

## American College of Radiology ACR Appropriateness Criteria®

**Clinical Condition:** Breast Microcalcifications — Initial Diagnostic Workup

**Variant 1:** Pleomorphic, fine, linear, branching in any distribution.

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
Mammography diagnostic	9		☼ ☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution, and an underlying invasive component is suspected.	O
Mammography short interval follow-up	1		☼ ☼
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 2:** Documentation of skin calcification.

Radiologic Procedure	Rating	Comments	<a href="#">RRL*</a>
Mammography diagnostic	9		☼ ☼
Mammography short interval follow-up	2		☼ ☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:****Breast Microcalcifications — Initial Diagnostic Workup****Variant 3:****Milk of calcium, any distribution.**

<b>Radiologic Procedure</b>	<b>Rating</b>	<b>Comments</b>	<b><a href="#">RRL*</a></b>
Mammography diagnostic	9		☼☼
Mammography short interval follow-up	2		☼☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼☼☼☼
Tc-99m sestamibi scan breast	1		☼☼☼☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 4:****Amorphous, single cluster.**

<b>Radiologic Procedure</b>	<b>Rating</b>	<b>Comments</b>	<b><a href="#">RRL*</a></b>
Mammography diagnostic	9		☼☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass or focal asymmetry.	O
Mammography short interval follow-up	1		☼☼
MRI breast without and with contrast	1		O
PET breast	1		☼☼☼☼
Tc-99m sestamibi scan breast	1		☼☼☼☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:****Breast Microcalcifications — Initial Diagnostic Workup****Variant 5:****Amorphous, multiple clusters, one breast.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼☼
Mammography short interval follow-up	2		☼☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼☼☼☼
Tc-99m sestamibi scan breast	1		☼☼☼☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 6:****Amorphous, multiple bilateral clusters.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	5	If further evaluation is needed to better characterize the calcification.	☼☼
Mammography short interval follow-up	2		☼☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼☼☼☼
Tc-99m sestamibi scan breast	1		☼☼☼☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:****Breast Microcalcifications — Initial Diagnostic Workup****Variant 7:****Amorphous in a regional distribution.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼ ☼
Mammography short interval follow-up	2		☼ ☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 8:****Amorphous in a linear or segmental distribution.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼ ☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution and an underlying invasive component is suspected.	O
Mammography short interval follow-up	2		☼ ☼
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:****Breast Microcalcifications — Initial Diagnostic Workup****Variant 9:****Coarse (popcorn), large rod-like, dystrophic, suture, lucent-centered, eggshell rim.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	1		☼ ☼
Mammography short interval follow-up	1		☼ ☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 10:****Round or punctate, clustered.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼ ☼
Mammography short interval follow-up	2		☼ ☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:****Breast Microcalcifications — Initial Diagnostic Workup****Variant 11:****Round or punctate, regional.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	4	If further evaluation is needed to better characterize the calcification.	☼ ☼
Mammography short interval follow-up	2		☼ ☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 12:****Punctate calcifications in a linear or segmental distribution.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼ ☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution and an underlying invasive component is suspected.	O
Mammography short interval follow-up	2		☼ ☼
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition:****Breast Microcalcifications — Initial Diagnostic Workup****Variant 13:****Punctate and amorphous, diffuse, bilateral.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	3		☼ ☼
Mammography short interval follow-up	2		☼ ☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 14:****Coarse heterogeneous, single cluster.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼ ☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution and an underlying invasive component is suspected.	O
Mammography short interval follow-up	2		☼ ☼
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Clinical Condition: Breast Microcalcifications — Initial Diagnostic Workup**

**Variant 15: Coarse heterogeneous, multiple clusters, one breast.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	8		☼☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution and an underlying invasive component is suspected.	O
Mammography short interval follow-up	2		☼☼
MRI breast without and with contrast	1		O
PET breast	1		☼☼☼☼
Tc-99m sestamibi scan breast	1		☼☼☼☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate</b>			<b>*Relative Radiation Level</b>

**Variant 16: Coarse heterogeneous, multiple bilateral clusters.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	3		☼☼
Mammography short interval follow-up	1		☼☼
US breast	1		O
MRI breast without and with contrast	1		O
PET breast	1		☼☼☼☼
Tc-99m sestamibi scan breast	1		☼☼☼☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale: 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate</b>			<b>*Relative Radiation Level</b>

**Clinical Condition: Breast Microcalcifications — Initial Diagnostic Workup**

**Variant 17: Coarse heterogeneous, in regional distribution.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	5	If further evaluation is needed to better characterize the calcification.	☼ ☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution and an underlying invasive component is suspected.	O
Mammography short interval follow-up	2		☼ ☼
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

**Variant 18: Coarse heterogeneous, in linear or segmental distribution.**

Radiologic Procedure	Rating	Comments	RRL*
Mammography diagnostic	9		☼ ☼
US breast	4	Only after diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated mass/focal asymmetry or having an extensive distribution and an underlying invasive component is suspected.	O
Mammography short interval follow-up	1		☼ ☼
MRI breast without and with contrast	1		O
PET breast	1		☼ ☼ ☼ ☼
Tc-99m sestamibi scan breast	1		☼ ☼ ☼ ☼
Core biopsy breast	1		NS
Fine needle aspiration breast	1		NS
Imaging localization for surgical excision breast	1		NS
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

## BREAST MICROCALCIFICATIONS — INITIAL DIAGNOSTIC WORKUP

Expert Panel on Women's Imaging—Breast: Christopher H. Comstock, MD<sup>1</sup>; Carl D'Orsi, MD<sup>2</sup>; Lawrence W. Bassett, MD<sup>3</sup>; Mary C. Mahoney, MD<sup>4</sup>; Lisa Bailey, MD<sup>5</sup>; Lenore I. Everson, MD<sup>6</sup>; Jennifer A. Harvey, MD<sup>7</sup>; Phan Tuong Huynh, MD<sup>8</sup>; Peter M. Jokich, MD<sup>9</sup>; Roberta A. Jong, MD<sup>10</sup>; Constance D. Lehman, MD, PhD<sup>11</sup>; Elizabeth A. Morris, MD<sup>12</sup>; Rachel Rabinovitch, MD.<sup>13</sup>

### **Summary of Literature Review**

Ductal carcinoma-in-situ (DCIS) represents 25%-30% of all reported breast cancers. Approximately 95% of all DCIS is diagnosed because of mammographically detected microcalcifications [1]. Prior to the widespread use of screening mammography, DCIS, detected as a mass on physical examination, was an uncommon disease representing less than 3% of all breast cancers. Screening mammography is the only reliable tool available for detecting breast microcalcifications and DCIS [2].

Breast microcalcifications are detected commonly on screening mammograms. Other initial radiologic procedures for workup of the various types of screening-detected calcifications are described below. Most breast calcifications are benign and can be classified accordingly without any additional workup [3-5]. In women with an indeterminate or higher probability of malignancy calcifications on screening studies, microfocus (0.1 mm focal spot) magnification views in orthogonal projections are useful [1,4]. Interpretation using softcopy readout on 5M cathode ray tube (CRT) or liquid crystal display (LCD) monitors allows evaluation comparable to that of film [6,7]. Although initial studies suggest that 3M LCD monitors may allow accurate analysis of calcifications, further studies are needed [8].

On magnification images, additional calcifications may be apparent, the morphology of individual calcifications can be characterized, and the distribution of calcifications can be better determined. For probably benign calcifications, short-interval follow-up with diagnostic mammography may be appropriate [9]. In women with malignant calcifications, magnification images may be helpful in

establishing the extent of disease [1]. In cases of extensive malignant calcifications or malignant calcifications with an associated soft-tissue density, ultrasound may be useful in diagnosing an invasive component [10].

Currently, the role for computer-aided detection (CAD) of calcifications [11-17] has not yet been determined. However, recent studies indicate that CAD can be clinically useful to avoid false negatives when used properly [18-20]. CAD applied to directly to full-field digital mammography (FFDM) images is comparable to CAD applied to digitized analog mammograms. CAD may improve detection of DCIS; however, due to its variable sensitivity for amorphous calcifications, CAD findings should not be used to avert call-back of suspicious calcifications [21-24].

Currently, only lossless compression (3:1 compression ratio or less) of digital mammograms is recommended for storage or transport. Although initial studies suggest compression ratios as high as 15:1 (lossy) may still allow accurate analysis of calcifications, larger studies are needed to evaluate the possible effects of data compression of >3:1 on calcification detection and analysis [25].

The use of magnetic resonance imaging (MRI), breast-specific gamma imaging (BSGI), positron emission mammography (PEM), and ductal lavage in evaluating clustered microcalcifications has not been established [26-29]. In general, they should not be used to avoid biopsy of mammographically suspicious calcifications.

Stereotactically guided core biopsy using a variety of devices can sample areas of microcalcifications [30]. Stereotactically guided fine needle aspiration (FNA) of microcalcifications has been shown to be inaccurate [31]. Core biopsy specimen radiographs should be obtained to establish the presence of calcifications in the core, as is done with surgically excised specimens [32,33]. Use of eleven-gauge vacuum-assisted core devices may improve the probability of obtaining calcifications compared to 14-gauge spring-loaded or 14-gauge vacuum-assisted biopsy devices. For 11-gauge vacuum biopsy, obtaining 12 samples has been shown to be optimal [34,35]. For subtle residual calcification or calcifications that have been completely removed, a marker clip should be placed. The position of the marker clip in relation to the biopsy site should be documented in the report and on postbiopsy mammograms.

### **Summary**

- Diagnostic mammographic workup (including spot magnifications views in the craniocaudal and 90 ml projections) remains the optimal initial procedure for evaluating screening-detected calcifications that are not typically benign.
- Ultrasound should only be performed if the diagnostic mammographic workup demonstrates suspicious microcalcifications with an associated

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The American College of Radiology seeks and encourages collaboration with other organizations on the development of the ACR Appropriateness Criteria through society representation on expert panels. Participation by representatives from collaborating societies on the expert panel does not necessarily imply society endorsement of the final document.

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mass/focal asymmetry or in cases of suspicious calcifications with an extensive distribution. This may be useful in determining the method of biopsy guidance, diagnosing invasive disease, and facilitating a single-step surgery (excision and lymph node dissection).

- Currently, short-term follow-up or biopsy of calcifications directly from screening mammography is not recommended. In addition, the utility of PEM, BSGI, or MRI for the initial evaluation of screening-detected microcalcifications has not been established.

### Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria® [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
⊕	<0.1 mSv	<0.03 mSv
⊕ ⊕	0.1-1 mSv	0.03-0.3 mSv
⊕ ⊕ ⊕	1-10 mSv	0.3-3 mSv
⊕ ⊕ ⊕ ⊕	10-30 mSv	3-10 mSv
⊕ ⊕ ⊕ ⊕ ⊕	30-100 mSv	10-30 mSv

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

### Supporting Document(s)

- [ACR Appropriateness Criteria® Overview](#)
- [Procedure Contrast Information](#)
- [Evidence Table](#)

### References

- Holland R, Hendriks JH. Microcalcifications associated with ductal carcinoma in situ: mammographic-pathologic correlation. *Semin Diagn Pathol* 1994; 11(3):181-192.
- Holland R, Peterse JL, Millis RR, et al. Ductal carcinoma in situ: a proposal for a new classification. *Semin Diagn Pathol* 1994; 11(3):167-180.
- American College of Radiology. ACR BI-RADS®—Mammography. 4th Edition. *ACR Breast Imaging Reporting and Data System, Breast Imaging Atlas*. Reston, VA: American College of Radiology; 2003.
- Bassett LW. Mammographic analysis of calcifications. *Radiol Clin North Am* 1992; 30(1):93-105.
- Sickles EA. Breast calcifications: mammographic evaluation. *Radiology* 1986; 160(2):289-293.
- Kim HH, Pisano ED, Cole EB, et al. Comparison of calcification specificity in digital mammography using soft-copy display versus screen-film mammography. *AJR* 2006; 187(1):47-50.
- Zuley ML, Willison KM, Bonaccio E, et al. Full-field digital mammography on LCD versus CRT monitors. *AJR* 2006; 187(6):1492-1498.
- Uematsu T, Kasami M, Uchida Y. Soft-copy reading in digital mammography of microcalcifications: diagnostic performance of a 5-megapixel cathode ray tube monitor versus a 3-megapixel liquid crystal display monitor in a clinical setting. *Acta Radiol* 2007; 48(7):714-720.
- Sickles EA. Periodic mammographic follow-up of probably benign lesions: results in 3,184 consecutive cases. *Radiology* 1991; 179(2):463-468.
- Soo MS, Baker JA, Rosen EL. Sonographic detection and sonographically guided biopsy of breast microcalcifications. *AJR* 2003; 180(4):941-948.
- Brettelle DS, Ward SC, Parkin GJ, Cowen AR, Sumsion HJ. A clinical comparison between conventional and digital mammography utilizing computed radiography. *Br J Radiol* 1994; 67(797):464-468.
- Chan HP, Niklason LT, Ikeda DM, Lam KL, Adler DD. Digitization requirements in mammography: effects on computer-aided detection of microcalcifications. *Med Phys* 1994; 21(7):1203-1211.
- Nishikawa RM, Doi K, Giger ML, et al. Computerized detection of clustered microcalcifications: evaluation of performance on mammograms from multiple centers. *Radiographics* 1995; 15(2):443-452.
- Nishikawa RM, Giger ML, Doi K, Vyborny CJ, Schmidt RA. Computer-aided detection of clustered microcalcifications: an improved method for grouping detected signals. *Med Phys* 1993; 20(6):1661-1666.
- Vyborny CJ, Giger ML. Computer vision and artificial intelligence in mammography. *AJR* 1994; 162(3):699-708.
- Workman A, Cowen AR, Brettelle DS. Physical evaluation of computed radiography as a mammographic X-ray imaging system. *Br J Radiol* 1994; 67(802):988-996.
- Zhang W, Doi K, Giger ML, Wu Y, Nishikawa RM, Schmidt RA. Computerized detection of clustered microcalcifications in digital mammograms using a shift-invariant artificial neural network. *Med Phys* 1994; 21(4):517-524.
- Freer TW, Ulissey MJ. Screening mammography with computer-aided detection: prospective study of 12,860 patients in a community breast center. *Radiology* 2001; 220(3):781-786.
- Warren Burhenne LJ, Wood SA, D'Orsi CJ, et al. Potential contribution of computer-aided detection to the sensitivity of screening mammography. *Radiology* 2000; 215(2):554-562.
- Zheng B, Ganott MA, Britton CA, et al. Soft-copy mammographic readings with different computer-assisted detection cuing environments: preliminary findings. *Radiology* 2001; 221(3):633-640.
- Fenton JJ, Taplin SH, Carney PA, et al. Influence of computer-aided detection on performance of screening mammography. *N Engl J Med* 2007; 356(14):1399-1409.
- Ge J, Hadjiiski LM, Sahiner B, et al. Computer-aided detection system for clustered microcalcifications: comparison of performance on full-field digital mammograms and digitized screen-film mammograms. *Phys Med Biol* 2007; 52(4):981-1000.

23. Soo MS, Rosen EL, Xia JQ, Ghate S, Baker JA. Computer-aided detection of amorphous calcifications. *AJR* 2005; 184(3):887-892.
24. Wei J, Hadjiiski LM, Sahiner B, et al. Computer-aided detection systems for breast masses: comparison of performances on full-field digital mammograms and digitized screen-film mammograms. *Acad Radiol* 2007; 14(6):659-669.
25. Suryanarayanan S, Karellas A, Vedantham S, Waldrop SM, D'Orsi CJ. Detection of simulated lesions on data-compressed digital mammograms. *Radiology* 2005; 236(1):31-36.
26. Bazzocchi M, Zuiani C, Panizza P, et al. Contrast-enhanced breast MRI in patients with suspicious microcalcifications on mammography: results of a multicenter trial. *AJR* 2006; 186(6):1723-1732.
27. Berg WA, Weinberg IN, Narayanan D, et al. High-resolution fluorodeoxyglucose positron emission tomography with compression ("positron emission mammography") is highly accurate in depicting primary breast cancer. *Breast J* 2006; 12(4):309-323.
28. Gommans GM, van der Zant FM, van Dongen A, Boer RO, Teule GJ, de Waard JW. (99M)Technetium-sestamibi scintimammography in non-palpable breast lesions found on screening X-ray mammography. *Eur J Surg Oncol* 2007; 33(1):23-27.
29. Khan SA, Wolfman JA, Segal L, et al. Ductal lavage findings in women with mammographic microcalcifications undergoing biopsy. *Ann Surg Oncol* 2005; 12(9):689-696.
30. Liberman L, Smolkin JH, Dershaw DD, Morris EA, Abramson AF, Rosen PP. Calcification retrieval at stereotactic, 11-gauge, directional, vacuum-assisted breast biopsy. *Radiology* 1998; 208(1):251-260.
31. Pisano ED, Fajardo LL, Caudry DJ, et al. Fine-needle aspiration biopsy of nonpalpable breast lesions in a multicenter clinical trial: results from the radiologic diagnostic oncology group V. *Radiology* 2001; 219(3):785-792.
32. Berg WA, Arnoldus CL, Teferra E, Bhargavan M. Biopsy of amorphous breast calcifications: pathologic outcome and yield at stereotactic biopsy. *Radiology* 2001; 221(2):495-503.
33. Margolin FR, Kaufman L, Jacobs RP, Denny SR, Schrumph JD. Stereotactic core breast biopsy of malignant calcifications: diagnostic yield of cores with and cores without calcifications on specimen radiographs. *Radiology* 2004; 233(1):251-254.
34. Jackman RJ, Rodriguez-Soto J. Breast microcalcifications: retrieval failure at prone stereotactic core and vacuum breast biopsy--frequency, causes, and outcome. *Radiology* 2006; 239(1):61-70.
35. Lomoschitz FM, Helbich TH, Rudas M, et al. Stereotactic 11-gauge vacuum-assisted breast biopsy: influence of number of specimens on diagnostic accuracy. *Radiology* 2004; 232(3):897-903.

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.