DYNAMIC BREAST ANATOMY

Giorgio Rizzatto, Roberta Chersevani,
Donatella Macorig, Rosaria Perrone

Department of Diagnostic Imaging, General Hospital, Italy

The form, function, and pathology of the female breast are continuously changing through the life.
Growth of this milk-producing system is dependent on numerous hormonal factors that occur in two sequences, first at puberty and then in pregnancy. Breast tissue reacts to estrogen and progesterone stimulation during the menstrual cycle. As the postmenopausal period evolves, progressive atrophy of the epithelial and connective tissue components of the breast occurs. Finally, the lobule is converted into ordinary stroma, which in the process of involution is replaced by fat.

The mature breast is made up of 15 to 20 irregular lobes of branched tubuloalveolar glands. The lobes radiate from the nipple and subdivide into lobules. The gland is surrounded by subcutaneous connective tissue that forms septa between lobes and lobules, providing a support for the glandular elements. These septa, known as Cooper's ligaments, go from the dermis down to the superficial fascia. Adipose tissue is also present among the lobes.

All macroscopic breast structures can be easily imaged with adequate sonographic equipment.
The breast can be divided into four regions (1):
- skin, nipple, subareolar tissues
- subcutaneous region
- parenchyma (between the subcutaneous and retromammary regions)
- retromammary region.

The skin is the superficial component of the breast and requires, for a correct evaluation, the use of high resolution dedicated probes, associated to a standoff pad in case of lower frequencies (2). The sonographic pattern is a more or less homogeneous band that is more echogenic than the underlying fat tissue. Normal skin thickness varies between 0.5 mm and 2 mm, and is usually maximum in the lower quadrants, towards the inframammary fold.

The nipple may be visualized as a rounded, well-defined nodule, having a medium level echogenicity. Distal attenuation is due to some degree to its fibrous structure, but also to the uneven surface of the nipple-areola complex, that does not adhere properly to the scanning surface of most probes. Probes having a soft surface in contact with the skin, made of rubber, show less attenuation.

With a correct examination, the subareolar tissues are usually echogenic, because subcutaneous fat is interrupted at this level. Main ducts coming to the nipple may be visualized as anechoic bands, with a progressively increasing diameter. The lactiferous

sinus is the widest portion of normal ducts, up to 3 mm. wide, and is located just behind the nipple.

The subcutaneous region contains fat and lymphatics.
Fat tissue is a normal breast component. It is localized in the subcutaneous layers, inside breast parenchyma and in the retromammary area. No matter its location, breast fat is always hypoechoic, that is less echogenic than breast parenchyma. Subcutaneous fat is thicker than retromammary fat and measures up to 2-3 cm. It may be very thin or absent in patients with very dense breasts. Subcutaneous fat is crossed by thin, echogenic representing Cooper's ligaments; they run oblique to the skin surface (figure 1). These ligaments go from the skin to the deep pectoral fascia and are well visualized both in subcutaneous fat as well as in fatty breasts, with a regular orientation and in contrast with hypoechoic fat. They disappear inside the hyperechoic structure of breasts with a fibroglandular pattern.

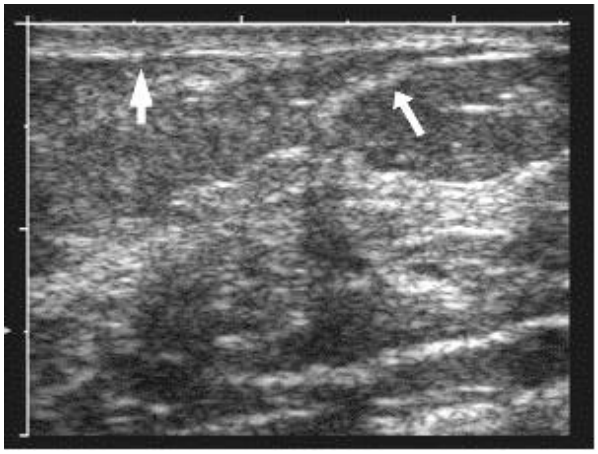

Fig. 1. Cooper's ligament (➞) connecting the hyperechoic fibroglandular tissue and the skin (➡)

Breast lymphatics form a microscopic network in the superficial areas of the breast, mainly between the skin and subcutaneous tissues and also along ducts. Normal lymphatics cannot be visualized, but in case of dilatation - due to inflammation or tumoral infiltration as in inflammatory carcinoma - they can be visualized as hypo-anechoic, thin lines, parallel and perpendicular to the skin, forming a network.

Breast parenchyma has a triangular shape, with the apex towards the nipple and the base at the chest. The sonographic pattern varies with age and individually, and depends on the amount and type of contents, i.e. fat, fibrous and glandular tissues. The fibrous and glandular components are variably echogenic, while fat is hypoechoic. So breast parenchyma is not homogeneous. Fat may be represented as hypoechoic lobules, inside echogenic fibroglandular tissue, having a rounded or oval shape, or be the main breast constituent in fatty involution, a wholly hypoechoic breast crossed by the echogenic ligaments.

A breast with a predominant fibrous structure is echogenic. A breast with a fibroglandular structure is non homogeneous because of hypoechoic bands, coursing in a radial array around and towards the nipple, representing the ductal pattern.
In younger women, with a rich glandular component, the hypoechoic bands contain echogenic lines, better demonstrated when the longitudinal scan is along the ducts' main axis. Going towards the nipple these lines progressively separate and delineate the peripheral ducts.

Breast ducts are visualized more easily with radial scans around the nipple as they branch in a dichotomic pattern, and progressively increase in size, towards the lactiferous sinus, the widest portion of normal ducts (3 mm), located in the subareolar tissues.

Blood supply to the breast originates from the intercostal, internal and external mammary arteries and subscapular arteries. The advent of very sensitive equipment, with high frequency Doppler and able to detect slow flows, allows the demonstration of vessels in a greater number of patients.
Intramammary breast vessels can occasionally be visualized also with conventional imaging as tubular anechoic structures, having a more or less echogenic wall; veins have a more superficial location, parallel to the skin, and disappear if compression is too vigorous.

There is a deep and superficial venous network, with a variable individual pattern, although quite symmetrical in the two breasts. Color Doppler sonography can pick up flow signals in the superficial portions of normal breasts, and the signal has been reported to be more intense at the time of ovulation.

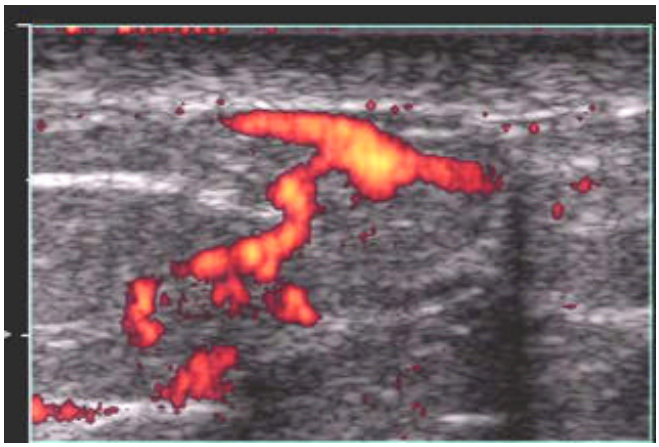

Fig. 2. Intramammary vessel running branching under the skin.

Power Doppler representing blood flow by mapping the density of blood cells, and not their velocity, and being angle independent, allows a more spectacular demonstration of normal flow signals in the more superficial portions of breast parenchyma, where a richer network of intersecting vessels can be demonstrated (figure 2).

Power Doppler is more sensitive to detect blood flow signals also in the deeper areas of breast parenchyma.
The visualization of the axillary vessels requires adequate scanning of the axilla. The internal mammary artery and vein can be visualized through longitudinal scans of the 1st and 2nd intercostal spaces, parallel to the sternum.

Intramammary lymph nodes can be demonstrated with sonography, and they are more often located in the upper quadrants of the outer breast. Normal lymph nodes have an elongated shape, with a hypoechoic rim surrounding an echogenic center: the node's hilum. The longest diameter is usually less than 1 cm. Morphology changes according to the scanning plane. Although pathology remains the gold standard to rule out malignancy, sonography can give some information on the size, shape and structure of lymph nodes.
Color Doppler imaging can add information by showing blood flow at the hilum. Lymphatic drainage is to the axillary, subclavicular and internal mammary chain nodes, through penetrating lymphatics. All these nodes can be easily demonstrated when enlarged.

The retromammary region consists of retromammary fat, the pectoralis muscle, ribs, intercostal muscles and the pleural reflection.
Retromammary fat tissue is a hypoechoic band, having a structure similar to subcutaneous fat tissue, only thinner. The deep fascia cannot be visualized. The pectoralis muscle lies just behind retromammary fat and has a fibrillary pattern. The identification of this muscle is a guarantee that we are examining the gland in its whole depth. The ribs are easily identified because of location and morphology, that changes according to the scanning plane. An axial scan on a rib shows an oval, hypoechoic formation, that cannot be mistaken for a nodule, because it is located underneath the muscle. Even the cartilagenous portion of the ribs produces some distal attenuation that increases in case of calcifications, resembling a target. The intercostal muscles are identified in the spaces among the ribs and show a muscular pattern. The echogenic reflection of the pleural line, that shifts during respiration, is the deepest structure we can identify.

The sonographic pattern of breast parenchyma changes with age, parity, and among individual women, in the same condition, according to the amount of fat, of glandular and connective tissue. Furthermore the mammary gland is stimulated by a variety of hormones in the different phases of life (3).
At puberty, estrogens stimulate the development of ducts, of glandular and connective tissue: a circumscribed, hypoechoic area may be demonstrated and it may result asymmetric with the controlateral breast.
Changes occurring during the menstrual cycle (an increase in size, density, nodularity and tenderness of the breast in the second half of the cycle) do not produce a significant effect on the sonographic pattern; an increased echogenicity due to edema is sometimes appreciated, and improves the visualization of solid or liquid masses.

A more thorough change happens during pregnancy, with the development of alveoli and tubules. A lobular pattern is seen around ducts that are enlarging. During lactation breast parenchyma becomes intensely and diffusely echogenic, with thinning of subcutaneous fat; dilated ducts, with a slightly echogenic content due to milk, can be visualized.

Fatty involution cannot be considered a typical condition of menopause. Glandular atrophy and increase in fat contents is very often encounterd in elderly women, but it is also a frequent and therefore a normal variant of the reproductive period. In such cases no macroscopic glandular tissue can be identified, both on mammograms as well as on sonograms; with pregnancy an increase in the glandular component takes place and replaces fat. After lactation, fatty involution may again take place in these patients. Maybe the term involution should not be used, and we should only describe the breasts as fatty, glandular or fibroglandular.

Sonography can easily define the type of breast and can predict the mammographic pattern we shall find in case of young women undergoing mammography after sonography.

References

1.Bassett, W. L., Kimme-Smith, C. Breast sonography: technique, equipment, and normal anatomy. Seminars in Ultrasound, CT, and MR 10: 82-89, 1989.

2.Chersevani, R., Tsunoda-Shimizu, H., Giuseppetti, G. M., Rizzatto, G. Breast. In: (eds) Solbiati, L., Rizzatto, G. Ultrasound of Superficial Structures: high-frequency, Doppler and interventional. Chuchill Livingstone, Edinburgh, 1995.

3.Birkenfeld, A., Kase, N. G. Functional anatomy and physiology of the female breast. Obstet Gynecol Clin North Am 21: 433-443, 1994.

MAMMOGRAPHIC AND SONOGRAPHIC EVALUATION OF MASSES

Ellen B. Mendelson, M.D., F.A.C.R.
The Western Pennsylvania Hospital, Breast Diagnostic Imaging Center, U.S.A.

Aims of mammography are detection of breast carcinoma at an early stage prior to lymph nodal involvement, and for masses, as small as is possible to detect and characterize them. The chance to offer the patient a variety of treatment options and possibly a better prognosis is incentive for wide-spread screening mammography. Also necessary, considering the large number of studies performed on asymptomatic women yearly, is high specificity as well as maximum sensitivity for the technique. An evaluation of masses can be challenging but rewarding with well executed mammographic studies. Increased specificity can be provided with use of spot compression, magnification, tangential, lateral and other views to portray margins, calcifications, and other features. Careful, directed sonography is definitive in identifying circumscribed solitary or multiple masses as cysts and useful in characterizing palpable masses indeterminate on mammography or not demonstrated because of dense breast tissue.

By definition, masses have volume, weight, and three dimensions. Inadequate compression and unlucky positioning can create a pseudomass or summation density. Asymmetric glandular tissue can also simulate a mass. A summation density and anatomic variants such as asymmetric glandular tissue can be excluded by special mammographic views such as spot compression, minor shifts in obliquity ("rolled" views), and true lateral in which the mass-like soft tissue density changes shape and “spreads out”, presenting a concave rather than a rounded, convex border that pushes against the surrounding fat. Carefully correlated ultrasound studies can provide additional diagnostic confidence if no mass is seen and the sonographic pattern of breast tissue and fat is similar to that seen on the mammogram. Additional simulators of intramammary masses are skin lesions, the rounded appearance of a nipple not imaged in profile, and the sternal insertion of the pectoralis muscle.

After careful mammography, physical examination, and, where indicated, supplemental sonography have established a mass, it can be categorized as benign, indeterminate, or malignant by analysis of its features. The American College of Radiology (ACR) has developed a standardized reporting system (Breast Imaging Reporting and Data System) using consistent descriptive terms for masses and calcifications. In this system, masses are characterized by shape (round, oval, lobular, irregular), margins (circumscribed, microlobulated, obscured, indistinct, or speculated), and density (relative to surrounding

fibroglandular tissue). Using this or a similar scheme to arrive at reporting assessment categories, management recommendations and self-audits can be correlated better to provide valid data regarding positive predictive value of interpretations. As of April 28, 1999, in the United States, mammographic reports must specify an assessment category [appendix] "level of concern".

Any soft tissue density identified on a mammogram or any mass perceived during physical examination can be analyzed by the features listed in Table 1. None of these features alone is definitive but combined, they can suggest the probability of malignancy for each lesion.

TABLE 1: Features of Masses

Location
Size
Shape
Margins
Density (Mammography)
Echogenicity (Ultrasound)
Orientation (Ultrasound)
Calcifications
Number

Location

The importance of this feature is the recognition that some masses and calcifications are not within the breast at all. Moles, keloids, as well as nitroglycerin patches and other articles adherent to the skin or projected over the breast that simulate breast masses can be identified by technologists and diagrammed on the patient information sheet that accompanies the films. To remove doubt about the extramammary origin of a soft tissue density seen on the mammogram, a small radiopaque marker can be placed on the skin and a view with the radiographic beam tangential to the marker can be obtained.

For breast masses, the location along with other features can help suggest the identity of the mass. Intramammary lymph nodes are found frequently in the upper outer quadrants in the posterior 2/3 of the breast, epidermal inclusion cysts in the axilla or inframammary fold, and hamartomas and papillomas in the retroareolar area. The location of a breast mass cannot be used to specify its identity. Carcinomas, fibroadenomas, and cysts can occur in any area of breast tissue.

Shape

As with other features of masses, shape is a nonspecific feature. Carcinomas can be round, oval, or amorphous, and indistinctness of one or more margins will suggest that the lesion is not benign. For definition of shape and margins, a small, round spot compression device will displace overlying parenchymal tissue strands better than the larger, rectangular compression plates. Ultrasound is indicated for characterizing circumscribed round or oval masses which are often cysts. Fibroadenomas are frequently lobulated and may appear round at mammography, but they are often oval in at least one view. The long axis of a fibroadenoma is ordinarily parallel to the skin surface as seen with US, but many carcinomas can also have this orientation. The shape of a fibroadenoma is neither specific for nor against its identity. A reniform mass near or in the axilla suggests a lymph node, but demonstration of its fatty central hilus is required for the mammographic or ultrasonographic diagnosis.

Size

The size of a mass is important if a lesion is a carcinoma. Although many circumscribed soft tissue densities less than 1 cm are benign, meticulous mammographic evaluation is required to evaluate them. Spot compression and magnification, along with ultrasound to exclude a cyst should be used to arrive at an assessment and defensible management plan for the patient.

For small masses, no matter how well circumscribed, change in size is an important sign of activity. Radiologists should actively seek out developing densities, subtle increases in size on sequential studies. Ideally, all the preceding examinations should be reviewed in sequence with the current study; it is insufficient just to look at the study performed immediately prior to the current one. A mass may show no perceptible increase in a one year period. A mammographic increase of one or two mm can be attributed to differences in compression or positioning. In comparing masses with ultrasound, the orientation of the mass in two projections and the appearance of the surrounding anatomy should be the same on successive studies. The perception of true growth may require comparison of the mass over an interval of several years. In addition, apparent change or stability is better established when positioning and technique are comparable, and this may require a search through all of the previous examinations, not just the most recent.

Margins

Of the features used to characterize masses, marginal analysis is the most important.

A mass with spiculated, irregular, or indistinct borders is likely to be malignant; a well-circumscribed mass favors a benign assessment. Visualization of all of the borders of a mass is dependent on both the density of the fibroglandular tissue that surrounds it and facility with mammographic techniques to demonstrate the lesion. Resolution will be improved by views that bring the mass closer to the film such as a lateromedial view for medial lesions; spot compression will do a better job of pushing away the obscuring parenchymal tissue to focus on the mass than the routinely used rectangular compression plates. Carefully designed mammographic evaluation supports more confident estimation of the probability of malignancy: the wispy tail of an otherwise well-circumscribed mass will thus be seen, and the mass will not be mistaken for a benign cyst or fibroadenoma.

Spiculated masses

Spiculated masses are most often carcinomas, and infiltrating ductal carcinoma comprises approximately 80 percent of breast cancers. Other types of malignancies which can appear as spiculated masses at mammography include invasive lobular carcinoma and tubular carcinoma. Invasive lobular carcinomas, in addition to its presentation as a spiculated mass, may demonstrate only subtle architectural distortion on the mammogram and a vague induration on physical examination. Although sonography is not needed when the mammographic appearance is unequivocal, ultrasound can be very helpful in ambiguous cases, first, to identify a mass and then to characterize it. Sonographically, infiltrating lobular carcinoma will be hypoechoic relative to glandular tissue, show irregular margins, a spreading, horizontal orientation, and often be more extensive than expected from the accompanying mammogram.

Spiculation is not synonymous with malignancy. Surgical scars, particularly after breast conservation therapy, can be indistinguishable from the malignancies they replace, and the clinical history and time sequence is important. Radial scars mimic cancers and require biopsy. Fat necrosis and breast abscesses need correlation with clinical data. Sonograms of spiculated masses, benign or malignant, will show lesions hypoechoic with respect to the more echogenic glandular tissue and frequently to hypoechoic fat. Posterior acoustic attenuation, the shadowing which reflects presence of fibrous elements, is frequently seen. With abscesses, the fluid component may be evident despite marginal irregularity on both mammography and sonography. Here the chief diagnostic competitor is necrotic tumor. Aspiration is invited, and sonographic guidance will assure that an appropriate area of the lesion has been sampled or that the mass has been evacuated.

Management of spiculated masses is clearer than for circumscribed nodules. Unless

spiculated masses can be identified as postsurgical scars, they require tissue analysis for identification. Radial scar may be a diagnosis considered for a spiculated lesion that entraps central radiolucencies, but the mammographic appearance is ultimately indeterminate, the histology frequently carcinoma, and biopsy is necessary.

Circumscribed masses

Just as spiculation of a mass is highly suggestive of malignancy, masses that are well circumscribed are most often benign. Cysts, fibroadenomas, intramammary lymph nodes, and a miscellany of other lesions such as papillomas, hamartomas, and focal fibrosis account for most benign lesions. In demonstrating that a mass is smoothly bordered and its perimeter defined by an unbroken line, spot compression and carefully selected additional views are often necessary. Ultrasound can also depict a smooth, pencil-line thin margin.

A well-defined mass less than 1 cm is unlikely to be malignant, and Moskowitz found that sharply delineated masses greater than 1 cm had only a two percent chance of being carcinoma. Sickles did not apply a strict size criterion for masses that were probably benign at mammography. The distinguishing feature, however, is whether or not the mass was palpable. If cysts, accounting for approximately half of the masses, had been excluded by ultrasound and the study limited to solid masses, the expectation of malignancy might be twice that number, or four percent.

Well-circumscribed masses are so frequent an occurrence on mammograms that surgical intervention for most of them would yield few cancers while being costly, anxiety-provoking, and ultimately unacceptable to women. In Stomper's review of 1500 screening mammograms, one or more than one nonspecific nodule was seen in seven percent of studies with an additional seven percent demonstrating hilar radiolucency within a circumscribed small mass indicative of an intramammary lymph node.

High quality, carefully performed ultrasound is indicated for circumscribed masses show identity cannot be determined mammographically. With the gain and focal zone settings appropriately chosen for the size and depth of a lesion, a cyst of .3cm or larger can be identified definitively even in a fatty breast, and routine follow-up advised for the patient. If low-level echoes are seen or the sonographic appearance is otherwise atypical or a simple cyst, the lesion may be either a complex cyst, abscess or hematoma, or else a solid lesion such as a fibroadenoma or papilloma. Recognizing that the mass still may be fluid-filled rather than solid, it should then be aspirated using sonographic or mammographic guidance.

Safe, conservative management of solid, well-defined nodules is a goal of breast imagers. Diagnostic criteria, technical excellence, equipment capabilities, the comfort level of

the radiologist as interventionalist and the medicolegal demands all play a role. Experience with follow-up suggests a low percentage of malignancy (<2%) for completely well-circumscribed masses. With regard to probably benign masses, less than 1-1.5 cm, a common management plan is to repeat a unilateral mammogram in six months, then a bilateral study in another six months (the annual examination for that patient), with resumption of annual mammography thereafter if the lesion is unchanged. Where the anxiety of the patient, the radiologist, or the referring physician is high, an intermediate level option is sonographically- or stereotactically-guided core or FNAB. The expense of these additional procedures can be justified for the individual patient.

Sickles' experience supports the safety in follow-up of carefully evaluated, well-circumscribed masses. Using ultrasound to exclude cysts, he observed 589 solid, well-marginated masses for interval change over a 3-3.5 year period. Nodules that had changed were biopsied, and malignancy found in 12 of the 583 masses or only two percent. In only one instance were axillary nodes positive, and in this case only a single lymph node was involved.

A thin radiolucent ring around a sharply marginated mass, the "halo sign", often used as evidence for the benign nature of a mass, is an optical illusion occurring at the junction of two areas of different density. It can be seen in circumscribed carcinomas as well.

Circumscribed breast malignancies include medullary, mucinous, the rare intracystic papillary and, even more commonly, invasive ductal carcinoma. Usually from lung, melanoma, ovarian, and GI primaries, metastases to the breast may be rounded nodules with sharp borders. They may be unilateral or solitary. Lymphoma, presenting as a mass, may be fairly well defined. To detect subtle irregularities, breaks in the margin, or wisps extending from the mass signifying infiltration, firm, small spot compression, best with magnification also, is effective.

A new mass, a "neodensity", in a postmenopausal woman who is not receiving hormonal replacement therapy must be regarded with suspicion despite smooth margins once a cyst has been excluded with sonography.

Density

Sharply marginated masses that contain low density regions of fat or are entirely fatty are benign. Examples sharply marginated, of purely fatty lesions are lipomas and oil cysts (fat necrosis). Mixed density lesions such as hamartomas, galactoceles, and intramammary lymph nodes are also benign. For galactoceles, history of lactation suggests that etiology for the mass, which may show fluid-fluid layering on a lateral view. Sonography can show an

anechoic cystic mass or homogeneous low-to-mid level echoes that simulate a solid lesion. Aspiration of milky fluid will be definitive. Care must be taken to demonstrate that a focus of fat is within the mass not just projected over it from the surrounding area.

Fat containing lesions that are not well circumscribed should be analyzed using marginal characteristics, calcifications, and other features. Some cancers may trap fat within them, notably infiltrating lobular carcinoma, which can have a low density overall. Radial and postsurgical scars may have central areas of fat within the fibrous, spiculated lesions. Fat necrosis can appear spiculated and poorly marginated but contain oil cysts with rim and other calcifications. Correlation with previous surgical intervention or trauma will support the diagnosis.

Carcinomas are reputed to be denser than benign lesions for their size. When increased density is observed, this feature is neither specific for carcinomas nor can it be used to support a benign interpretation when the mass is of a density similar to that of the surrounding glandular tissue. Infiltrating lobular carcinomas and all other cancers may be isodense with nearby breast parenchyma. Marginal irregularity, associated microcalcifications, and other features are more reliable indicators than breast density.

Uninfected sebaceous or epidermal inclusion cysts are of extremely high density. They are oval with sharply etched, benign marginal characteristics. The blurred margins and density of infected sebaceous cysts and some hematomas make these lesions indistinguishable from malignancy.

Calcifications

In association with a circumscribed mass, coarse calcifications or smaller calcifications at the periphery of a fibroadenoma, rim calcifications of a cyst or oil cyst and milk of calcium layering in a cyst are in accord with the benign assessment founded on marginal features or sonographic demonstration of fluid.

For calcifications, the most important diagnostic feature is particle morphology, equivalent in importance to marginal detail for masses. Despite the smooth margins of a round or oval small mass, calcifications just beginning to form in fibroadenomas and papillomas may have an indeterminate morphology [BIRADS assessment category 4], with biopsy the end result. Pleomorphic microcalcifications in or around a sharply defined mass take precedence over the benign marginal characteristics of the mass, and recommendation for biopsy should be made.

Number

If multiple masses are seen, careful marginal evaluation of each should be performed. Malignant microcalcifications should be excluded. Similar benign-appearing masses--usually cysts, fibroadenomas, papillomas, or a combination--diminish the likelihood of malignancy. In our practice, we perform sonography for all patients with multiple circumscribed masses at the first visit. Where most of the masses are cysts, we aspirate symptomatic lesions along with those with low level echoes or other sonographic features not typical of a simple cyst. On subsequent visits, if the breasts are fatty and masses can be identified and followed up mammographically, repeat sonography is unnecessary. When the breasts are dense and multiple masses are present, sonography is performed at each visit.

Conclusion

In evaluating masses, the most suspicious feature should guide patient management. If margins are smooth but suspicious microcalcifications are seen within the mass or nearby, biopsy is warranted. If the margins of a new mass in a postmenopausal woman are smooth, and the mass is not identified as a cyst with sonography, fine needle aspiration core biopsy, or possibly surgical biopsy will be recommended. If calcifications appear fibroadenomatous, but the margins of the mass are indistinct and irregular on spot or magnification spot compression, the level of suspicion is increased.

Ultrasound is an integral part of the work-up of a circumscribed mass or masses, palpable masses not seen radiographically, or those masses which are mammographically indeterminate. In a combined *Breast Imaging* report, the mass should be described in consistent terminology, such as the ACR's, the sonographic findings should be included and correlated with the mammographic appearance in arriving at an assessment and level of suspicion for malignancy. The assessment should be indicated to the referring physician. As of April 28, 1999, in the United States, an assessment with its corresponding management recommendation is required by Federal law. Moreover, a specific strategy or management options for the patients should be stated.

References

(1) Adler DD, Helvie MA, Oberman HA, et al. Radial sclerosing lesion of the breast: mammographic features. Radiology, 1990; 176:737-740.

(2) American College of Radiology (ACR). Breast imaging reporting and data system (BIRADS ™). Third Edition. Reston [VA]: American College of Radiology; 1998.

(3) Feig SA. Breast masses. Mammographic and sonographic evaluation. RCNA, 1992;

30(1):67-92.

(4) Hilton SvW, Leopold GR, Olson LK, et al. Real-time breast sonography: application in 300 consecutive patients. AJR, 1986; 147:479-486.

(5) Kopans DB. Standardized mammography reporting. RCNA, 1992; 30(1):257-264.

(6) Mendelson EB. The Breast. In: Rumack CM, Wilson SR, Charboneau JW (eds): *Diagnostic Ultrasound,* 2nd edition. St. Louis, Mosby-Year Book, Inc., 1998; pp. 751-789.

(7) Mendelson EB, Harris KM, Doshi N, et al. Infiltrating lobular carcinoma: mammographic patterns with pathologic correlation. AJR, 1989; 153:265-271.

(8) Moskowitz M. The predictive value of certain mammographic signs in screening for breast cancer. Cancer, 1983; 51:1007-1011.

(9) Sickles EA. Mammographic features of 300 consecutive nonpalpable breast cancer. AJR, 1986; 146:661-663.

(10) Sickles EA. Nonpalpable, curcumscribed, noncalcified solid breast masses: Likelihood of malignancy based on lesion size and age of patient. Radiology, 1994; 192:439-442.

(11) Sickles EA. Periodic mammographic follow-up of probably benign lesions: Results in 3184 consecutive cases. Radiology, 1991; 179:463-468.

(12) Sickles EA. Quality assurance. How to audit your own mammography practice. RCNA, 1992; 30(1):265-275.

(13) Stomper PC, Leibowich S, Meyer JE. The prevalence and distribution of well circumscribed nodules on screening mammography: Analysis of 1500 mammograms. Breast Dis, 1991; 4:197-203.

(14) Stavros AT, Thickman D, Rapp CL, Dennis MA, Parker SH, Sisney GA. Solid breast nodules: Use of sonography to distinguish between benign and malignant lesions. Radiology, 1995; 196:123-134.

MAMMOGRAPHIC EVALUATION OF CALCIFICATIONS

Edward A. Sickles, M.D.
University of California, San Francisco, U.S.A.

Breast calcifications are found in most women undergoing mammography. The great majority of these calcifications are clearly benign, therefore causing no problem in diagnosis. Typical calcifications also are seen in some breast cancers, clusters of tiny particles characterized by thin linear, curvilinear, or branching shapes. These malignant calcifications, although usually nonpalpable, are often just as easy to identify and evaluate as their obviously benign counterparts.

Difficulties in interpretation arise primarily with the small remainder of calcifications, specifically, with those that are tiny and clustered but not characteristically malignant in shape. Because both benign and malignant lesions can have such a mammographic appearance, some radiologists encourage biopsy in this situation, even though only about 20% - 30% of cases prove to be cancer. Other radiologists, using fine-detail images and relying on considerable interpretive expertise, have succeeded in substituting periodic mammographic follow-up in place of biopsy for the subset of these calcifications that appear very unlikely to be malignant. This practice can substantially reduce the number of mammography-generated biopsies for benign lesions.

Calcifications are the smallest structures identified on mammograms. They are best visualized using high-resolution imaging techniques, the most effective of which utilize spot compression, minimal geometric unsharpness (small focal spot), and direct radiographic magnification. Those radiologists who have had the greatest success in differentiating benign from malignant calcifications rely heavily on these techniques.

The purpose of this article is to present a systematic and practical approach to the evaluation of all breast calcifications. Because the ability to distinguish benign from malignant calcifications depends on mammographic image quality, and because imaging quality can vary considerably, some portions of this approach probably will not work for everyone. Furthermore, interpretive skill cannot be learned simply by reading an article such as this. There is no substitute for personal experience - working with your own patient population, mammographic equipment, technologists, and images. For those radiologists interested in implementing the more difficult aspects of this approach, specific suggestions are provided to test your level of performance and to assess clinical acceptability for your own practice.

Identify Characteristically Benign Calcifications

The first step in evaluating breast calcifications is to identify those cases that are so characteristically benign as to require no further study. The more common types of typically benign calcification are discussed here; other varieties have been described in the literature but will be encountered rarely. All such lesions should be mentioned in the mammography report, if only to assure a less experienced practitioner viewing the mammograms that the calcifications in question raise absolutely no suspicion of malignancy.

1. Calcifications with radiolucent centers ("eggshell" calcifications): These calcifications may be located within the breast parenchyma or within the skin. If multiple, usually they are widely scattered throughout both breasts. The entire circumference of these particles need not be fully calcified to present a typically benign appearance. They may be as small as 0.5 mm in greatest dimension, but most vary from 1 to 4 mm. A very large (greater than 1 cm) eggshell calcification may represent a cyst with calcification in its wall or a lipid cyst of fat necrosis in an early stage of calcification. In most instances, however, the precise nature of the abnormalities responsible for eggshell calcifications in the breast is unknown.

2. Arterial calcification: Calcification within arterial walls due to atherosclerosis produces the characteristic pattern of two parallel calcific lines (arterial walls imaged tangentially) with amorphous calcification in between (arterial walls imaged *en face*). Both breasts usually are affected, though often to different degrees. The appearance of arterial calcification is readily recognized, except perhaps in its earliest identifiable stage when so little calcification is present that parallel calcific lines are not yet visible. In otherwise equivocal cases, spot compression magnification mammography usually is sufficient to demonstrate the truly vascular (i.e., two-wall) structure of suspect calcifications.

3. Duct ectasia (secretory calcification, plasma cell mastitis): Calcification of inspissated secretions in or immediately adjacent to dilated benign ducts produces a typical mammographic appearance: linear, oval, or round calcifications, usually bilateral and often asymmetrical in distribution. If the calcifications are periductal rather than intraductal in location, they frequently demonstrate radiolucent centers, which represent the noncalcified duct lumina. The calcifications commonly appear oriented with long axes pointing toward the nipple; branching shapes may occasionally be seen. Almost always, the calcifications are substantially larger in both length and caliber than those

associated with malignancy. Rarely, this condition presents with only a few calcifications in one segment of one breast. Even in this situation, however, the relatively large size and characteristic shapes of the calcific particles usually are sufficient to differentiate benign duct ectasia from malignancy.

4. Calcified fibroadenoma: Many fibroadenomas calcify as they undergo myxoid degeneration. In most cases the calcifications display typically benign features that present no problems in diagnosis. Early calcification in a fibroadenoma frequently occurs at the periphery of the mass; such a lesion can be recognized when the presence of adjacent fat permits clear visualization of the margins of the mass and the eccentric location of the calcifications. As calcification progresses in a fibroadenoma, some of the calcific particles become irregular in shape and increase in size so that they are much too large to be confused with malignant calcifications. By the time calcification in a fibroadenoma has become extensive, it often demonstrates a characteristic "popcorn" configuration that is essentially pathognomonic in appearance. Finally, fibroadenomas that are totally replaced by calcification also are typically benign, although they are indistinguishable from fully calcified hematomas or end-stage fat necrosis. Fibroadenomas that calcify in any of these patterns should never be mistaken for carcinoma. Only in the unusual circumstance when calcifications in a fibroadenoma are numerous, small, and non-eccentric in location can it be difficult to exclude the possibility of malignancy.

5. Postsurgical ("dystrophic") calcification: Calcification following biopsy often demonstrates a very characteristic mammographic appearance: large, amorphous sheets, strands, and clumps of calcification oriented along the plane of surgical dissection. Lipid cysts of fat necrosis also are seen occasionally following breast surgery, and when calcification develops in these structures, it can present in a variety of forms progressing from eggshell shapes to very dense calcific masses. These types of postsurgical calcification are found only infrequently, but they are easy to recognize and should arouse no suspicion of malignancy.

6. Milk of calcium in tiny benign cysts: Milk of calcium within cysts is a not uncommon finding; it has been observed in approximately 5% of a representative mixture of symptomatic patients. It commonly appears as multiple calcifications scattered throughout both breasts, a typically benign distribution. However, in approximately 20% of cases, it is unilateral and clustered in distribution, making more challenging its differentiation from malignant calcifications. Because milk of calcium settles to the dependent portions of cysts, fluid-calcium levels (semilunar, curvilinear, or linear

calcifications) are seen when radiographs are taken with a horizontal x-ray beam. On the other hand, vertical-beam radiographs provide a view of the sedimented calcific debris from above, depicting the calcifications only as poorly defined smudges. This characteristic disparity in the shapes of calcifications on 90^{o} lateral and craniocaudal projection mammograms establishes the correct radiographic diagnosis. Since milk of calcium frequently occupies just a small portion of each cyst, and since the cysts themselves typically are no larger than 1-2 mm, the calcifications visualized with mammography usually are very small, so tiny that their characteristic shapes often are recognized only on spot-compression magnification mammograms.

7. Foreign-body injection granulomas: Many years ago, a popular method of breast enlargement involved the injection of inert material into and deep to the breast parenchyma. Silicone was used most commonly in North America, whereas in Asia paraffin or a paraffin-like substance was usually injected. One complication of breast augmentation by injection, readily detectable with mammography, is calcification in the granulomas that form around the injected foreign material. Siliconomas are larger in size and calcify less frequently and to a lesser degree than paraffinomas, but the radiographic features of all such lesions are both characteristic and clearly benign.

Define and Analyze Suspicious Calcifications

Once characteristically benign calcifications have been dismissed from consideration, the remaining cases must be evaluated further. The two mammographic features that indicate calcifications suggestive of malignancy are small size and clustered distribution. Virtually all breast cancers that present with calcifications demonstrate at least some small (< 0.5 mm) calcific particles within the tumor. Several studies have shown that with increasing numbers of mammographically visible calcifications there is a corresponding increase in the likelihood of cancer. On the other hand, the earliest possible cancer detection occurs when only a few calcifications are seen. What then defines the lower limit of calcific particles that constitute a suspicious “cluster”? The smaller the number one uses to trigger a biopsy, the smaller is the size of cancers detected but the higher is the percentage of biopsies done for benign lesions. Therefore, to choose a clinically acceptable trigger point, it is necessary to compromise between sensitivity and specificity. Many radiologists suspect malignancy in any group of calcifications within a 1 cm^3 volume comprising a least five discrete particles smaller than 0.5 mm in size. For certain groups of only three or four small calcifications, it is also reasonable

either to obtain spot-compression magnification mammograms (such fine-detail images often display additional smaller calcific particles) or to recommend periodic follow-up mammography to assess interval change.

Once a significant grouping of calcifications is identified, the next step in the evaluation is to determine their location and distribution. Isolated clustered calcifications located within the skin rather than the parenchyma never represent primary breast carcinoma. Therefore, for calcifications that appear to be fairly superficial on a mammogram obtained using any standard projection, it is important to obtain an additional tangential view of the calcific particles in order to establish or exclude (benign) dermal location. This can be accomplished simply by rotating the breast to bring the involved skin tangent to the x-ray beam. An alternate method involves repeating an exposure in one projection after placing a radiopaque skin marker so that it overlies the calcifications. Then an additional exposure is taken in any other projection; the marker will again superimpose on the calcifications if they indeed are in the skin. If this extra view is taken with the x-ray beam tangential to the skin marker, then dermal calcification actually will be seen within the skin. It is also important to characterize the overall distribution of calcifications, because bilateral scattered calcifications carry such a low probability of malignancy that periodic mammographic follow-up examination is the subsequent procedure of choice. This does not relieve the radiologist of the responsibility to search for a cluster or clusters of calcification among the scattered particles, but such clusters usually are viewed as potentially malignant only if they appear substantially different from the rest of the calcifications.

Those cases remaining unresolved at this point involve isolated clusters of tiny parenchymal calcifications. Only 20% - 30% of the cases will prove to be cancerous, but all must be considered suspicious for malignancy. Some radiologists stop their analysis here, suggesting biopsy to make a definitive diagnosis.

Other radiologists, interested in reducing the number of biopsies for benign lesions, can carry the evaluation one step further in an attempt to identify additional cases that have such high likelihood of benignity that periodic mammographic follow-up becomes a safe management alternative. Such an approach is based on the observation that many benign lesions presenting as tiny clustered calcifications have a characteristic mammographic appearance: the calcifications all are round or oval and occasionally are so tightly grouped together that they are partially superimposed on one another. However, using these criteria with standard mammographic techniques often proves difficult because the calcific particles are so small that their shapes cannot be seen reliably. Fine-

detail images are required, as well as considerable experience in interpreting them. Spot-compression magnification mammography is particularly helpful in this regard. It must be remembered that even with state-of-the-art imaging, many "probably benign" clusters of calcifications still will not be portrayed with sufficient detail to demonstrate characteristic shapes. For these lesions, malignancy remains a major differential diagnostic possibility and biopsy is indicated. On the other hand, the calcifications in many other benign lesions will be seen to be typical in appearance, thereby making malignancy so unlikely as to permit subsequent management with periodic follow-up mammography instead. Of course, as in all follow-up situations, any change during the interval should prompt immediate biopsy. My own experience with this approach involves more than 5,000 such cases, each followed for a minimum of 3 years. In only 0.1% of these patients has breast cancer developed in the area of calcifications for which follow-up was initiated.

Evaluate Clinical Applicability

The success or failure of the calcification-analysis scheme described above will depend on several factors, most important being image quality and the radiologist's expertise. In evaluation of clusters of tiny calcifications, fine-detail images are an absolute requirement. On the other hand, average-quality mammograms are sufficient to characterize many of the larger, typically benign calcifications. Interpretive skill is crucial in all circumstances; this must be gained through personal experience with substantial numbers of cases for which the eventual outcome can be determined. Initially, standard mammography textbooks and articles may be welcome guides. The retrospective study of pathologically proved cases in established teaching files also may be helpful. However, clinical acceptability for your practice can be assessed only on the basis of experience with your own patients, using your own images.

If you anticipate that you will be suggesting periodic mammographic follow-up in cases for which you previously would have suggested biopsy, the implementation of this approach should be done with great caution. It could be disastrous to put such a change into practice only to discover later that it did not work for you, that is, that the diagnosis of some cancers was being delayed. Rather, you should evaluate the efficacy of revised interpretative criteria before actually using them. This can be done by retrospectively reviewing a large series of your cases from the past year to determine whether the new criteria would have reduced the number of biopsies without increasing false-negative

interpretations. However, this method is limited because prior knowledge of clinical outcomes might well bias your results. A more reliable assessment would be done prospectively, by reading each fresh case using both old and new criteria, basing actual management decisions only on the old criteria, and then evaluating cases with discordant interpretations to determine the potential impact of the new criteria.

Summary

Breast calcifications may be categorized as benign, probably benign, and suggestive of malignancy. The interpretation scheme presented here utilizes a systematic structured approach: (*a*) identify characteristically benign calcifications, for which no further evaluation is needed; (*b*) define as suggestive of malignancy those remaining calcifications that present as isolated parenchymal clusters of tiny calcific particles; and (*c*) (optional) attempt to downgrade some of these suspicious calcifications into the probably benign category, so that they can be managed by periodic mammographic follow-up rather than biopsy. The clinical acceptability of this approach will vary with local conditions; success in implementing it will encourage increased use of mammography, and ultimately, improved breast health care.

Suggested Reading

Bassett LW. Mammographic analysis of calcifications. Radiol Clin North Am 1992; 30:93-105.

Egan RL, McSweeney MB, Sewell CW. Intramammary calcification without any associated mass in benign and malignant diseases. Radiology 1980; 137:1-7.

Homer MJ. Imaging features and management of characteristically benign and probably benign breast lesions. Radiol Clin North Am 1987; 25:939-951.

Lanyi M. Diagnosis and differential diagnosis of breast calcifications. Berlin: Springer-Verlag, 1986:81-139.

Linden SS, Sickles EA. Sedimented calcium in benign breast cysts: the full spectrum of mammographic presentations. Am J Roentgenol 1989; 152:967-971.
Sickles EA. Further experience with microfocal spot magnification mammography in the assessment of clustered breast microcalcifications. Radiology 1980;137-137;9-14.

Sickles EA. Mammographic detectability of breast microcalcifications. Am J Roentgenol 1982;139:913-918.

Sickles EA. Breast calcifications: mammographic evaluation. Radiology 1986; 160:289-293.

Sickles EA. Periodic mammographic follow-up of probably benign lesions: results in 3,184 consecutive cases. Radiology 1991; 179:463-468.

MR-IMAGING OF BREAST CANCER

Werner A. Kaiser
Professor and Chairman, Institute of Diagnostic and Interventional Radiology
Friedrich Schiller University Jena, Germany

For more than 15 years MR mammography (MRM) has been clinically tested. In the early phases there was no agreement as to the value of this method, because of the multitude of different measurement possibilities. The considerably worse spatial resolution as compared to X-ray mammography, the inability to detect microcalcifications and the high costs of the method in addition to the necessity to use a contrast medium were all considered as major disadvantages. Because of these disadvantages many experienced mammography experts regarded this method with great skeptizism.

Since then, however, numerous publications have shown that MRM yields the highest sensitivity in the diagnosis of early and small breast cancers and that in particular the multifocality/multicentricity of breast cancers can be recognized adequately only with this method. The utility of contrast media enhanced MRM can be explained through the generation of early tumor angiogenesis, which probably represents a reliable sign of a breast tumor in a size of 3 milimeters or greater. Such a tumor needs an increased blood supply for nourishment and removel of metabolic waste materials to grow uncontrollably.

Although a sensitivity of more than 98 % for the detection of breast cancers in a field strength of at least 1.0 Tesla has been proved on many patients in different centers, there is still some uncertainty about the specificity of MR mammography. Meanwhile there appears to be consensus that for an exact diagnosis of breast cancer the selection of high spatial and temporal resolution in a so-called dynamic technique is of the utmost importance. In these dynamic sequences, that is the repetitive imaging and measurement of the same breast slices before and in short time intervals after the injection of contrast medium, the best differentiation between benign and malignant lesions occurs within the first two minutes. Therefore it is imperative to maintain optimal study conditions. The

evaluation of dynamic MRM is simple in some cases but exceptionally delicate in others and demands a high level of experience on the part of the examiner.

False positive results can occur due to biological or technical reasons. Biologically false positives can be achieved in the examination of myxoid, fibroadenoma, proliferative displeasures and acute mastitis. However, most of these cases do not show a plateau phenomenon or a wash-out effect, which is the decrease of signal intensity after the initial striking increase within the first two minutes. This decrease can be explained by arteriovenous shunts within the tumorangiogenetic network which induce a sudden washout of contrast medium and therefore a drop in signal intensity. Only few benign cases in the literature did show these so-called wash-out effects. Furthermore the type of enhancement (centrifugally, centripetally), the fact of a membran or septa within in the lesion can be used for the differentiation between malignant and benign enhancing lesions. Besides these false positive cases, due to pathophysiological reasons there exists an enormous variety of other reasons for different types of enhancement. These include the wrong dosage of contrast medium, the different types of physiological enhancement and hormone effects. In addition there exists an enormous variety of technical reasons for various enhancements: For example wrong coil adjustments, inhomogenous coil adjustments, injection technique, out of phase-echo times and comparison within different MR-sequences without any objective standardizations and calibrations. The number of false positive diagnoses due to biological or technical reasons effects the level of specificity. As long as there are no definite standardizations and optimizations MRM must be considered as a research technique in demand of further optimization.

False negatives, on the other hand, are pretty rare and this is meanwhile accepted in a large series of cases revealing levels of sensitivity above 98 %. However, different in-situ cancers, especially low-grade DCIS cancers, need not show a tumor angiogenesis and therefore could be left undetected in MRM. There is an open discussion, if all DCIS cases, especially low-grade DCIS cases, must be detected and removed, since the long-term survival rate is excellent (above 98 % according to Swedish long-term results). The detection of DCIS by using MR mammography is still a matter of research. Other causes

for false negatives include rare cases of special lobular cancers and situations after previous bleeding following a core biopsy or fine needle biopsy or open biopsy.

In conclusion false positives are pretty frequent (20-50 %, according to measurement conditions and experience of the examiner), false negatives are comparatively rare.

References

(1) Boetes, R.D. Mus, J.O. Barentz, et al: Characterization of suspect breast lesions by using a gadolinium-enhanced dynamic turboFLASH subtraction technique. Radiology 189(P):301, 1993

(2) Ercolani, G.M. Giuseppetti, E. De Nigra, et al: Dynamic Gd-DTPA MRI evaluation of breast lesions: ECR '91 European Congress of Radiology, September 15-20, 1991, Abstraktband 109

(3) Ercolani, A. Giovagnoni, G. Giuseppetti, et al: Imaging dinamico con rosonanza magnetica nella senologia diagnostica. Radiol Med Torino 82:422-426, 1991

(4) Fischer, D. von Heyden, R. Vosshenrich, et al: Malignitätskriterien in der dynamischen MRT der Mamma. Zentralbl Radiol 147:967, 1993

(5) Fischer, D. von Heyden, R. Vosshenrich, et al: Fortschr Röntgenstr 158:287-292, 1993

(6) Gilles, J.M. Guinebretiere, L.G. Shapeero, et al: Assessment of breast cancer recurrence with contrast-enhanced subtraction MR imaging: Preliminary results in 26 patients. Radiology 188:473-478, 1993

(7) Gribbestad, G. Nilsen, H.E. Fjesne, et al: Signal intensity measurements in dynamic MR mammography studies. In: Proceedings of 12th Annual Meeting of Society of Magnetic Resonance in Medicine, New York, August 14-20, 1993, p 854

(8) Hachiya, T. Seki, T. Nitatori, et a.: Contrast-enhanced MRI in breast masses. ECR'91 European Congress of Radiology, September 15-20, 1991, Abstraktband 109.

(9) Hachiya, T. Seki, M. Okada, et al: MR imaging of the breast with Gd-DTPA enhancement: Comparison with mammography and ultrasonography. Radiat Med 9:232-240, 1991

(10)Hess, M.V. Knopp, G. Brix et al: Improved dynamic MR imaging methods and magnetization transfer contrast in breast carcinoma. Radiology 189(P):239, 1993

(11)Hess, M.V. Knopp, G. Brix, et al: Pharmakokinetische Analyse der Kontrastmittelanreicherung in der MRT beim Mammakarzinom. Zentralbl Radiol 147:969, 1993

(12)Heywang SH, Hahn D, Schmidt H, Krischke I, Eiermann W, Bassermann R, Lissner J (1986): MR imaging of the breast using Gadolinium-DTPA. J Comput Assist Tomogr 1986; 10: 199-204.

(13)Heywang SH, Wolf A, Pruss E, Hilbertz T, Eiermann W, Permanetter W (1989) MR Imaging of the breast with Gd-DTPA: Use and Limitations. Radiology 171: 95-103.

(14)Heywang-Köbrunner SH, Beck R, Hilbertz R, Mayr B, Schlegel A, Diergarten K, Permanetter W (1991) Kernspintomographie mit Gd-DTPA beim kleinen und präinvasiven Mammakarzinom. Zentralbl Radiol 143.3, 198.

(15)Heywang-Köbrunner SH, Beck R, Schmidt F, Kösling S, Schlegel A, Perlet C et al (1993) Use of Contrast-enhanced MR Imaging of the Breast for Problem Cases. Radiology 189 (P) 105.

(16)Kaiser: MR imaging of both breasts within 6 minutes: Technique and first results. Radiology 173(P):164, 1989

(17)Kaiser: MR-Diagnostik der Mamma: Erfahrungen nach 253 Untersuchungen. Dt. Med. Wochenschr 114:1351-1357, 1989

(18)Kaiser: MR-imaging of the breast: Optimal imaging technique, results, limitation, and histopathologic correlation. Radiology 173(P):230, 1989

(19)Kaiser: Dynamic magnetic resonance breast imaging using a double breast coil: An important step towards routine examination of the breast. European Frontiers in Radiology 7:39-68, 1990

(20)Kaiser: Optimierungsmöglichkeiten in der MR-Diagnostik der Mamma. In: Lissner J., Doppman J., Margulis A. (Eds): MR'89, 3. Internationales Kernspintomographie-Symposium Garmisch-Partenkirchen, Referateband, Deutscher Ärzte-Verlag Köln, 1990, pp 143-148

(21)Kaiser: Magnetic Resonance Mammography. Berlin, Springer Verlag, 1993

(22)Kaiser, M. Deimling: Eine neue Multischicht-Meßsequenz für die komplette dynamische MR-Untersuchung an greren Organen: Anwendung an der Brust. Fortschr Röntgenstr 152:577-582, 1990

(23)Kaiser, S. Girschik, E. Zeitler: MR der Mamma mit schnellen Sequenzen. Zentralbl Radiol 36:649, 1988

(24)Kaiser, H. Kess: Prototyp-Doppelspule für die Mamma-MR-Messung. Fortschr Röntgenstr 151:103-105, 1989

(25)Kaiser, O. Mittelmeier: MR-Mammographie bei Risikopatientinnen. Fortschr Röntgenstr 156:576-581, 1992

(26)Kaiser, A. Oppelt: Kernspintomographie der Mamma mit Schnellbildverfahren (FISP und FLASH). 2. Internat. Kernspintomographie-Symposium, Jan. 29-Febr. 1, 1987, Garmisch-Partenkirchen. Konstanz, Schnetztor-Verlag, pp 303-310

(27)Kaiser, M. Reiser: Multifocality of breast cancer detected with dynamic MR-mammography. Radiology 185(P):245, 1992

(28)Kaiser, E. Zeitler: MR imaging of the breast: Fast imaging sequences with and without Gd-DTPA. Radiology 165(P):120, 1987

(29)Kaiser, E. Zeitler: MR imaging of the breast: Fast imaging sequences with and without Gd-DTPA. Radiology 170:681-686, 1989

(30)Kaiser: False positive results in dynamic MR Mammography: Causes, Frequency and Methods to avoid. MRI Clinics of North America. 2.4, November 1994, 539-555.

(31)Kelcz, G.E. Santyr, S.J. Mongin, et al: Reducing false-positive gadolinium-enhanced breast MR imaging results through parameter analysis of the enhancement profile. Radiology 189(P):409, 1993

(32)Megido-Ravid, Y. Itzchak, M. Shabtai, et al: Accuracy of MR imaging in the diagnosis of breast fibroadenoma. Radiology 189(P):301, 1993

(33)Megido-Ravid, Y. Itzchak, M. Shabtai, et al: MR imaging for evaluation of breast scar tissue. Radiology 189(P):301, 1993

(34)Mezrich, S. Segin, R. Shahidi et al: Functional segmentation of MR mammogram for 3D display of breast lesions. In: Proceedings of 12th Annual Meeting of Society of Magnetic Resonance in Medicine, New York, August 14-20, 1993

(35)Mus, C. Boetes, J.O. Barentsz, et al: Combination of gadolinium-enhanced subtracted dynamic turboFLASH and 3D MPRAGE sequences in the diagnosis of breast cancer. Radiology 189(P):105, 1993

(36)Oh, H.D. Lee, W.H. Jung, et al: Gd-DTPA-enhanced dynamic contrast MR imaging in breast disease. Radiology 189(P):408, 1993

(37)Stack, O.M. Redmond, M.B. Codd, et al: Breast disease: Tissue characterization with Gd-DTPA enhancement profiles. Radiology 174:491-494, 1990

(38)Turkat, B. Klein, R. Richman, et al: Dynamic MR mammography: Techniques for improved specificity in the diagnosis of carcinoma without sacrificing specificity. Radiology 189(P):406, 1993

(39)Turner, JZ Wang, S.G. Economou, et al: Detection of breast cancer with parametric images from dynamic, contrast-enhanced, 3D Fourier transform MR images. Radiology 189(P):406, 1993