know the changes that the breast undergoes during the menstrual cycle, during pregnancy, and after menopause.

Development of the Breast

The breast undergoes multiple changes throughout life, from intrauterine life to senescence. The development of the breast has several implications that impact the breast surgeon. These include not only developmental anomalies that the breast surgeon may face, but also the routine surgical approach to both benign and malignant disease. Although the majority of growth occurs with puberty, the development and differentiation of the breast are truly completed by the end of the first term of pregnancy. This is relevant to the development of cancer, because breast cancer risk is clearly and inversely related to the age at which pregnancy first occurs. It is possible that this is secondary to an increased risk of carcinogenesis when the pre-parity, undifferentiated, and proliferating mammary epithelium is exposed to carcinogens, as compared to the effect of these same carcinogens on the differentiated breast.

BOX 1–1 STAGES OF EMBRYOLOGIC BREAST DEVELOPMENT

Ridge stage (<5-mm embryo)
Milk hill stage (7 to 8 weeks, 5- to 10-mm embryo)
- Thickening of the mammary anlage in the region of the thorax
- Regression of the remainder of the milk streak

Mammary disc stage (10-mm embryo)
- Invagination into the chest wall mesenchyme

Lobule stage (11- to 25-mm embryo)
- Tridimensional growth

Cone stage (10 to 14 weeks, 25- to 30-mm embryo)
- Flattening of the ridge

Budding stage (12 to 16 weeks, 30- to 70-mm embryo)
- Mesenchymal cells differentiate into smooth muscle of nipple and areola
- Epithelial buds develop

Indentation stage (70 mm to 10 cm)
Branching stage (16 weeks, 10-cm fetus)
- Epithelial buds branch into 15 to 25 strips of epithelium
- Differentiation of hair follicle, sebaceous gland, and sweat gland elements
- Apocrine glands develop to form Montgomery glands around the nipple

Canalization stage (20 to 32 weeks of gestation)
- First stage dependent on hormonal influences
- Placental sex hormones induce canalization of the branched epithelial tissues

End-vesicle stage (newborn)
- Development of lobuloalveolar structures containing colostrum

Embryology

Breast development takes place in several stages (Box 1–1). Essentially, the breast arises from a single ectodermal bud. At approximately the fifth to sixth week of fetal life, a *milk streak* develops as an ectodermal thickening, extending from the axilla to the pelvis. This is also referred to as the *galactic band*. By the ninth week, most of this has atrophied except for a mammary ridge in the pectoral region. It is here that a mass of basal cells proliferates to form the *nipple bud*. By the 12th week, squamous cells from the surface begin to invade the nipple bud. While the epithelial cells grow downward as mammary ducts, terminating in lobular buds, the mesenchymal cells differentiate into smooth muscle of the nipple and areola. The anlage of the lactiferous ducts invades the mesodermal connective tissue by 16 to 24 weeks.

The fact that the entire gland thus originates as a large dermal and subcutaneous organ from a single focus on the skin is relevant to the breast surgeon. One can think of the breasts as modified eccrine glands. This is pertinent to the lymphatic drainage, and has implications for lymphatic mapping and sentinel lymph node biopsy (see Chapter 13). Failure of some of these steps to take place can result in congenital abnormalities of the breast (Box 1–2). Most of these are quite rare; however, ectopic breast tissue may be found in 1% to 6% of individuals and is commonly encountered by the breast surgeon. Ectopic breast tissue is a result of a failure of the milk streak to completely atrophy. The ectopic tissue is usually located in the axilla, and women may present with complaints of a mass or pain in this area. Both benign fibrocystic changes and cancer can arise in this tissue.

During the second trimester, the breast continues to develop with the appearance of sweat glands, sebaceous glands, and apocrine glands, which will develop into the Montgomery glands around the nipple. The epithelial buds begin to branch into between 15 and 25 branches. Until this point, all of this has occurred independent of the placental sex hormones. In the third trimester, these hormones can enter the fetal circulation and stimulate

BOX 1–2 ABNORMAL BREAST DEVELOPMENT

Accessory Nipple (Polythelia)

Ectopic nipple tissue due to failure of complete regression of the milk streak
May occur anywhere from axilla to groin

Accessory Mammary Gland (Polymastia)

Accessory breast tissue due to failure of complete regression of the milk streak
Most often in axilla; may enlarge during pregnancy

Hypoplasia

Underdevelopment of the breast, which may be unilateral or bilateral with asymmetry

Poland's syndrome

Unilateral hypoplasia of the breast, thorax, and pectoralis muscles
Can also be associated with hand abnormalities (symbrachydactyly, hypoplasia of the middle phalanges, and central skin webbing)

Hyperplasia

Overdevelopment of the breast; may be unilateral or bilateral with asymmetry

Amazia

The nipple is present but there is no underlying breast tissue

Congenital Amastia

Absent breast and nipple

Acquired Amastia

Iatrogenic amastia due to excisional biopsy of the breast bud
Can also result from radiation or trauma (burn)

the branched epithelial tissues to canalize. The ends of these branches differentiate into lobuloalveolar structures that contain colostrum. This colostral milk is stimulated by the placental hormones and can be expressed for 4 to 7 days after birth, in both male and female newborns (often referred to as "witch's milk"). During these final weeks of development, the mammary gland mass increases fourfold and the nipple-areolar complex develops and becomes pigmented. Shortly after birth there is withdrawal of the placental hormones, causing colostral secretion to stop and involution of the breast.

After birth, mammary gland development does very little more other than keeping pace with the growth of the body. During early childhood, there is further canalizing and branching of the vesicles, but no significant changes will take place until puberty.

Development during Puberty

Under the influence of gonadotropin-releasing hormone from the hypothalamus, puberty begins in children between 8 and 12 years of age. This leads to the release of follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from the pituitary gland, resulting in maturation of the ovarian follicles and the secretion of estrogens. As puberty begins, the circulating estrogen causes the ductal epithelium and surrounding stroma to grow. These ducts begin to extend into the superficial pectoral fascia and arborize within the supporting stroma to form collecting ducts and terminal duct lobular units. These ultimately form buds that precede further breast lobules. Surrounding the ducts, vascularity increases and connective tissues increase in volume and elasticity, replacing adipose tissue and providing support for the developing ducts (Fig. 1–1).

In addition to the development of pubic hair, breast budding is one of the first signs of adolescence in girls, along with the adolescent growth spurt, beginning anywhere between age 8 and 13 years. Although there are many ways one can define the stages of breast development from puberty to adulthood, the most commonly used system is the Tanner phases, which is based on the external appearance of the breast (Table 1–1). Approximately a year or 2 following menarche, the breasts acquire their mature structure (Tanner stage 5).

Anatomy of the Adult Breast

The adult breast sits atop the anterior chest wall (Fig. 1–2). Superiorly, the breast extends to the second intercostal space, while inferiorly it extends to the inframammary fold, located at the sixth or seventh intercostal space. The medial margin is at the lateral margin of the sternum, and the lateral margin sits at the midaxillary line. The shape of the breast is not spherical, but rather that of a teardrop, with an extension of breast tissue toward the axilla known as *the tail of Spence*. This is an important concept to keep in mind when performing a mastectomy (see Chapter 12: Surgical Management of Breast Cancer). These are the classic descriptions of the boundaries of the breast, but breast tissue can extend

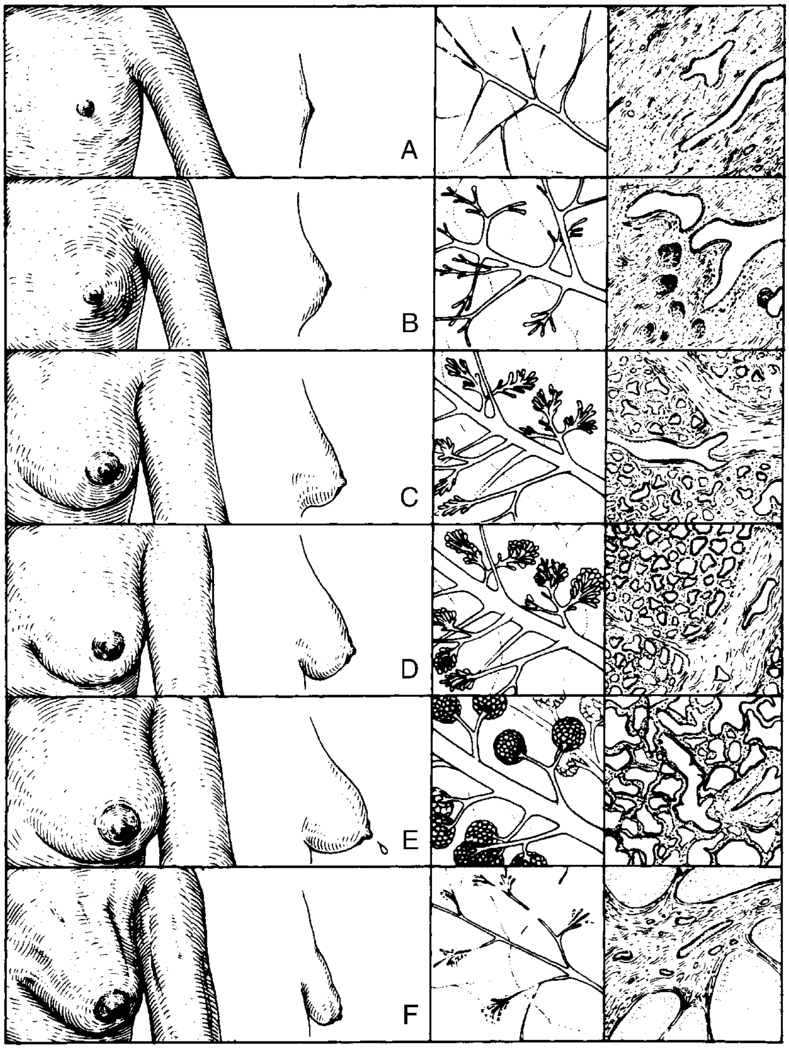

Figure 1–1. Schematic drawing illustrating mammary gland development. Anterior and lateral views of the breast are shown in columns 1 and 2. The microscopic appearances of the ducts and lobules are illustrated in columns 3 and 4, respectively. **A**, Prepubertal (childhood). **B**, Puberty. **C**, Mature (reproductive). **D**, Pregnancy. **E**, Lactation. **F**, Postmenopausal (senescent) state. (From Copeland EM III, Bland KI. The breast. In Sabiston DC Jr, ed. Essentials of surgery. Philadelphia: WB Saunders, 1987.)

TABLE 1–1 • *Tanner Stages*

Stage	Approximate Age	Description
Stage 1	Puberty	Preadolescent, with slight elevation of the papilla
Stage 2	11.1 ± 1.1 yr	Elevation of the breast and papilla as a small mound Increase in size of the areola
Stage 3	12.2 ± 1.1 yr	Further enlargement of the breast
Stage 4	13.1 ± 1.2 yr	The areola and papilla form a secondary mound above the breast
Stage 5	15.3 ± 1.7 yr	Areola recedes into the general contour of the breast

beyond these described boundaries. Ductal tissue can extend as high as the clavicle, beyond the inframammary fold, into the axilla, or beyond the border of the latissimus dorsi. The two breasts may be widely separated on the chest, or partially synthesized at the midline, although ducts do not communicate across the midline of the chest.

On average, the breast is 10 to 12 cm in diameter and 5 to 7 cm thick at its center. The contour of the breast is typically conelike with breast tissue projecting into the axilla as the axillary tail of Spence. The volume of the breast can range from 21 to 2000 mL, with an average of 400 mL. The volume fluctuates with the menstrual cycle (see later). The breast

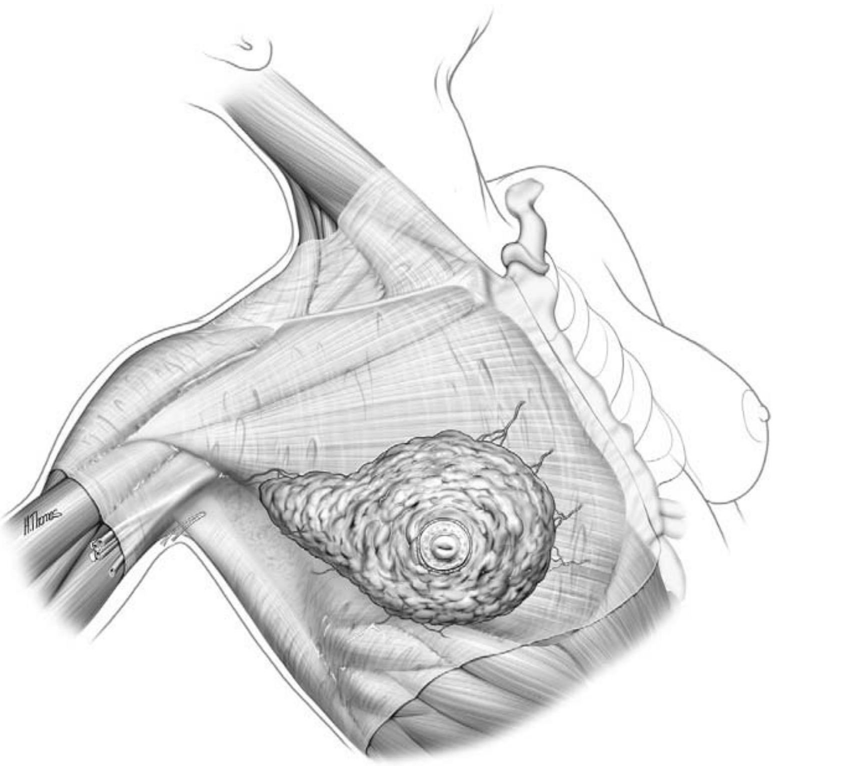

Figure 1–2. The breast tissue typically extends from the 2nd rib to the inframammary fold at the 6th or 7th rib, and from the lateral border of the sternum to the midaxillary line. The breast is teardrop shaped, with an extension of breast tissue extending into the axilla, known as the axillary tail or the tail of Spence. (From Bloom N, Beattie E, Harvery J. Atlas of cancer surgery. Philadelphia: Elsevier, 2000.)

is more conical in the nulliparous woman and more pendulous in women who have had children. The contour and volume of the breast, however, vary greatly among individuals, and may vary from left to right. More than half of women have volume differences of greater than 10% and more than one fourth of women have volume differences greater than 20%. These differences are typically not appreciated by most women.

The breast comprises three major structures: the skin, the subcutaneous tissue, and the fibroglandular breast tissue. The skin of the breast is thin and contains hair follicles, sebaceous glands, and eccrine sweat glands. The nipple-areolar complex is typically located over the fourth intercostal space (in the nonpendulous breast). Both the nipple and areola consist of a keratinizing stratified squamous epithelium with a dense basal melanin deposition, which accounts for the pigmentation. It can range from 15 to 60 mm in diameter. Within the nipple are multiple sensory nerve endings, including Ruffini-like bodies and end bulbs of Krause. Within the dermis are radially arranged smooth muscle fibers that contract with stimulation, hardening and elevating the nipple. The areola has hair follicles, sebaceous glands, and sweat glands. At the periphery of the areola are the Morgagni tubercles, elevations formed by openings of the ducts of the Montgomery glands. These glands are a cross between sweat and mammary glands, and are capable of producing milk.

Underneath the skin is the subcutaneous fat, which contributes to the size of the breast and which fluctuates with the amount of total body fat. Beneath this is the superficial pectoral fascia (Fig. 1–3). The gland of the breast lies within the superficial fascia, with the anterior layer between the skin and the mammary gland, and the posterior layer between the gland and the fascia of the pectoralis major muscle. Connecting these two fascial layers are fibrous bands (Cooper suspensory ligaments). Cooper's ligaments help give the breast its shape and anchor the gland to the skin. They are particularly dense at the lower periphery of the breast, where they maintain the inframammary fold.

The breasts maintain mobility on the chest wall because of the retromammary bursa. Between the posterior layer of the superficial pectoral fascia and the pectoralis major muscle fascia is a cleft known as the *retromammary space*, or *retromammary bursa*. The deep surface

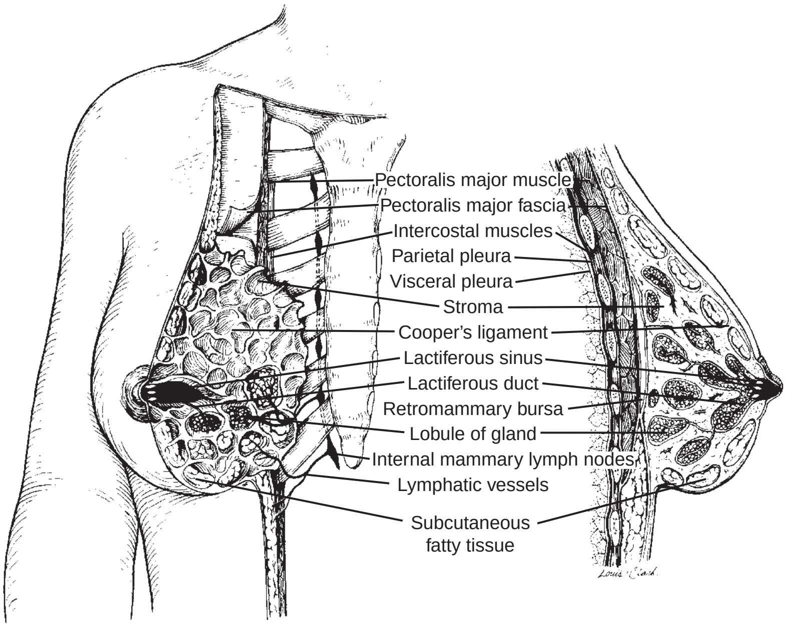

Figure 1–3. Tangential and sagittal view of the breast. The breast lies in the superficial fascia just deep to the dermis, attached to the skin by the suspensory ligaments of Cooper. The retromammary bursa separates it from the investing fascia of the pectoralis major muscle. Cooper's ligaments form fibrosepta in the stroma that provide support for the breast parenchyma. From 15 to 20 lactiferous ducts extend from lobules comprised of glandular epithelium to openings located on the nipple. Subcutaneous fat and tissue are distributed around the lobules of the gland and account for much of its mass. (From Copeland EM III, Bland KI. The Breast, 3rd ed. Philadelphia: WB Saunders, 2004.)

of the breast rests on portions of the deep investing fasciae of the pectoralis major, serratus anterior, and external oblique muscles, as well as the upper extent of the rectus sheath. As the breast tissue develops through the layers of the superficial fascia, they remain relatively close to the skin. This is especially true at the nipple-areolar complex. These relationships are all important when performing a mastectomy.

The fibroglandular tissue, or parenchyma, of the breast, is divided into 15 to 20 segments that converge at the nipple in a radial arrangement (Fig. 1–4). These segments are not always evenly distributed around the breast. The upper half of the breast, particularly the upper outer quadrant, tends to contain more glandular tissue than does the remainder of the breast. Each segment contains a lobe made of 20 to 40 lobules, each consisting of 10 to 100 alveoli. Two-millimeter ducts drain each segment into subareolar lactiferous sinuses of 5 to 8 mm in diameter. Ten major collecting milk ducts then open at the nipple. The ductal-lobular unit is the biologically active unit of the breast. The epithelial lining of the lobule consists of superficial (luminal) A cells that are involved in milk synthesis. The B cells (basal) have stem cell activity. Finally there are myoepithelial cells located around the alveoli and small excretory mild ducts between the inner aspect of the basement membrane and the tunica propria. These cells are not innervated, but rather are stimulated to contract by the hormones prolactin and oxytocin.

Muscular Anatomy of the Chest Wall

Underneath the breast lies the musculature of the chest wall and upper abdomen (Table 1–2). The pectoralis major muscle broadly originates over the medial half of the clavicle, lateral sternum, and sixth and seventh ribs, and then converges to an insertion point on the greater tubercle of the humerus. It is fan shaped and made of two divisions. The clavicular division originates from the clavicle. The costosternal division originates from the sternum and costal cartilages, and is the larger of the two divisions. When the deep pectoral fascia has been reflected laterally, the natural cleavage between the clavicular and costosternal portions of the pectorals major can be appreciated.

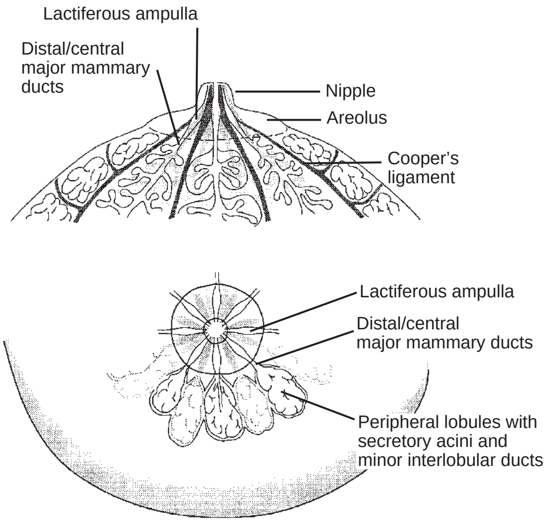

Figure 1–4. The secretory acini of the lobular tissue open into small intralobular ducts, which then drain into major lobar ducts. These ducts are organized into 16 to 18 lobular groupings separated by Cooper's ligaments. As they approach the nipple, they dilate into lactiferous ampullae, just below the nipple-areolar complex, before traversing the nipple. There may be as many as 18 openings at the apex of the nipple, although two major ducts may converge into one ampulla. (From Copeland EM III, Bland KI. The Breast, 3rd ed. Philadelphia: WB Saunders, 2004.)

Separation of this cleavage can provide access to the axillary fat pad. The pectoralis major acts primarily in flexion, adduction, and medial rotation of the arm at the shoulder joint (bringing the arm across the chest).

The cephalic vein runs along the upper lateral border of the pectoralis major muscle and sits between the pectoralis major and deltoid muscle (Fig. 1–5).

Underneath the pectoralis major muscle is the pectorals minor muscle, arising from the medial surfaces of the third, fourth, and fifth ribs and inserting as a tendon into the coracoid process of the scapula. The pectoralis minor helps depress the shoulder inferiorly. However, except for the loss of some mass on the anterior thoracic wall, no significant disability comes from the loss of the pectoralis minor muscle. The functional loss following division or removal of the pectoralis minor muscle is small and well tolerated. This should be kept in mind when performing an axillary dissection in a patient with clinically involved nodes, because division of the pectoralis minor results in minimal morbidity but does allow for a more extensive dissection of the high level II and level III axillary nodes.

The serratus anterior muscle arises from a series of digitations from the lateral aspect of

TABLE 1–2 • *Muscular Anatomy Relevant to Breast Surgery*

Muscle	Attachments	Innervation	Action
Pectoralis major	Clavicle, sternum, and costal cartilages 1 to 6 to the greater tubercle of the humerus	Medial and lateral pectoral nerves	Flexion, adduction, and medial rotation of the arm
Pectoralis minor	Ribs 2, 3, 4, and 5 to the coracoid process of the scapula	Medial pectoral nerve	Inferior depression of the shoulder
Serratus anterior	Ribs 1 to 8 to the anteromedial border of the scapula	Long thoracic nerve	Abduction and lateral rotation of the scapula, fixation of the scapula
Latissimus dorsi	Spinous processes T-6 to T-12, L-1 to L-5, sacrum, and lilac crest to the intertubercular groove of the humerus	Thoracodorsal nerve	Extension, adduction and medial rotation of the arm
Subscapularis	Scapula to the lesser tubercle of the humerus	Subscapular nerve	Medial rotation and adduction of the arm
Coracobrachialis	Coracoid process of the scapula to the medial humerus	Musculocutaneous nerve	Flexion and adduction of the arm
Subclavius	First rib of costochondral junction to the clavicle	Subclavian nerve	Depression of the clavicle
Rectus abdominis	Pubis to cartilage of ribs 5, 6, and 7	Intercostal nerves, iliohypogastric nerve, ilioinguinal nerve	Tension of the anterior abdomen, flexion of the vertebral column
External abdominis oblique	Ribs 5 to 12 to the linea alba, pubis, inguinal ligament, and iliac crest		Respiration, increased abdominal pressure (micturition, defecation)

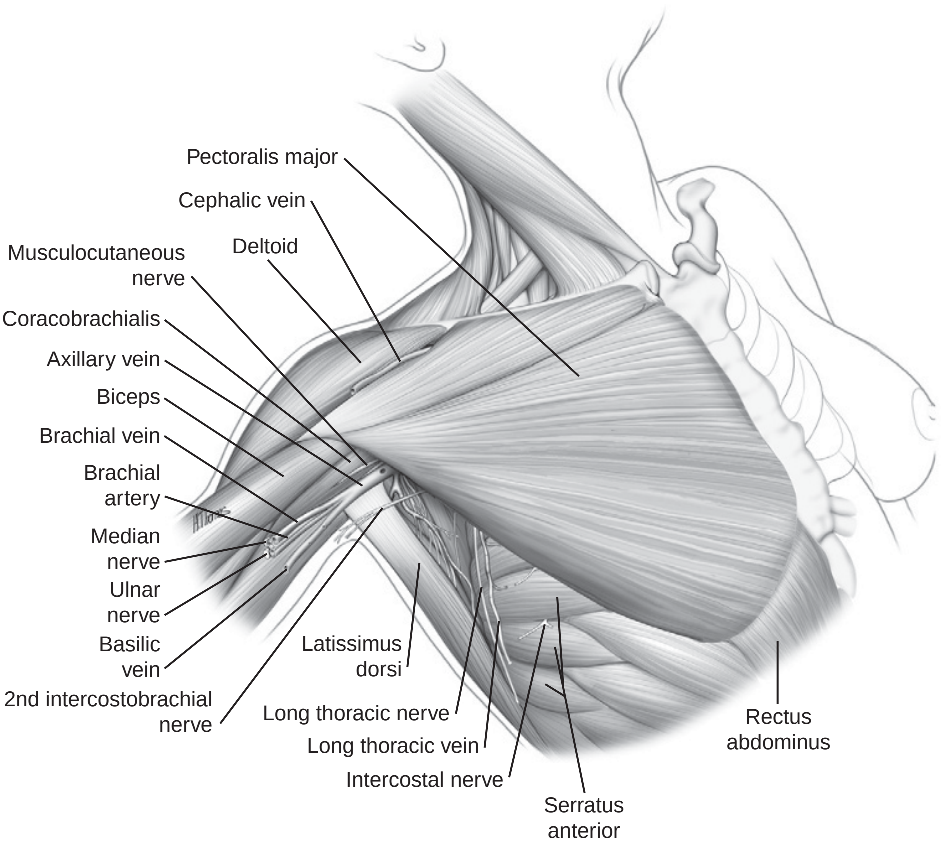

Figure 1–5. Muscular anatomy of the chest wall. (From Bloom N, Beattie E, Harvery J. Atlas of Cancer Surgery. Philadelphia: Elsevier, 2000.)

the upper eight ribs. It inserts into the vertebral border of the scapula on its costal surface and stabilizes the scapula on the chest wall. The functional deficit of losing function of the serratus anterior is an inability to raise the arm above the level of the shoulder. The serratus anterior is also important in stabilization of the scapula on the thorax, and an injury to the long thoracic nerve, which innervates the serratus anterior, can result in a "winged scapula."

The latissimus dorsi muscle has a wide origin from the spinous processes and supraspinous ligaments of the thoracic (7-12), lumbar, and sacral vertebrae. It inserts into a 2.5-cm insertion in the bicipital groove of the humerus. The narrow tendon of the latissimus dorsi forms the posterior axillary fold. The latissimus dorsi functions to extend, internally rotate, and adduct the humerus.

The subclavius muscle arises from the costochondral junction of the first rib. At the tendinous part of the lower border of this muscle, the clavipectoral fascia forms a well-developed band stretching from the coracoid process to the first costochondral junction. This costocoracoid ligament (the Halsted ligament) defines the point anatomically where the axillary vessels enter the thorax (under the clavicle, over the first rib).

These muscles also form a compartment between the chest wall and the arm, known as the *axilla*. This is of obvious importance to the breast surgeon because the axillary lymph nodes reside here. The nerves and vessels to some of these muscles run through the axilla, and can be injured during axillary dissection. The axilla is described in more detail later. One muscular abnormality that can occur in this region is the presence of the Langer axillary arch (Fig. 1–6). This represents a portion of the latissimus dorsi muscle that arises separately and crosses the base of the axilla superficially, passing deep to the pectoralis major muscle to the coracoid process. This band of tissue occurs in 7% of cases and can often cause confusion when performing an axillary dissection.

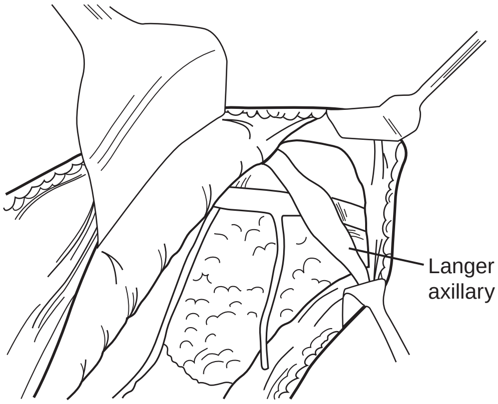

Figure 1–6. The Langer axillary arch is a portion of latissimus dorsi muscle that arises separately and crosses the axilla superficially before joining the coracoid process. This band of muscle can cause confusion during an axillary lymph node dissection.

The skeletal component of the thoracic wall consists of 12 thoracic vertebrae, 12 ribs and their costal cartilages, and the sternum. The intercostal spaces between the ribs are filled with the external, internal, and innermost or intimal intercostal muscles. The external intercostal muscles are the most superficial layer, running from the tubercles of the ribs toward the costochondral junction. The internal intercostal muscles run downward and posterior, from the sternum toward the angle of the ribs. The intercostal veins, arteries, and nerves pass in the plane that separates the internal intercostal muscle from the intimal layer.

Fascia of the Breast and Chest Wall

As stated earlier, the breast is enveloped by the superior pectoral fascia, with the anterior layer ventrally and a posterior layer dorsally. Connecting these two fascial layers are Cooper's suspensory ligaments, the fibrous bands that provide support of the breast. Above the breast, the superior pectoral fascia is continuous with the superficial cervical fascia. At the inferior aspect of the breast, the anterior and posterior layers of the superior pectoral fascia rejoin and are continuous with Camper's and Scarpa's superficial abdominal fascia at the inframammary fold.

The proximity of the breast parenchyma to the skin is of critical importance to the breast surgeon. The ducts and lobules of the breast extend to the anterior layer of the superficial fascia and extend directly to the nipple-areolar complex. Preserving the nipple areolar complex, as is done in a "subcutaneous mastectomy," will leave breast tissue. For this reason the nipple-areolar complex is routinely removed with a mastectomy, although some surgeons have begun examining the possibility of preserving just the areola or the entire nipple-areolar complex (see Chapter 12). The anterior layer of the superior pectoral fascia may be absent in some patients; in others, only a few millimeters from the overlying dermis may be present. Raising a flap below the fascia will also leave residual breast tissue, which is often done when "thick flaps" are maintained.

Leaving residual breast tissue has important implications if a mastectomy is being performed to prevent either a recurrence (as in the case with invasive or intraductal cancer) or a primary cancer (as with a prophylactic mastectomy). It is important that the surgeon operate between the dermis and the superficial fascia. This not only minimizes residual breast tissue, but allows the surgeon to operate in an almost bloodless plane, leaving the blood vessels and lymphatics passing in the deeper layer of the superficial fascia undisturbed.

The deep pectoral fascia covers the pectoralis major muscle and is attached to the sternum and clavicle. Inferiorly it is continuous with the deep fascia of the abdominal wall. As with the superficial fascia, the ducts and lobules are in close proximity to the deep fascia, so the fascia should be removed with a mastectomy (or during a lumpectomy for a posterior tumor).

The clavipectoral fascia runs deep to the pectoralis major muscle and envelops the pectoralis minor muscle. Superiorly, this fascia thickens and attaches to the clavicle. Surgically, this is an important landmark because this fascia forms the "roof" of the axillary space; it is also known as the *axillary fascia*. This fascia covers the serratus anterior and envelops the axillary vessels, forming the vascular sheath. The fatty areolar tissue posterior to the clavipectoral fascia encompasses the large axillary lymphatics and axillary lymph nodes. When performing a sentinel lymph node biopsy, the surgeon needs to incise this fascia in order to reach the lymph nodes. When performing an axillary lymph node dissection, the flaps should be raised above this fascia.

Neural Anatomy of the Breast and Chest Wall

There are several motor and sensory nerves that the breast surgeon needs to be familiar with. Segmental thoracic nerves provide the cutaneous sensation to the breast via anterior and lateral perforating branches. The most sensitive portion of the breast is the nipple, which is innervated by branches of the fourth thoracic nerve. The surgeon should be aware that these nerves approach the nipple medially and laterally. For this reason, circumareolar incisions in the superior or inferior aspect of the nipple are less likely to disturb the nipple's sensory innervation.

The pectoralis major muscle is innervated by the *medial and lateral pectoral (anterior thoracic) nerves*. What is often confusing is that these names come from their origin from the medial and lateral cords of the brachial plexus, and not their position on the chest wall (Fig. 1–7). The *lateral* pectoral nerve actually innervates the *medial* portion of the pectoralis, and courses *medial* to the pectoralis minor muscle to reach its destination. The nerve passes over the first part of the axillary vein medial to the pectoralis minor muscle, and its branches pierce the clavipectoral fascia to enter the deep surface of the muscle. The pectoralis major muscle is mainly innervated by the lateral pectoral nerve, as this innervates the clavicular and sternal origins of the pectoralis major muscle.

The *medial* pectoral nerve innervates the *lateral* portion of the muscle; the lower third and the costoabdominal insertions of the pectoralis major muscle. It courses lateral (or in some cases through) the pectoralis minor muscle (which it also innervates). By understanding the anatomy of the pectoral nerves, it is possible to perform an axillary lymph node dissection without sacrificing the innervation. If one of these nerves is cut, the denervated portions of the muscle become flaccid and atrophic.

The *long thoracic nerve* (also called the external respiratory nerve of Bell) innervates the serratus anterior muscle. Arising from the fifth, sixth, and seventh cervical nerves, it passes deep to the axillary artery and vein, staying close to each segment of the thoracic wall. As it passes caudally, it gives branches to each segment of the serratus anterior muscle. The long thoracic nerve is superficial to the deep fascia investing the serratus anterior. During an

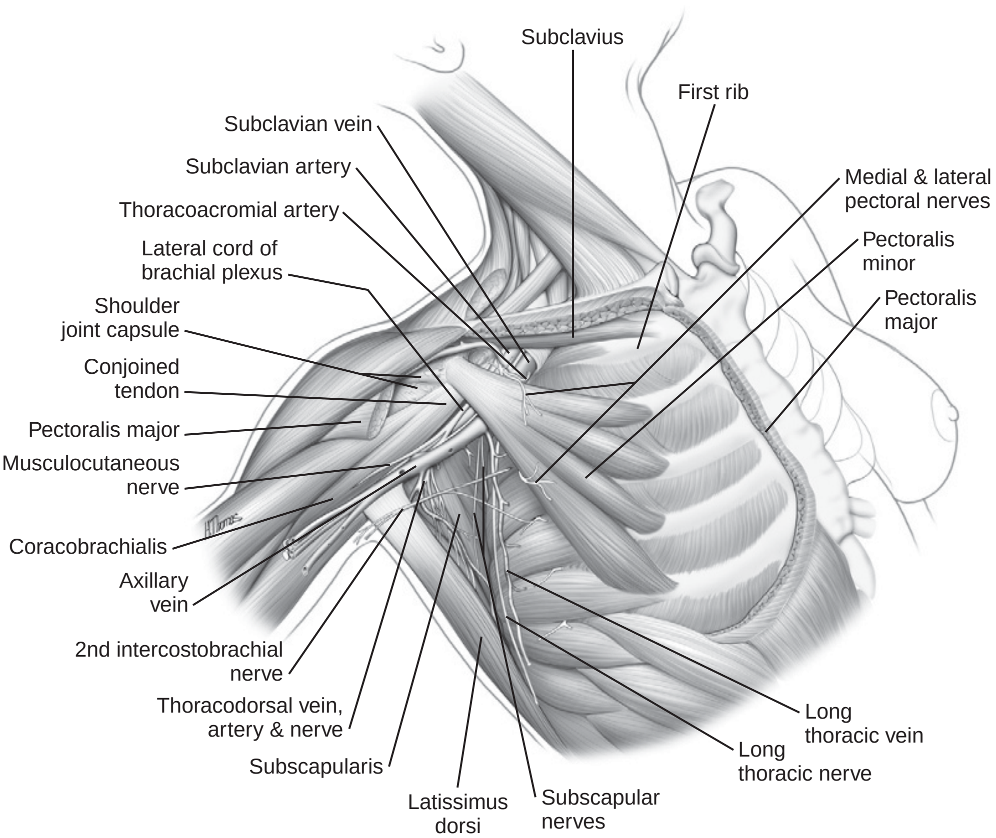

Figure 1–7. Neurovascular anatomy of the axilla. (From Bloom N, Beattie E, Harvery J. Atlas of Cancer Surgery. Philadelphia: Elsevier, 2000.)

axillary dissection, the nerve can be seen by stripping the fascia away from the serratus anterior. Dissection directly on top of the serratus anterior (between the muscle and superficial fascia) will be medial to the nerve, pulling it into the specimen and increasing the likelihood of injury. The result of this would be an inability to raise the arm above the level of the shoulder, as well as a winged scapula.

The *thoracodorsal nerve* innervates the latissimus dorsi muscle. It arises from the posterior cord of the brachial plexus, runs beneath or dorsal to the axillary vein along the posterior axillary wall, and passes through the fibrofatty tissue of the axilla to the upper portion of the muscle. Injury to this nerve denervates the latissimus dorsi, which weakens extension, internal rotation, and adduction of the humerus. Although this is extremely well tolerated by most patients, every attempt should be made to preserve the nerve during axillary dissection both to lessen functional loss and preserve the muscle for reconstructive purposes.

An important nerve to preserve during surgery is the nerve to the subscapularis muscle. This muscle passes between the subscapular fossa and the lesser tubercle of the humerus. It is seen at the posterior wall of the axilla, inferior to the axillary vein. The nerve sits on the upper anterior surface of the muscle and can be injured when dissecting the fascia from the muscle inferior to the vein. Injury to this nerve denervates the muscle, affecting medial rotation of the arm. As the muscle both stabilizes the humerus in the glenoid fossa and assists with flexion, extension, abduction, and adduction of the arm, palsy can produce significant morbidity.

The intercostobrachial nerve is a sensory nerve that runs through the axilla and innervates the skin of the axilla and upper medial aspect of the arm. The intercostobrachial nerve is the posterior ramus of the lateral perforating branch of the second intercostal nerve. It appears in the second intercostal space and courses anterior to the long thoracic nerve and thoracodorsal nerve. Often it divides early, giving the appearance of two nerves. It is important because the nerve is always exposed during an axillary dissection. Although many surgeons routinely divide this nerve, it is possible to dissect these nerves out and preserve them (see Chapter 13). The nerve typically innervates the upper arm, but can extend as far as the level of the elbow, so division can sometimes result in a significant area of numbness.

Vascular Anatomy

The breast is supplied by multiple sources (Fig. 1–8). Multiple muscle-perforating branches of the thoracoabdominal artery perforate the pectoralis major muscle to enter the breast. The inner quadrants also receive blood flow from the perforating branches of the internal mammary arteries. These penetrate each intercostal space and the pectoralis major muscle to reach the breast. The outer quadrants receive blood from branches of the lateral thoracic artery, which both penetrate and come around the pectoralis major. Additional blood supply comes from lateral cutaneous branches of the posterior intercostal arteries. All of these arteries connect with each other by collateral branches in both the breast and overlying skin. Overall, 60% of the breast is supplied by the internal mammary artery, 30% of the breast is supplied by the lateral thoracic artery, and 10% is supplied by minor contributions from the thoracoacromial, intercostals, subscapular, and thoracodorsal arteries.

The venous drainage does not completely follow the arterial supply. Rather, venous

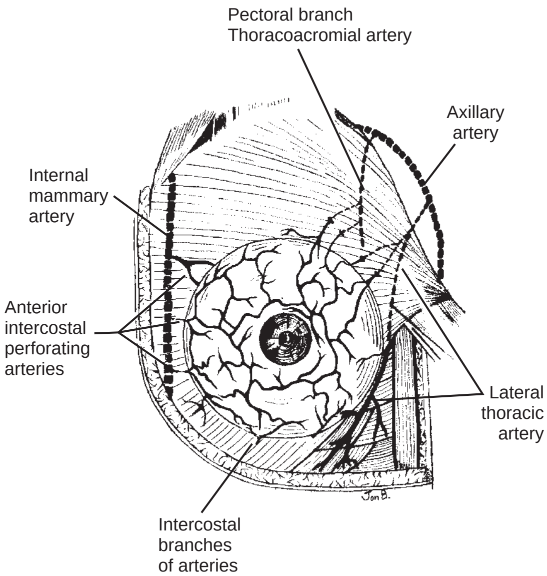

Figure 1–8. Arterial distribution of blood to the breast. The breast receives its blood supply via three major routes: (1) medially from anterior perforating intercostal branches off of the internal thoracic artery, (2) laterally from branches of the thoracoacromial trunk or lateral thoracic artery (both of which come off the axillary artery), and (3) lateral cutaneous branches off of the intercostal arteries. (From Copeland EM III, Bland KI. The Breast, 3rd ed. Philadelphia: WB Saunders, 2004.)

drainage heads toward an anastomotic circle in the subcutaneous tissue beneath and around the areola. This plexus then drains centrifugally toward the periphery via large subcutaneous veins. These veins then travel with the arteries supplying the breast. When venous flow increases, as with lactation, these veins become more apparent.

Lymphatic Anatomy

The lymphatic drainage of the breast is through two sets of lymphatic vessels; the superficial (also known as subepithelial or subdermal) and the deep (Fig. 1–9). The subepithelial plexus of lymphatic vessels exists throughout the entire body surface. These vessels are valveless, allowing lymph to flow in any direction, although it does so sluggishly. The subepithelial plexus connects to subdermal lymphatic vessels by vertical lymphatics. The subdermal vessels do have valves. Thus lymph flows unidirectionally from the superficial to the deep plexus. In the breast, the subepithelial and subdermal plexuses are confluent with the subareolar plexus. Also draining into the subareolar plexus are the fine lymphatics of the lactiferous ducts and the lymphatics of the areola and nipple. It is because of these connections between the subareolar plexus and the subepithelial and subdermal lymphatics that subareolar or periareolar injection of tracers during intraoperative lymphatic mapping and sentinel lymph node biopsy is possible.

From the deep lymphatics, the lymph flow moves centrifugally toward the axillary and internal mammary lymph nodes. Approximately 3% of the lymph from the breast goes to the IM chain, which can come from all quadrants of the breast, not just the inner quadrants. The internal mammary nodes (IMN) are found with the internal mammary artery and vein within the intercostal spaces at the sternal border, deep to the intercostal muscles and within the extrapleural fat. Most of the nodes are in the upper parasternal area (upper three interspaces); however, the number of nodes is variable and can extend as low as the fifth intercostal space and as high as the retroclavicular region. The other 97% of lymph flows to the axillary lymph nodes.

Anatomy of the Axilla

The anatomy of the axilla and axillary lymph nodes is obviously crucial to the breast surgeon. The axilla is typically thought of as a four-walled pyramid that sits between the upper arm and the chest (Fig. 1–10). The dome-shaped base of the pyramid is the armpit, made of the axillary fascia and the skin. The apex of the pyramid is an aperture that extends into the posterior triangle of the neck through the cervicoaxillary canal. This canal is

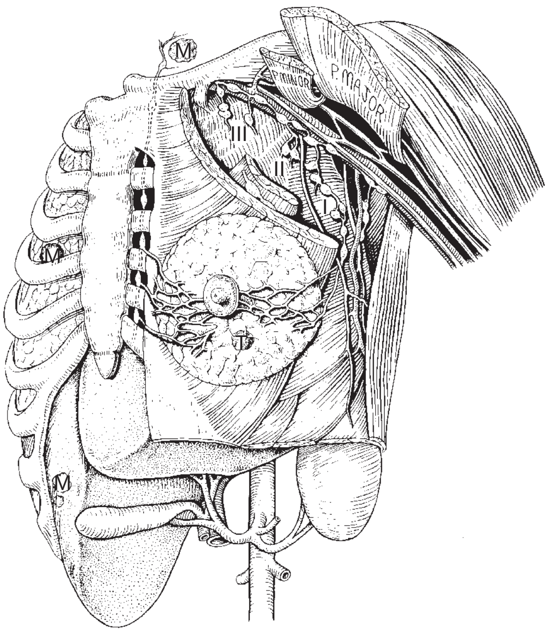

Figure 1–9. Lymphatic drainage of the breast. (From Copeland EM III, Bland KI. The Breast, 3rd ed. Philadelphia: WB Saunders, 2004.)

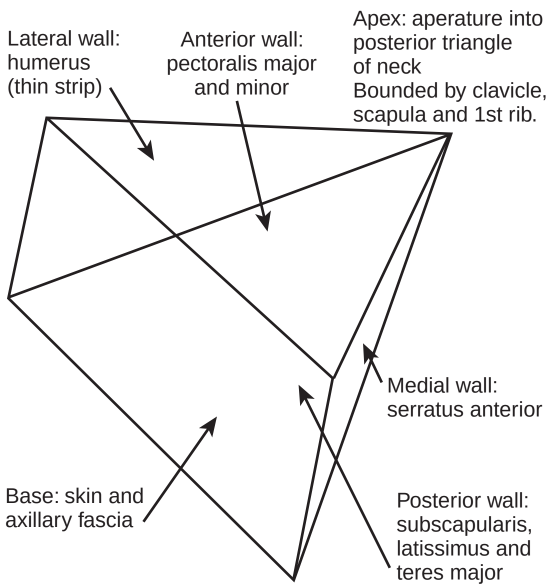

Figure 1–10. The axillary pyramid.

bounded by the clavicle anteriorly, the scapula posteriorly, and the first rib medially. Almost all of the structures heading toward the upper extremity pass through the cervical axillary canal. This leaves the four walls. The anterior wall is the pectoralis major and minor muscles. The posterior wall is the subscapularis muscle (and to a lesser extent the teres major and latissimus dorsi muscles and tendons). The medial wall is the serratus anterior muscle. The lateral wall is a thin strip of humerus between the insertions of the muscles of the anterior and posterior walls.

Coming through the apex of the pyramid are the great vessels and nerves of the upper extremity, enclosed within a layer of fascia, the axillary sheath. The sheath is dense connective tissue extending from the neck, but gradually disappears as the nerves and vessels begin to branch. Throughout their course in the axilla, the axillary artery and vein are associated with the cords of the brachial plexus (medial, lateral, and posterior).

The axilla is enveloped in fascia. The most significant fascia is the clavipectoral fascia. This fascia extends from the clavicle toward the floor of the axilla (the axillary fascia). It encloses both the subclavius muscle and the pectoralis minor muscle. The upper portion of the clavipectoral fascia is known as the *costocoracoid membrane*. The lower portion is sometimes called the *suspensory ligament of the axilla* or the *coracoaxillary fascia*. A dense condensation of the clavipectoral fascia, extending from the medial end of the clavicle to the first rib, is known as *Halsted's ligament*. This ligament covers the subclavian artery and vein as they cross the first rib and is an important landmark when performing a level III axillary lymph node dissection.

Within the pyramid, in addition to the great vessels and nerves and their branches, are the axillary lymph nodes. We tend to group the lymph nodes by their anatomic location, having been arbitrarily divided into levels based on their relation to the pectoralis minor muscle. The level I lymph nodes lie lateral to the muscle, the level II nodes like directly beneath the muscle, and the level III nodes are medial to the medial border of the pectoralis minor. However, the lymph nodes are better categorized by several groups (Fig. 1–11):

- The lateral group, or axillary vein group, consists of four to six nodes that lie medial or posterior to the axillary vein. These lymph nodes receive most of the lymph draining from the upper extremity.

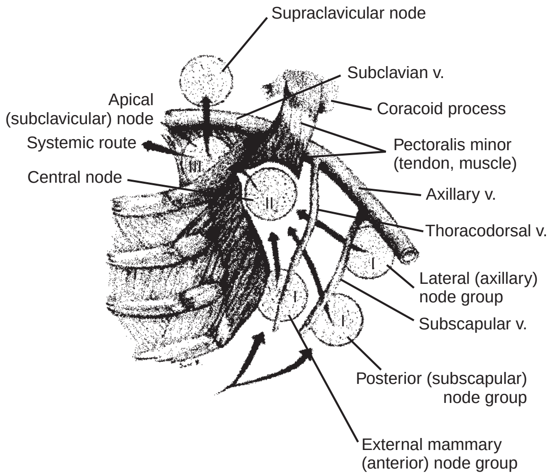

Figure 1–11. The major lymph node groups of the axilla. The Roman numerals indicate the three levels of the axillary nodes in relation to the pectoralis minor muscle. (From Copeland EM III, Bland KI. The Breast, 3rd ed. Philadelphia: WB Saunders, 2004.)

- The anterior group, or external mammary group, consists of four or five lymph nodes that lie along the lower border of the pectoralis minor muscle in association with the lateral thoracic vessels. These lymph nodes receive the major portion of the lymph draining from the breast.
- The posterior, or scapular, group consists of six or seven nodes that lie along the posterior wall of the axilla at the lateral border of the scapula. These nodes receive lymph primarily from the posterior neck and trunk.
- The central group consists of three or four lymph nodes that lie within the fat beneath the pectoralis minor muscle. These lymph nodes receive drainage from the lateral, anterior, and posterior groups.
- The subclavicular, or apical, nodes consist of 6 to 12 lymph nodes that sit at the apex of the axilla, superior to the pectoralis muscle and along the medial side of the axillary vein. These receive drainage from all of the other lymph node groups.
- The interpectoral nodes, or Rotter's nodes, consist of one to four nodes between the pectoralis major and minor muscles and drain into the central and subclavicular nodes) (Table 1–3).

Thus the level I lymph nodes, those nodes lateral or below the lower border of the pectoralis minor muscle, include the external mammary, axillary vein, and scapular lymph node groups. The level II lymph nodes, located deep

TABLE 1–3 • *Major Lymph Node Groups of the Axilla*

Group	Location	Nodes	Drainage From
Lateral (axillary vein)	Medial-posterior to axillary vein	4 to 6	Upper extremity
Anterior (external mammary)	Along lower border of pectoralis minor	4 to 5	Breast
Posterior (scapular)	Lateral border of scapula	6 to 7	Posterior neck/trunk
Central	Beneath pectoralis minor	3 to 4	Lateral, anterior, and posterior groups
Subclavicular (apical)	Apex of axilla	6 to 12	All other groups
Interpectoral (Rotter's)	Between pectoralis major and minor	1 to 4	

to the pectoralis minor muscle, include the central and some of the subclavicular lymph node groups. The remainder of the subclavicular lymph nodes are the level III lymph nodes, located medial to the pectoralis minor.

The locations of the axillary groups and the flow of the lymph are important in regard to metastatic dissemination of breast cancer. Typically there is unidirectional flow toward the regional lymph nodes; however, when the lymphatics are blocked by neoplasm, flow can reverse, leading to endolymphatic metastases of both the dermis and breast parenchyma. Therefore the presence of metastases in the regional nodes, which can obstruct the lymphatic vessels, will increase the likelihood of parenchymal metastases (manifesting as in breast recurrences) and dermal metastases (e.g., chest wall recurrences after mastectomy).

Physiology of the Breast

The purpose of the breast is milk production for the sustenance of the newborn. The secretory units of the breast are the alveoli, small saccules off of the lactiferous ducts. The growth of these secretory units and their production of milk is controlled by an intricate network of hormones. Fluctuation of these hormones and changes in their relative ratios cause several histologic changes in the breast, not just during pregnancy but also during the menstrual cycle. Changes occur in both the epithelium and the stroma and profoundly influence the morphology of the breast.

Hormones Affecting the Breast

See Table 1–4.

TABLE 1–4 • *Hormones Influencing Breast Development During Pregnancy*

Hormone	Effect During Development	Effect During Pregnancy and Lactation
Estrogen	Causes ductal growth during adolescence	Required for lobuloalveolar growth
Progesterone	Required for lobuloalveolar differentiation and growth	
Glucocorticoids	Contributes to ductal growth in puberty	Enhances lobuloalveolar growth Stimulus for lactation
Growth hormone	Contributes to ductal growth in puberty	Stimulus for lactation Maintains mammary epithelial cell survival
Insulin	Enhances growth of mammary epithelium Enhances ductal alveolar growth	
Prolactin	Contributes to ductal growth in puberty	Required for lactogenesis and maintenance of lactation
Human placental lactogen		Stimulates alveolar growth and lactogenesis
Thyroid hormones		Increases epithelial secretory response to prolactin
Oxytocin		Causes contraction of myoepithelial cells and milk ejection

Estrogen

Estrogen stimulates the growth of the breast at puberty. However, while development is dependent on estrogen, estrogen alone will have no effect. In the presence of other hormones, such as hydrocortisone, insulin, or growth hormone, it leads to growth of the ductal system.

Progesterone

Progesterone also stimulates breast growth at puberty, but unlike estrogen, which works primarily on the ducts, progesterone induces development of the terminal ducts and lobuloalveolar structures. As with estrogen, this response requires the presence of other hormones, specifically growth hormone and insulin.

Prolactin

Prolactin is produced by lactotrophs in the pituitary gland. Prolactin stimulates mammary growth and differentiation and ultimately milk production. The synthesis of prolactin is stimulated by a wide variety of hormones and neurotransmitters (Box 1–3). Thyrotropin releasing hormone (TRH) is the primary stimulator of prolactin secretion, dopamine is the primary inhibition. However, prolactin can also be produced by cells in the breast; thus prolactin can not only behave as a classic hormone, but also as a paracrine or autocrine factor. The extrapituitary prolactin is not regulated by TRH or dopamine but is controlled by progesterone.

Oxytocin

Oxytocin is a peptide hormone secreted by the pituitary gland. Oxytocin is released in response to a variety of stimuli. Suckling results in oxytocin release and may also be a conditioned reflex in response to an infant's cry. Oxytocin receptors are located on the myoepithelial cells located in the basement membrane of the alveoli and intralobular ducts. These receptors increase in number at parturition. When oxytocin binds to these receptors, contraction of the myoepithelial cells occurs.

BOX 1–3 HORMONES AND NEUROTRANSMITTERS AFFECTING PROLACTIN PRODUCTION

- Thyrotropin releasing hormone (TRH) [stimulatory]
- Vasoactive intestinal peptide (VIP) [stimulatory]
- Dopamine [inhibitory]
- Estrogen [stimulatory]
- Insulin [stimulatory]
- EGF [stimulatory]
- Relaxin [stimulatory]

Human Placental Lactogen

Human placental lactogen (hPL) is produced by the placenta and serum levels continue to rise throughout pregnancy. The major role of hPL is related to breast growth and differentiation during pregnancy. After delivery, the decrease in the serum concentration is rapid.

The Breast during the Menstrual Cycle

Follicular Phase

The follicular phase of the menstrual cycle is defined as the first day of menstruation until ovulation. It is initiated by a rise in follicle-stimulating hormone (FSH) levels at the first day of the cycle. This is triggered by a decrease in progesterone and estrogen (which act to inhibit FSH secretion). FSH stimulates the development of follicles and their secretion of estrogen (Fig. 1–12).

In the breast, the increased estrogen levels initiate cellular mitoses, RNA synthesis, increased nuclear density, and other changes within the epithelial cells. In addition, estrogen has a histamine-like effect on the mammary microcirculation. This leads to an increased blood flow to the breast in the 3 to 4 days before menstruation. The breast can increase in volume from 15 to 30 cm^3 due to both the increasing interlobular edema and the enhanced cellular proliferation.

Estrogen inhibits the secretion of FSH, and FSH levels decrease. Estrogen levels peak toward

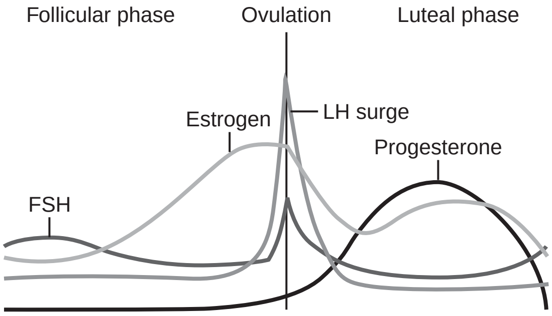

Figure 1–12. Changes in hormone levels with the menstrual cycle.

the end of the follicular phase of the menstrual cycle, which exerts a positive feedback on luteinizing hormone (LH). There is a dramatic preovulatory LH surge at this point, which is required for ovulation. The LH causes the follicle to swell and rupture, with expulsion of the oocyte, and corona radiate into the peritoneal cavity and ultimately into the fallopian tube.

Luteal Phase

The luteal phase is initiated by the surge in LH. During the luteal phase, progesterone synthesis is maximum. The major effects of the LH surge are the conversion of granulose cells from primarily androgen-converting cells to predominantly progesterone-synthesizing cells. At this point there is increased progesterone secretion with some estrogen secretion.

In the breast, the progestogens trigger the mammary ducts to dilate and the alveolar epithelial cells to differentiate into secretory cells. The breast epithelial cell proliferation increases during the luteal phase of the menstrual cycle.

Menstruation

The high progesterone levels exert a negative feedback on GnRH, and as this decreases so does FSH and LH secretion. Ultimately there is a decrease in estrogen and progesterone levels, which removes the inhibition of FSH, which begins to rise once again to initiate the next menstrual cycle.

In the breast, the rapid decline in the circulating levels of estrogen and progesterone lead to a regression of the secretory activity of the epithelium. The tissue edema is reduced, with the minimum breast volume observed 5 to 7 days after menstruation.

The Breast after Menopause

Menopause typically occurs when a woman is in her late 40s and early 50s; it is associated with a variety of symptoms related to the loss of estrogen and progesterone. These include hot flashes, night sweats, mood disturbances and difficulty sleeping, and vaginal dryness.

The breasts will also undergo changes with menopause. The loss of hormonal stimulation produces a decrease in the absolute number of lobular units, as well as a diffuse atrophy of the residual lobular units. This results in a decrease in the glandular tissue, which is replaced with fatty tissue. This decrease in breast density makes it easier to detect breast cancer on mammography, which is why sensitivity increases with age. The duct system remains intact. The loose paralobular and intralobular connective tissue become progressively collagenized and less cellular. The loss of strength of the connective tissue results in an increase in size and sag to the breasts. However, these changes of atrophy are variable and incomplete. Some women in their 60s and 70s still have a lobular appearance similar to a premenopausal state.

We tend to associate fibrocystic disease with the menstrual cycle, matching the increase in pain and palpable masses to the changes in hormone levels. It would therefore seem logical that fibrocystic disease should resolve with menopause, but this is not always the case. For some women, the breasts can become more tender with menopause, with an increase in "lumpiness" or cysts.

The Breast during Pregnancy

It is not until pregnancy that the breast attains its maximum development. In the pregnant patient, there is marked growth of the ducts, lobules, and alveoli under the influence of luteal and placental sex steroids and prolactin. During the first 3 to 4 weeks of pregnancy, under the influence of estrogen, there is growth and branching of the ducts, as well as increased lobule formation. By the second month, the breasts have enlarged dramatically. The superficial veins dilate and there is increased pigmentation of the nipple-areolar complex. The breasts become tender and the nipples become sore. This can begin just a few weeks after conception.

Estrogen and progesterone prohibit the hypothalamus from producing prolactin-inhibiting factor (PIF). With this influence gone, prolactin is released and this continues progressively during pregnancy, although increase in prolactin levels is slow during the first trimester.

In the second trimester of pregnancy, the effects of progesterone cause the lobular formation to exceed the ductal sprouting. During this time, prolactin levels continue to rise and by the third trimester, blood levels of prolactin are three to five times higher than normal.

At this point the alveoli contain colostrum, but no fat. The breast continues to enlarge, but this is not due to epithelial proliferation but rather the filling of the alveoli with colostrum, as well as the hypertrophy of myoepithelial cells.

In the third trimester of pregnancy, the stroma surrounding the lobules diminishes to make room for the hypertrophied lobules. As pregnancy continues, colostrum composed of desquamated epithelial cells and fluid accumulates. This is released in the immediate postpartum period.

Lactation

During pregnancy, prolactin is being produced, starting during the eighth week of pregnancy and increasing until birth. During that time, the high levels of estrogen and progesterone block the prolactin receptors and inhibit milk production. After birth, there is a decline in the serum levels of estrogen and progesterone over several days. This removes the inhibition of milk production and lactogenesis begins.

Prolactin is one of two hormones responsible for milk production, with the other being oxytocin. Prolactin levels were increasing until birth, and after delivery begin to decline. If the mother is not nursing, the prolactin levels will drop slowly (>14 days). In the nursing mother, prolactin will also drop, but much more slowly, dependent on the time that the infant nurses. Prolactin drives the synthesis and secretion of milk into the alveolar spaces. When the myoepithelial cells contract, the milk passes through the ductal system and out of the breast.

Oxytocin is the second hormone responsible for milk production and delivery. When an infant suckles at the mother's breast, this causes the increase in both prolactin, to stimulate more production, and oxytocin, to increase milk delivery.

During the first few days after delivery, the body does not produce milk but rather a liquid substance called *colostrum*. This is high in immunoglobulins, which help protect the infant against infections at a time when the infant's own immune system has not fully developed. Colostrum may help decrease the infant's chances of developing asthma and other allergies.

When breast-feeding stops, it may take several months for milk production to completely stop. The breasts usually return to their previous size, although they may be smaller after breast-feeding is completed.

Suggested Readings

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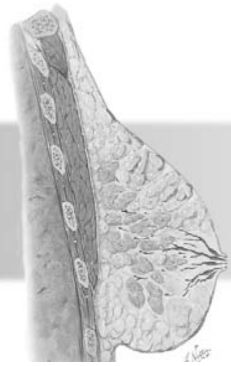

Principles of Breast Cancer Screening

MODALITIES OF BREAST IMAGING
Mammography
Ultrasound
Magnetic Resonance Imaging
Positron Emission Tomography
PRINCIPLES OF BREAST CANCER SCREENING

Key Points

- Describe how mammography is performed for screening and additional techniques used for diagnostic mammography.
- Know the differences between film and digital mammography.
- Be familiar with the BI-RADS system and the abnormalities on mammogram that warrant close observation versus biopsy.
- Describe how ultrasound is performed and its indications.
- Know the strengths and limitations of breast MRI in both screening and diagnosis.
- Understand the principles of cancer screening.

Breast imaging has changed the management of breast disease dramatically over the past few decades. Not only has screening changed the face of breast cancer, but improvements in technology and newer modalities have altered the approach to the diagnosis of breast abnormalities. Understanding the indications, benefits and limitations of the various modalities used in the evaluation of the breast is critical to the breast surgeon.

Modalities of Breast Imaging

Mammography

Technique

Mammography is by far the most important imaging modality used today for the evaluation of breast disease. Mammography is used both for screening the asymptomatic woman and helping diagnose women who present with a complaint regarding the breasts. When a screening mammography is performed, two standard views are used; the mediolateral oblique (MLO) view and the craniocaudal (CC) view (Fig. 2–1). The MLO view compresses the breast along a plane of approximately 45 degrees extending from the upper inner quadrant to the lower outer quadrant, with the x-ray tube rotated parallel to the pectoralis muscle fibers. The natural mobility of the breast is used to get as much breast tissue as possible included, and when done properly in the MLO view, shows both axillary tail and abdominal wall. The CC view positions the breast directly on top of the x-ray cassette holder, with the x-ray tube positioned for superior to inferior imaging.

For both the MLO and CC views, maximum compression of the breast is necessary to decrease the thickness of the breast, and to make the breast more uniform in appearance, spreading out overlapping structures. If there is an abnormality detected on a screening mammogram, or if a diagnostic mammogram is being performed, additional views beyond the MLO and CC views are often necessary (Table 2–1). These are done under the direct supervision of the radiologist, who reviews the results of the procedure with the patient at the time of the examination.

Digital Mammography

Standard mammography uses film for the acquisition of the image, display for the radiologist, and storage. In contrast to what some people believe, both traditional and digital mammography use x-rays to obtain the image (Fig. 2–2). The difference is that with digital mammography the image is stored on a computer rather than film. This does have several advantages, however. On the computer screen, the image can be manipulated. Postexposure processing may be performed to adjust

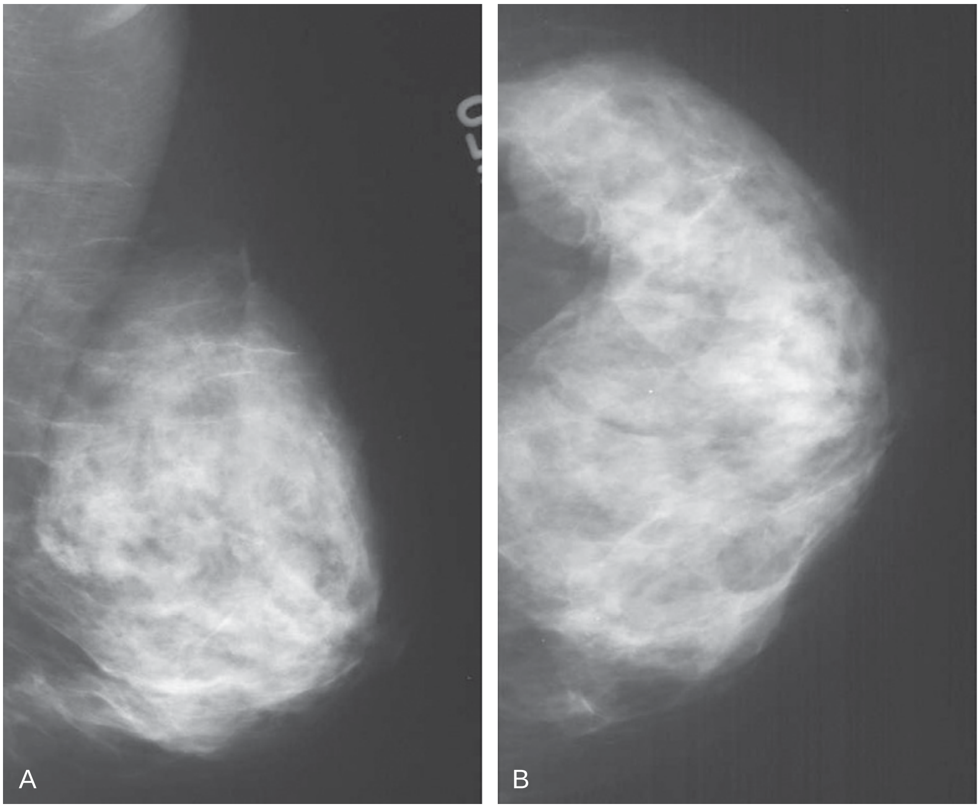

Figure 2–1. The MLO view **(A)** compresses the breast along a plane of approximately 45 degrees extending from the upper inner quadrant to the lower outer quadrant, with the x-ray tube rotated parallel to the pectoralis muscle fibers. When done properly, the MLO view shows both axillary tail and abdominal wall. The CC view **(B)** positions the breast directly on top of the x-ray cassette holder, with the x-ray tube positioned for superior to inferior imaging. The CC and MLO views of the right breast are negative for malignancy. (Image courtesy of Dr. Alexis Nees, Department of Radiology, University of Michigan.)

TABLE 2–1 • *Additional Views Obtained During Diagnostic Mammography*

Magnification views	Magnified views are taken of a specific area, with increased resolution to better look at the lesion.
Spot compression views	A small compression paddle is used to spread out the tissue, bringing the area of concern closer to the film.
Exaggerated CC views	Typically the CC view starts at the medial aspect and includes as much of the lateral breast as possible. However, in some women, additional views are obtained to include the entire lateral half of the breast.
Rolled views	The breast tissue is reoriented about the axis of the nipple to determine whether an abnormality is real or simply overlapping tissue.
Tangential views	For palpable lesions, a metallic BB is placed on the skin and then the area is rolled, placing it tangential to the x-ray beam.

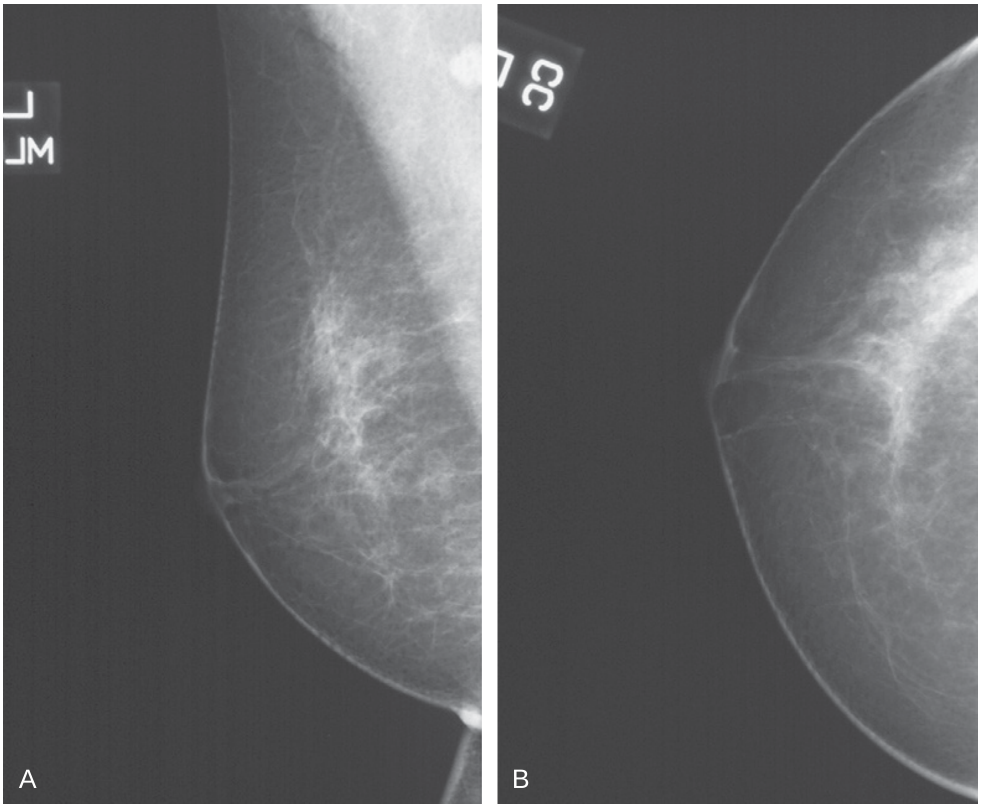

Figure 2–2. Digital mammographic MLO and CC views are negative for malignancy. (Images courtesy of Dr. Alexis Nees, Department of Radiology, University of Michigan).

contrast, brightness, and magnification without the need to obtain additional images. There is greater contrast resolution than with film, and less "noise," which may enhance sensitivity and specificity. It also allows for the rapid and easy transmission of images so that second reads can be easily obtained.

Digital mammography is not without its drawbacks as well. Primarily, the cost is significant; in addition to the new machines, monitors and digital workstations are needed for the radiologists. As the transition is made from film to digital imaging, problems may arise when trying to compare a digital image to a previous mammogram on film. Plus, the spatial resolution is less than that of film mammography, which can limit the evaluation of microcalcifications or the margins of masses.

Digital mammography may provide better screening in women with dense breasts, particularly younger women. The multicenter Digital Mammographic Imaging Screening Trial showed improved performance of digital mammography in women who had dense breasts, with 70% sensitivity compared with 55% sensitivity for film-screen mammography. In addition to the previously mentioned benefits of digital mammography, computer systems have been designed to recognize mammographic patterns and deviations from normal patterns, which may help radiologists identify suspicious areas. This technology is rather new, but could possibly decrease the time it takes to read a mammogram, as well as improve accuracy.

Indications and Uses

Screening

The benefits of mammographic screening are well documented. Although it was clear from the outset that x-ray mammography could identify cancers at a smaller size than physical examination, it was not clear whether this would have an impact on survival. Ultimately this led to eight randomized trials that demonstrated that mammographic screening can decrease breast cancer mortality in women age 50 and older (Table 2–2). A meta-analysis estimated this reduction to be approximately 34% by 7 years. The overall decreases in breast cancer–specific mortality seen over the past decade also attest to the impact of screening. Screening is discussed in further detail later in the chapter.

For the benefits of screening to be optimized, the process needs to be cost and time efficient. The most commonly applied approach is to separate screening from diagnosis. Thus women come to screening centers where two views are obtained of each breast, the medial lateral oblique (MLO) and the craniocaudal (CC) views. The patient leaves and the images are read at a later time, allowing for efficiency and for "double reading," meaning two radiologists review the films, which increases the number of cancers detected. This may be facilitated by the use of digital images. The main disadvantage is that women leave, only to be called back if there is an abnormality requiring additional diagnostic images. Approximately 5% to 10% of women are called back. This can cause undue concern for women, even though most of the women called back will be found to have nothing (e.g., the benign overlap of tissue) or benign findings requiring nothing or short-interval follow-up. Simply receiving a telephone call that there was an abnormality on the mammogram can lead to increased stress in that time period between the telephone call and when the additional imaging is done. This has prompted calls for immediate reading, but this is not only cost-ineffective but also pressures the radiologists to read quickly, which leads to increased errors.

TABLE 2–2 • *Randomized Trials of Breast Cancer Screening*

Study	Years	Mammogram	Frequency	Breast Examination	Relative Risk (CI)	
HIP Study	1963-69	2 Views	q 1 year 4 rounds	Yes	40-49 50-64	0.77 (.53,1.11) 0.80 (.59,1.08)
Edinburgh	1979-88	1 or 2 Views	q 2 years 4 rounds	Yes	45-49 50-64	0.83 (.54,1.27) 0.85 (.62,1.15)
Kopparberg	1977-85	1 View	q 2 years 4 rounds	No	40-49 50-74	0.76 (.42,1.40) 0.52 (.39,.70)
Ostergotland	1977-85	1 View	q 2 years 4 rounds	No	40-49 50-74	1.06 (.65,1.76) 0.81 (.64,1.03)
Malmo	1976-90	1 or 2 Views	q 1.5 to 2 years × 5 rounds	No	45-49 50-69	0.64 (.45,.89) 0.86 (.64,1.16)
Stockholm	1981-85	1 View	q 2 year × 2 rounds	No	40-49 50-64	1.01 (.51, 2.02) 0.65 (.4, 1.08)
Gothenburg	1982-88	2 Views	q 1.5 year × 5 rounds	No	39-49 50-59	0.56 (.32, .98) 0.91 (.61,1.36)
CNBSS	1980-87	2 Views	q 1 year × 4 to 5 years	Yes	40-49 50-59	1.07 (.75,1.52) 1.02 (.78,1.33)