Elizabeth A. Morris, M.D.
Memorial Sloan Kettering Cancer Centre

MORPHOLOGIC FEATURES

Morphologic analysis is best performed with high spatial resolution techniques that allow evaluation of the mass shape and border so that suspicious spiculated masses can be differentiated from round benign-appearing masses. Also, with high spatial resolution, the borders and internal architecture of the lesion can be assessed and the pattern of enhancement can be readily characterized.

DESCRIPTION OF TERMS

Focus/Mass

A focus is a tiny punctate enhancement that is non-specific and too small to be characterized (usually <5mm). A focus is clearly not a space-occupying lesion or mass. An enhancing lesion on MRI can be described as a mass if it displaces tissue and has space-occupying properties.

Shape/Margin

The shape and margins of masses can be described. Mass shape can be described as round, oval or not otherwise specified (NOS). Margins of masses are smooth, lobulated, irregular or spiculated. Spiculated or irregular masses are suspicious for carcinoma whereas a smooth margin is more suggestive of a benign lesion and lobulated borders are of intermediate concern. It is important to realize that margin analysis is dependent on spatial resolution and that even irregular borders can appear relatively smooth when insufficient resolution is used. Therefore, carcinoma may present with benign imaging features on MR imaging, particularly when small. In general, margin and shape analysis should be performed on the first post-contrast image to avoid washout and progressive enhancement of the surrounding breast tissue, which could obscure lesion analysis.

Internal Enhancement

Internal enhancement of masses can be described as homogeneous or heterogeneous. Homogeneous enhancement is confluent and uniform. Heterogeneous enhancement is non-uniform with areas of variable signal intensity. Heterogeneous enhancement can be further classified as rim, dark internal septations, enhancing internal septations or central enhancement.

Homogeneous enhancement is suggestive of a benign process, however, again, in small lesions, one must be careful as spatial resolution may limit evaluation. Heterogeneous enhancement is more characteristic of malignant lesions especially if rim-enhancement is present.

Non-enhancing internal septations are classic for fibroadenomas though only 40% demonstrate this finding. When present, masses can be considered benign with a high degree of certainty (> 95% according to Nunes). Similarly, non-enhancing masses are also likely benign fibroadenomas that have a high hyaline content. Other benign lesions include an inflammatory cyst that enhances peripherally and benign fat necrosis that can exhibit rim enhancement with central low signal indicating fatty content. These latter two lesions should be recognized as potential pitfalls in interpretation of “rim” enhancing lesions. The cyst can generally be identified on a T2-weighted image and fat necrosis can often be recognized based on the patient’s history and mammographic findings.

Non-mass enhancement

If the enhancement is neither a focus nor mass then it is classified as non-mass-like enhancement. Non-mass enhancement is classified according to the distribution of the enhancement and can be described as linear-ductal, linear-nonspecific, regional, segmental or diffuse. Linear enhancement is enhancement in a line. Ductal enhancement may also be linear but would correspond to one or more ducts in orientation and is suspicious for DCIS. Ductal-nonspecific would not follow this pattern and is less suspicious for malignancy. Segmental refers to enhancement that is triangular in shape with the apex at the nipple and is suspicious for DCIS within a single branching duct system. Regional enhancement is enhancement that does not correspond to a single duct system however, may be within multiple ducts.

Linear enhancement can be further described as smooth, irregular or clumped. As with smooth masses, smooth linear enhancement is suggestive of a benign process. Irregular enhancement refers to any non-smooth enhancement and may be continuous or discontinuous. Clumped enhancement refers to an aggregate of enhancing masses or foci that may be confluent in a cobblestone pattern. Linear enhancement is suggestive of DCIS especially if clumped or irregular.

Segmental, regional or diffuse enhancement can be further described as homogeneous, heterogeneous-stippled/punctate, clumped, septal/dendritic or non-specific. Stippled refers to multiple, often innumerable punctate foci that are approximately 1-2 mm in size and appear scattered throughout an area of the breast that does not conform usually to a duct system. Stippled enhancement is more characteristic of benign normal variant parenchymal enhancement or fibrocystic changes. Regional enhancement and diffuse enhancement are more characteristic of benign disease such as proliferative changes although multicentric DCIS may have this appearance.

KINETICS

Enhancement kinetics becomes particularly helpful if the lesion has a benign morphologic appearance. Any suspicious morphologic feature should prompt biopsy and therefore, kinetic analysis in these cases, while interesting, is not necessary, as the decision to biopsy has already been made. However, in the case of a well-defined mass that could quite possibly be benign, enhancement kinetic data may help one decide whether biopsy is required or whether it is safe to recommend follow-up of the lesion.

In order to perform kinetic analysis, high temporal resolution is required so that multiple acquisitions can be obtained after the intravenous contrast bolus. At the time of this writing there is no uniform consensus on what the optimal time frame for each acquisition should be in order to capture dynamic data. In general, the time per sequential acquisition should be under 2 minutes. If breast MRI is performed in this manner, spatial resolution need not be sacrificed. Because there is usually a trade off between spatial and temporal resolution, an extremely rapid sequence that would provide excellent temporal resolution resulting in excellent dynamic data may be compromised with respect to the morphologic information of the lesion. Therefore, when choosing sequences to perform these examinations, a compromise between spatial and temporal resolution is necessary.

Kinetic techniques have benefited greatly from automated interrogation systems such as the several CAD systems that are available on the market. Prior drawbacks such

as ROI placement and generation of curves have been automated for the reader. This is a time-saving benefit. Additionally, as lesions are often heterogeneous in their kinetic pattern this can be demonstrated with ease on the angiogenic map overlays that are now available. With kinetics, the more acquisitions obtained after intravenous contrast administration, the more points on the curve. Additionally, the faster the acquisition, the more potential information obtained about the curve.

Kinetic techniques generate time/signal intensity curves (TIC). Kuhl et al. described three general types of curves that rely less on the absolute value of the enhancement than on the shape of the enhancement curve. A type-I curve is continuous enhancement increasing with time. A type-II curve reaches a plateau phase where maximum signal intensity is reached approximately 2 – 3 minutes after injection and the signal intensity remains constant at this level. Type-III is a washout curve where there has been a decrease in signal intensity after peak enhancement has been reached within 2 – 3 minutes. As a general rule, benign lesions follow type-I curve and malignant lesions follow a type-III curve. A type-II curve can be seen with both benign and malignant lesions. As with morphologic analysis, malignant lesions can exhibit benign kinetics and vice versa. Kuhl et al. showed that 57% of malignant lesions demonstrated a Type III curve and 83% of benign lesions showed a Type I or II curve.

PREDICTIVE APPEARANCES

Benign Disease

Certain specific morphologic features can be predictive of benign disease. Nunes et al. reported that certain MR findings are predictive of benign disease such as smooth or lobulated borders (negative predictive value (NPV) for malignancy = 97 – 100%), absence of lesion enhancement (NPV = 100%), enhancement less than surrounding breast stroma (NPV = 93 – 100%), and absence of a lesion (NPV = 92%). The presence of non-enhancing internal septations in a smooth or lobulated mass is highly specific for the diagnosis of fibroadenoma (specificity 93 – 97%).

Malignant disease

Certain morphologic characteristics are very suggestive of malignancy. Findings that are highly predictive of malignant disease include spiculated margins (positive predictive value (PPV) = 76 – 88%) and rim enhancement (PPV = 79 – 92%).

The strongest correlations that Nunes et al. found between lesion appearance and pathologic findings were: smooth mass and fibrocystic change, lobulated mass with non-enhancing internal septations and fibroadenoma, enhancing irregular or spiculated mass and invasive ductal carcinoma, spiculated mass and invasive tubular carcinoma or radial scar, enhancing lobulated mass and medullary or colloid carcinoma, ductal enhancement and DCIS, and regional enhancement and DCIS.

SUGGESTED ALGORITHM FOR INTERPRETATION

An approach to breast MR interpretation is outlined below. Initial evaluation of T2-weighted images is performed to determine if high signal masses such as cysts or myxoid fibroadenomas are present. Evaluation of the non-enhanced T1-weighted images documents the presence of high signal hemorrhagic or proteinaceous cysts as well as high signal within dilated ducts. The post-contrast T1-weighted images will demonstrate the presence of any enhancing masses or non-mass-like areas of enhancement. Morphologic

analysis of the architectural features of a mass would then determine if the margins are irregular or spiculated, findings that would be highly suggestive of malignancy. At this point, biopsy would be recommended. A search for the mass by ultrasound may be helpful to allow percutaneous biopsy.

If the mass demonstrates smooth margins and rim enhancement, as rim enhancement is highly predictive of malignancy, biopsy would be recommended in this case as well, once the false positive causes of rim enhancement such as inflamed cyst and fat necrosis have been excluded. Similarly, ductal enhancement that is irregular or clumped will be suspicious for DCIS and biopsy will generally result from this finding.

If however the mass is homogeneously enhancing and demonstrates smooth borders, possibly representing a benign finding, kinetic analysis case can be extremely helpful. Kinetics can determine whether this is indeed likely benign (Type I curve) or possibly malignant (Type II or III curve), prompting biopsy. Because a homogeneously enhancing smooth mass with a Type I curve has been reported in some malignant lesions, short term follow up in six months may be advisable, if this combination of findings is found to document benignity.

TIMING IN MENSTRUAL CYCLE

Normal parenchyma can demonstrate enhancement that can be problematic in the interpretation of breast MRI studies in the pre-menopausal patient. Areas of enhancement can appear and disappear at different phases of the menstrual cycle. Also problematic is the post-menopausal patient on hormone replacement therapy, who has parenchymal enhancement similar to that seen in the pre-menopausal state.

Exogenous and endogenous hormones can cause increased blood flow due to a histamine type of effect. There usually is no mass effect associated with the enhancement and the kinetics of the enhancement is generally gradual over time. Most often there will be diffuse uniform enhancement in a “stippled” fashion consisting of multiple tiny foci of enhancement that can be fairly confidently diagnosed as normal parenchymal enhancement. Sometimes, these areas of normal parenchyma can enhance intensely and appear mass-like causing concern.

In general, if possible, these patients should be scheduled in the second week of their menstrual cycle where proliferative changes are at their lowest in order to minimize this potential enhancement. If this is not possible and parenchymal enhancement is suspected, we will bring the patient back in week two of one of the subsequent menstrual cycles for short term follow up. In the case of post-menopausal patients on hormone replacement therapy, the hormones can be stopped if necessary and a short term follow up in six to eight weeks can be performed.