

Use of Microcalcification Descriptors in BI-RADS 4th Edition to Stratify Risk of Malignancy¹

Elizabeth S. Burnside, MD, MPH, MS
Jennifer E. Ochsner, MD
Kathryn J. Fowler, MD
Jason P. Fine, PhD
Lonie R. Salkowski, MD
Daniel L. Rubin, MD, MS
Gale A. Sisney, MD

Purpose:

To retrospectively evaluate whether microcalcification descriptors and the categorization of microcalcification descriptors in the Breast Imaging Reporting and Data System (BI-RADS) 4th edition help stratify the risk of malignancy, by using biopsy and clinical follow-up as reference standards.

Materials and Methods:

The institutional review board approved this HIPAA-compliant study and waived informed consent. The study included 115 women (age range, 26–82 years; mean age, 55.8 years ± 10.5 [standard deviation]) who consecutively underwent image-guided biopsy of microcalcifications between November 2001 and October 2002. Screening and diagnostic mammograms (including magnification views) obtained before biopsy were analyzed in a blinded manner by a subspecialty-trained breast imager who recorded BI-RADS descriptors on a checklist. The proportion of malignant cases was used as the outcome variable to evaluate the ability of the descriptors to help capture the risk of malignancy. Fisher exact test was used to calculate the difference among the individual descriptors and descriptor categories.

Results:

The positive predictive value of biopsy for malignancy was 21.7%. Each calcification morphologic descriptor was able to help stratify the probability of malignancy as follows: coarse heterogeneous, one (7%) of 14; amorphous, four (13%) of 30; fine pleomorphic, 10 (29%) of 34; and fine linear, 10 (53%) of 19. Fisher exact test results revealed a significant difference among these descriptor categories ($P = .005$). Significant differences among the risks suggested by microcalcification distribution descriptors ($P = .004$) and between that of stability descriptors ($P = .001$) were found.

Conclusion:

The microcalcification descriptors and categories in BI-RADS 4th edition help predict the risk of malignancy for suspicious microcalcifications.

© RSNA, 2007

¹ From the Department of Radiology, University of Wisconsin Medical School, E3/311 Clinical Science Center, 600 Highland Ave, Madison, WI 53792-3252 (E.S.B., J.E.O., L.R.S., G.A.S.); Mallinckrodt Institute of Radiology, Washington University School of Medicine, St Louis, Mo (K.J.F.); Department of Statistics and Department of Biostatistics and Medical Informatics, University of Wisconsin, Madison, Wis (J.P.F.); and Section on Medical Informatics, Stanford University, Stanford, Calif (D.L.R.). From the 2005 RSNA Annual Meeting. Received December 27, 2005; revision requested February 22, 2006; revision received March 10; accepted April 4; final version accepted June 5. Address correspondence to E.S.B. (e-mail: EBurnside@uwhealth.org).

The Breast Imaging Reporting and Data System (BI-RADS) has standardized the description and management of findings identified on mammograms, thereby facilitating communication between radiologists and referring physicians. Each descriptor signifies important features of mammographic abnormalities that convey the radiologist's level of suspicion. The standardized evaluation of findings with predictive terms enables stratification of patient risk to guide management decisions. For example, BI-RADS category 3 ("probably benign") represents a standardized constellation of findings associated with an estimated low risk of malignancy (< 2%), which enables management that is less invasive than biopsy but more aggressive than routine follow-up as the standard of care (1–4). Authors of the BI-RADS lexicon also have divided microcalcification morphologic descriptors into the following designated categories that predict benignity or malignancy: (a) typically benign, (b) intermediate concern, and (c) higher probability of malignancy (5,6). Although the probably benign category is used in large prospective studies, the categorization of microcalcification descriptors in BI-RADS is based on a combination of published research and the opinion of the panel of specialists who developed the lexicon (7–11).

In the past, authors of BI-RADS have used clinical research to drive the evolution of the lexicon. For example, amorphous microcalcifications have a 20% probability of malignancy, which supports the placement of amorphous microcalcifications in the category of intermediate concern (7). Investigators have identified weaknesses in the lexicon to prompt change. For example, in a study of interobserver variability of BI-RADS usage (12), microcalcification descriptors were the most difficult to apply consistently between readers.

Advance in Knowledge

- Microcalcification descriptors in the Breast Imaging Reporting and Data System 4th edition help stratify the risk of malignancy.

Furthermore, results of a large retrospective review (9) of biopsies indicated that two-thirds of all microcalcifications sampled for biopsy were described as pleomorphic—a descriptor that encompasses "a broad spectrum of calcification lesions."

In response, the BI-RADS 4th edition, which was published in 2003 (6), provided refined microcalcification descriptors by dividing the former pleomorphic descriptor into two descriptors—coarse heterogeneous and fine pleomorphic (Fig 1). Coarse heterogeneous microcalcifications (Fig 2) are "irregular, conspicuous calcifications that are generally larger than 0.5 mm" and are considered to be of intermediate concern, along with amorphous microcalcifications (6). Fine pleomorphic microcalcifications (Fig 3) "vary in sizes and shapes...usually less than 0.5 mm in diameter" and are considered to be of higher probability of malignancy, along with fine linear microcalcifications (6). The purpose of our study was to retrospectively evaluate whether microcalcification descriptors and the categorization of microcalcification descriptors in the BI-RADS 4th edition help stratify the risk of malignancy by using biopsy and clinical follow-up as reference standards.

Materials and Methods

Patients

The institutional review board at the University of Wisconsin approved this study and waived the requirement for informed consent. This study was also Health Insurance Portability and Accountability Act compliant. Our study included results of 115 image-guided biopsies performed in 115 women between November 2001 and October 2002 for microcalcifications deemed suspicious by radiologists. The women were 26–82 years of age (mean age, 55.8 years \pm 10.5 [standard deviation]). Results of 11-gauge stereotactic biopsies and needle localizations performed for diagnosis were included. Our exclusion criteria were as follows: (a) patient's images were not available

for review, (b) calcifications were not identified in the histologic specimen, and (c) mammographic or clinical follow-up of at least 12 months was not performed after biopsy. The first two criteria ensured accurate characterization of the microcalcifications and appropriate correlation with the histologic findings for each abnormality. The third criterion allowed follow-up evaluation to recognize misclassification at biopsy. Of 131 consecutive patients (131 biopsies), 16 were excluded (images were unavailable for 11 patients, calcifications were not identified in the histologic specimen for three patients, and follow-up was not performed in two patients), which resulted in the final group of 115.

Imaging and Evaluation

All mammographic examinations were performed with dedicated machines. Analog mammographic examinations were performed with one of two units (DMR, GE Medical Systems, Milwaukee, Wis; M-IV, Lorad, Danbury, Conn) and with a screen-film technique (Min-R 2000; Kodak Health Imaging, Rochester, NY). Digital mammograms were acquired by using a system with a cesium iodide-amorphous silicon detector (Senographe 2000D; GE Medical Systems). Digital mammograms were printed (DryView 8610 printer and DVB film; Kodak Health Imaging) to be analyzed alongside analog

Published online

10.1148/radiol.2422052130

Radiology 2007; 242:388–395

Abbreviations:

BI-RADS = Breast Imaging Reporting and Data System
CI = confidence interval
PPV = positive predictive value

Author contributions:

Guarantors of integrity of entire study, E.S.B., L.R.S.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; approval of final version of submitted manuscript, all authors; literature research, E.S.B., J.E.O., K.J.F.; clinical studies, E.S.B., J.E.O., K.J.F.; statistical analysis, E.S.B., J.P.F., L.R.S.; and manuscript editing, all authors

Authors stated no financial relationship to disclose.

images at the blinded hard-copy reading. Each mammographic examination was monitored for optimal exposure, contrast, and positioning at processing.

Screening and diagnostic mammograms obtained prior to biopsy were retrospectively analyzed in a blinded manner by a subspecialty-trained breast imager (E.S.B., 5 years of breast imaging experience), who recorded BI-RADS descriptors on a checklist. Both screening views (craniocaudal and mediolateral oblique) were evaluated, and diagnostic magnification views and a true lateral view (either with or without magnification) were also evaluated. Only images obtained prior to biopsy were available to the interpreting radiologist. Biopsy specimen radiographs and follow-up images were not available. Data were entered into a research database by using a Web-based interface.

For morphologic and distribution descriptors, the BI-RADS 4th edition lexicon was used to guide the radiologist during image evaluation. Because stability descriptors are not officially included in the lexicon (but nonetheless are widely used), a list with the terms *stable*, *increasing*, *decreasing*, and *unknown* was used by the radiologist. The descriptor *unknown* was used if the patient did not have prior images or the quality of or positioning at prior examinations precluded evaluation of stability. When available, the most recent prior study was reviewed. The majority

of these microcalcifications were detected at screening mammography; therefore, prior studies used for comparison had usually been performed 1 year or more prior to the study of interest.

The interpreting radiologist was allowed to use more than one descriptor from each descriptor class to describe the findings at mammography. Specifically, the reading radiologist could select multiple terms from the morphologic descriptors (*coarse heterogeneous*, *amorphous*, *fine pleomorphic*, and *fine linear*), the distribution descriptors (*scattered*, *regional*, *clustered*, *segmental*, and *linear ductal*), and/or the stability descriptors (*stable*, *increasing*, *decreasing*, and *unknown*). If more than one descriptor from a descriptor class was assigned to a single finding, we used the most suspicious descriptor in our analysis for two reasons. First, we wanted to avoid double-counting lesions to preserve the independence of descriptor groups for statistical testing. Second, according to BI-RADS, management decisions should be based on the most suspicious descriptor assigned to the mammographic finding of concern.

Study End Points

Pathologic findings at the patient's definitive surgical intervention served as the reference standard for malignant lesions. We considered lumpectomy with established negative margins or mastectomy to be the patient's definitive surgical intervention to avoid the possibility

of sampling error at percutaneous biopsy. Although it is possible that a malignancy may be removed completely at percutaneous biopsy and result in benign pathologic findings at lumpectomy, this did not occur in our study. For benign lesions, clinical follow-up was ac-

Figure 2

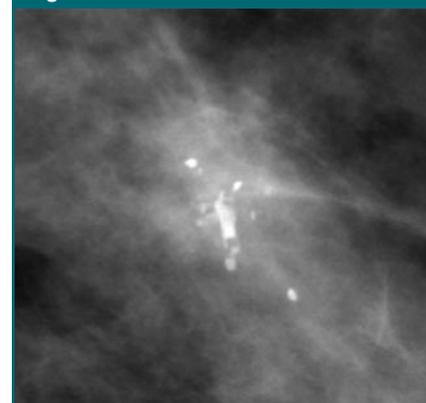


Figure 2: Magnification mammogram in 53-year-old woman with cluster of coarse heterogeneous microcalcifications in left breast. Pathologic findings at 11-gauge stereotactic biopsy revealed intraductal papilloma associated with benign calcifications.

Figure 3

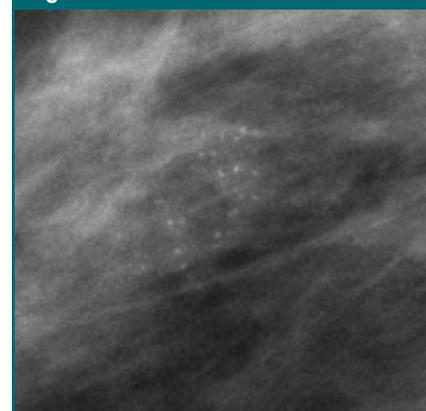
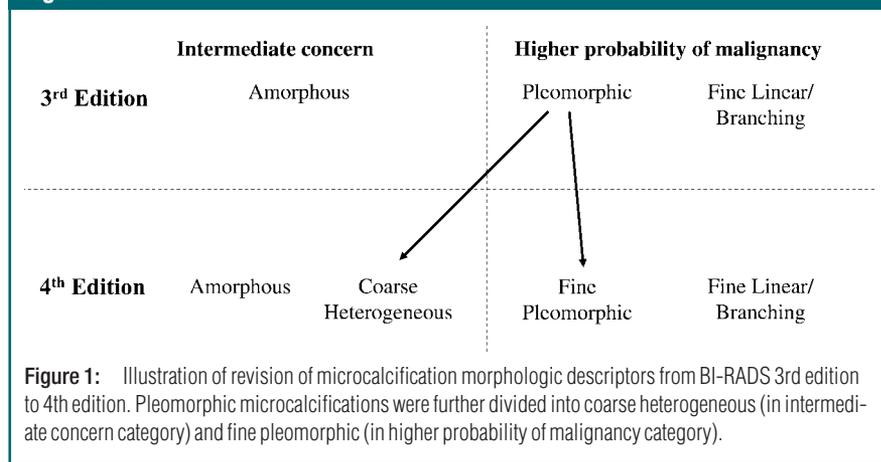


Figure 3: Magnification mammogram in 57-year-old woman with cluster of fine pleomorphic microcalcifications in right breast. Pathologic findings at 11-gauge stereotactic biopsy and subsequent lumpectomy revealed nuclear grade 2 cribriform ductal carcinoma in situ with necrosis and intraductal calcifications and 1-mm tubular carcinoma.

Figure 1



accomplished by using either imaging and/or medical records to determine whether a patient had developed breast cancer at or adjacent to the biopsy site within 1 year of a benign biopsy result. We used a 12-month follow-up as our reference standard because it has been recommended in mammographic practice audits as a sufficient interval to identify false-negative findings (6). Because the lesions included in this study may represent very early breast cancer, we performed additional follow-up when possible. Ten women who did not undergo mammographic follow-up underwent clinical follow-up ranging from 12 to 50 months (mean, 33.9 months \pm 13.2). Seven women who did not undergo clinical follow-up underwent mammographic follow-up ranging from 12 to 43 months (mean, 24.9 months \pm 13.7). Overall, mammographic (mean, 30.6 months \pm 13.7) and clinical follow-up (mean, 35.3 months \pm 13.7) of the 90 patients with benign lesions averaged far more than the 12-month interval recommended to ensure benignity.

Statistical Analysis

We used software (S-PLUS, version 6.2, Insightful, Seattle, Wash; R, version 2.1.1, R Foundation for Statistical Computing, Vienna, Austria) for statistical analysis. The Fisher exact test was used to calculate the difference among the descriptor groups with respect to the risk of malignancy; the proportion of malignant cases was the dependent

variable. A *P* value of less than .05 was considered to indicate a statistically significant difference. Post hoc analyses were used to explain significant results from the Fisher exact test, including odds ratios and 95% confidence intervals (CIs), for pairwise comparisons of descriptor groups, which were derived by using either asymptotic methods (S-PLUS) or exact methods (R). Pairwise odds ratios were considered to indicate a statistically significant difference if the 95% CI for the odds ratio excluded 1. All analyses were based on a single observation per patient so that the usual assumption of independent data was satisfied.

Results

Microcalcification Results

Of the 115 lesions, 25 were malignant and 90 were benign, which makes the overall positive predictive value (PPV) of biopsy for malignancy 21.7%. A total of 26 abnormalities were assessed with a single microcalcification descriptor. The remaining 89 cases were assigned two or more descriptors, in which case the most suspicious was used in our analysis.

Morphologic Descriptors

Each of the microcalcification morphologic descriptors further stratified the probability of malignancy as follows: coarse heterogeneous, one (7%) of 14;

amorphous, four (13%) of 30; fine pleomorphic, 10 (29%) of 34; and fine linear, 10 (53%) of 19 (Table 1). Eighteen cases were described as typically benign, specifically with the following terms: *round* (*n* = 7), *punctate* (*n* = 7), *round* and *punctate* (*n* = 1), *round* and *milk of calcium* (*n* = 1), *rodlike* (*n* = 1), and *dystrophic* (*n* = 1). None of these cases assessed as typically benign were malignant. Results of the Fisher exact test revealed a statistically significant difference among the morphologic descriptors (*P* = .005). The odds ratios of malignancy were 0.07 (95% CI: 0.01, 0.69) for coarse heterogeneous versus fine linear, 0.14 (95% CI: 0.03, 0.66) for amorphous versus fine linear, 0.37 (95% CI: 0.09, 1.34) for fine pleomorphic versus fine linear, and 0 (95% CI: 0, 0.32) for typically benign versus fine linear. Results of this analysis suggest that the fine linear descriptor, used as a base case, indicates a significantly increased risk of malignancy (95% CI for odds ratios excludes 1) compared with that of coarse heterogeneous, amorphous, and typically benign descriptors.

Categorization of Morphologic Descriptors

The probability of malignancy (Table 2) was five (11%) of 44 in the intermediate concern category and 20 (38%) of 53 in the higher probability of malignancy category, which was a statistically significant difference (*P* = .002). The odds ratio of malignancy was 4.69 (95% CI:

Table 1

Rate of Malignancy and High-Risk Microcalcifications in 115 Women according to Morphologic Descriptors

Descriptor	Total No. of Microcalcifications	No. of Invasive Cancers	No. of Ductal Carcinomas in Situ	No. of High-Risk Lesions*	Total No. of Lesions†
Typically benign‡	18	0 (0)	0 (0)	0 (0)	0 (0)
Coarse heterogeneous	14	0 (0)	1 (7)	0 (0)	1 (7)
Amorphous	30	2 (7)	2 (7)	4 (13)	4 (13)
Fine pleomorphic	34	5 (15)	5 (15)	1 (3)	10 (29)
Fine linear	19	6 (32)	4 (21)	1 (5)	10 (53)
Total	115	13 (11.3)	12 (10.4)	6 (5.2)	25 (21.7)

Note.—Numbers in parentheses are percentages.

* High-risk lesions included four cases of atypical ductal hyperplasia and two cases of lobular carcinoma in situ. High-risk lesions were considered benign for analysis.

† Percentages calculated by using the number of invasive cancers and ductal carcinomas in situ malignancies divided by the total number of cases for each morphologic descriptor.

‡ Includes round, punctate, dystrophic, milk of calcium, and rodlike microcalcifications.

1.48, 17.65) for microcalcifications with a higher probability of malignancy; this suggests a significant increase in breast cancer risk compared with that for microcalcifications of intermediate concern.

Distribution Descriptors

The distribution descriptors were also highly predictive of malignancy (Table 3). The risk of breast cancer increased progressively from diffuse (scattered or regional) to focal (clustered) to ductal (segmental or linear ductal) in distribution. None of the more diffuse calcifications were malignant. The differences among these descriptors were also statistically significant ($P = .004$). The odds ratios of malignancy were 3.26 (95% CI: 0.45, 18.76) for segmental versus clustered microcalcifications, 0 (95% CI: 0, 9.01) for regional versus clustered microcalcifications, 10.86 (95% CI: 2.43, 54.37) for linear ductal versus clustered microcalcifications, and 0 (95% CI: 0, 213.79) for scattered versus clustered microcalcifications. The CI for linear ductal versus clustered microcalcifications excludes 1, and this indicates a statistically significant difference.

Stability Descriptors

The stability descriptors also stratified the risk of malignancy in these patients (Table 4). Increasing microcalcifications were associated with the highest risk of malignancy (32%), followed by microcalcifications for which stability was unknown (13%) ($P = .001$). We did not see any cases of malignancy that had stable microcalcifications. No decreasing microcalcifications were identified in our study population. The odds ratio of malignancy for increasing versus stable microcalcifications was infinity (95% CI: 2.42, infinity), which suggests that increasing microcalcifications are strongly predictive of malignancy.

Combination of Descriptors

We determined the rate of malignancy by using a combination of descriptors (Figs 4, 5; Tables 3, 4). We did not perform statistical testing on these combined descriptors. Although these rates

Table 2

Rate of Malignancy according to Microcalcification Categories for Suspicious Findings

Microcalcification Morphologic Category	Total No. of Microcalcifications	No. of Benign Microcalcifications	No. of Malignant Microcalcifications
Intermediate concern*	44	39 (89)	5 (11)
Higher probability of malignancy†	53	33 (62)	20 (38)
Total	97	72 (74)	25 (26)

Note.—Numbers in parentheses are percentages.

* Includes coarse heterogeneous and amorphous microcalcifications.

† Includes fine pleomorphic and fine linear microcalcifications.

are of interest for future investigation, the numbers in our study are insufficient to formally analyze these interactions statistically.

Discussion

In this study, we found that the descriptors in the BI-RADS 4th edition can help predict the risk of malignancy for microcalcifications detected at mammography. The microcalcification morphologic descriptors—coarse heterogeneous, amorphous, fine pleomorphic, and fine linear—have a progressively increasing risk of malignancy. In addition, our data support the current categorization of microcalcification morphologic descriptors into intermediate concern and higher probability of malignancy categories.

It is not surprising that BI-RADS descriptors help stratify risk, considering that initial studies provided terms that were most predictive of malignancy (10,11). The BI-RADS lexicon was created and has evolved to help capture predictive mammographic descriptors in a standardized manner (5,6). According to results of prior research (9), the microcalcification descriptors in the BI-RADS 3rd edition stratified the risk of malignancy as follows: amorphous, 26%; pleomorphic, 41%; and fine linear, 81%. However, a flaw in the lexicon became evident when these researchers realized that a large proportion of microcalcifications were described as pleomorphic. The probability of malignancy of pleomorphic microcalcifications directly mirrored the PPV of biopsy rather than providing further stratification; the risk of

malignancy for pleomorphic microcalcifications was 41%, and the overall PPV of biopsy was 42% (9). In essence, pleomorphic microcalcifications, despite their categorization as indicating a higher probability of malignancy, had a malignancy risk similar to that of the entire biopsy population. Similarly, in our study, if coarse heterogeneous and fine pleomorphic microcalcifications were described as pleomorphic, the risk of malignancy for the pleomorphic cases would be 23% (11 malignancies of 48 total cases), which closely parallels our overall PPV of 21.7%. The addition of coarse heterogeneous and fine pleomorphic divided the previous pleomorphic descriptor into two distinct groups that help better stratify risk. The BI-RADS 4th edition provides descriptors that help stratify microcalcifications into separate risk groups—each distinct from the baseline malignancy risk for all microcalcifications recommended for biopsy—and appropriately designates these descriptors into intermediate concern and higher probability of malignancy categories.

Although microcalcification distribution descriptors are not divided into specific risk categories in BI-RADS, we find that they do help stratify the risk of malignancy. Microcalcifications in a ductal distribution (either segmental or linear) are much more likely to be located in contiguous terminal ductal lobular units and thus to represent ductal carcinoma in situ. Clustered microcalcifications represent an intermediate risk for malignancy. Descriptors related to diffuse microcalcifications (scattered or regional) show a low likelihood of malig-

nancy relating to the fact that these microcalcifications arise in scattered glands, lobules, or the stromal elements of the breast and thus are more likely benign. These results are similar to those of previous work (9).

Descriptors assessing the stability of microcalcifications were also highly predictive of malignancy in our study; a large proportion of malignant cases exhibited increasing microcalcifications. Again, our results support a foregoing investigation (13) that analyzes the predictive value of stability for microcalcifi-

cations. Stability descriptors are not included in the BI-RADS lexicon but are widely accepted to aid differentiation of benign and malignant disease. Of note in our study, all stable microcalcifications were benign. However, this finding must be viewed with caution because of our limited sample size. Results of previous research (13) document that stability of microcalcifications is not reliable for the exclusion of malignancy.

In our study, we analyzed the predictive abilities of BI-RADS microcalcification descriptor classes (ie, morpho-

logic, distribution, and stability) in isolation. In contrast to our study design, combinations of BI-RADS descriptors are routinely used in clinical practice to characterize mammographic abnormalities. In fact, the majority of abnormalities in our study were described with more than one descriptor. Although deciding management on the basis of the most suspicious descriptor is accepted practice, the use of combined descriptors may have a more powerful predictive ability than that of isolated descriptors. The BI-RADS 4th edition gives ra-

Table 3

Rate of Malignancy of Microcalcifications as Function of Distribution and Morphologic Descriptors

Distribution Descriptor	Morphologic Descriptor					Total
	Linear	Fine Pleomorphic	Amorphous	Coarse Heterogeneous	Typically Benign	
Linear ductal	6/7 (86)	2/3 (67)	0/1 (0)	NA	0/1 (0)	8/12 (67)
Segmental	NA	2/3 (67)	1/5 (20)	NA	NA	3/8 (38)
Clustered	4/11 (36)	6/27 (22)	3/24 (13)	1/14 (7)	0/14 (0)	14/90 (16)
Regional	NA	0/1 (0)	NA	NA	0/3 (0)	0/4 (0)
Scattered	0/1 (0)	NA	NA	NA	NA	0/1 (0)
Total	10/19 (53)	10/34 (29)	4/30 (13)	1/14 (7)	0/18 (0)	25/115 (21.7)

Note.—Numbers are raw data, with percentages in parentheses. NA = not applicable.

Figures 4, 5

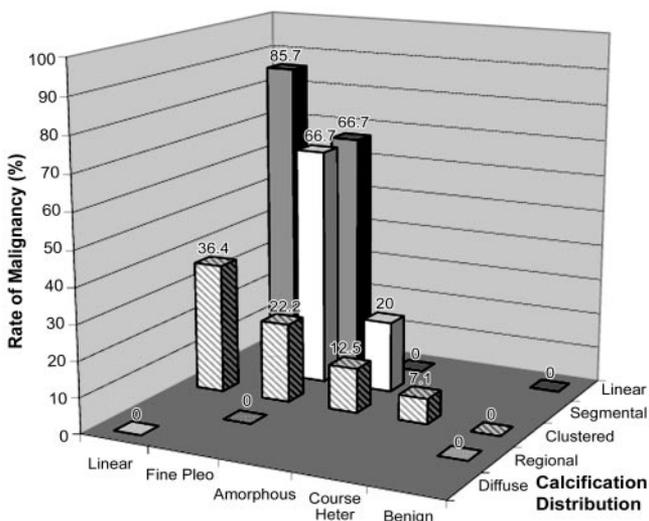


Figure 4: Graph demonstrates probability of malignancy of abnormalities according to combined morphologic and distribution descriptors. *Pleo* = pleomorphic, *Heter* = heterogeneous.

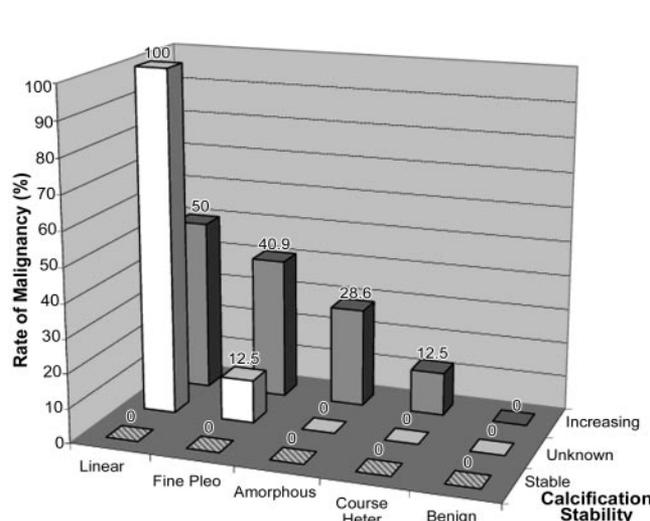


Figure 5: Graph demonstrates probability of malignancy of abnormalities according to combined morphologic and stability descriptors. *Pleo* = pleomorphic, *Heter* = heterogeneous.

radiologists the opportunity to categorize suspicious mammographic abnormalities into distinct risk groups by using categories. BI-RADS categories 4A, 4B, 4C, and 5 represent increasing estimates of the probability of malignancy of suspicious findings primarily based on the interpreting radiologist's overall impression of the findings. BI-RADS provides little guidance on how to perform this classification accurately. Further research with larger patient populations and formal statistical testing may determine the ability of combined BI-RADS 4th edition descriptors to predict the risk of malignancy and determine the appropriate BI-RADS category assignments in a more quantitative manner.

That the BI-RADS 4th edition can help stratify the risk of malignancy has important clinical implications because this information can contribute to physician-patient communication and shared decision making. There is increasing interest in shared decision making as it relates to screening tests (14,15). Each patient has a unique risk tolerance and comorbidities to weigh when contemplating the decision to undergo breast biopsy. A probability can be communicated to patients so that they are better informed about their own individual risk. The availability of a probability of malignancy would allow decisions to be based on personal preference in the context of discussions with radiologists, referring physicians, and others.

There were limitations to our study. First, our study was a retrospective analysis with one radiologist and a limited number of patients, which potentially limits the generalizability of our results to results of studies of prospectively assessed BI-RADS descriptors throughout a diverse group of radiologists and patients. Second, our study did not test the extent of interobserver variability. It would be valuable to prospectively test the predictive value of BI-RADS 4th edition descriptors by using multiple radiologists in a larger patient population to inform authors of future editions of the lexicon.

Third, because our study group consisted of patients selected to undergo

Table 4

Rate of Malignancy of Microcalcifications as Function of Stability and Morphologic Descriptors

Stability Descriptor	Morphologic Descriptor					Total
	Linear	Fine Pleomorphic	Amorphous	Coarse Heterogeneous	Typically Benign	
Increasing	8/16 (50)	9/22 (41)	4/14 (29)	1/8 (13)	0/8 (0)	22/68 (32)
Unknown	2/2 (100)	1/8 (13)	0/3 (0)	0/4 (0)	0/7 (0)	3/24 (13)
Stable	0/1 (0)	0/4 (0)	0/13 (0)	0/2 (0)	0/3 (0)	0/23 (0)
Total	10/19 (53)	10/34 (29)	4/30 (13)	1/14 (7)	0/18 (0)	25/115 (21.7)

Note.—Numbers are raw data, with percentages in parentheses.

breast biopsy for suspicious microcalcifications, it is possible that some patients with microcalcifications with suspicious descriptors were omitted from our study because they were not referred to undergo biopsy. For example, some cases of coarse heterogeneous microcalcifications (particularly multifocal) may not have been recommended to undergo biopsy and, consequently, were omitted from this analysis. Although further research is needed to determine the global risk of microcalcification descriptors in a screening population, our research is valuable in that it effectively informs us of the risk estimation for the specific population of women selected for biopsy. Finally, our PPV was lower than that of previous studies (7,9), a circumstance that may limit the generalizability of our results to results of other studies with a higher PPV. Despite our low PPV, stratification of malignancy risk based on descriptors still occurred. In fact, the level of our PPV appears to have uniformly lowered the risk for each type of microcalcification descriptor we investigated when compared with previous work (7,9). It is probable that further investigation with larger patient populations will confirm that microcalcification descriptors help stratify risk relative to the overall PPV of biopsy. We are encouraged by the preliminary results that demonstrate that the 4th edition of the BI-RADS lexicon is a useful tool in risk stratification.

In conclusion, our research provides clinical data regarding the intermediate concern and higher probability of malignancy

categories in the BI-RADS 4th edition for characterizing microcalcification morphology. Furthermore, results of our work demonstrate that each microcalcification descriptor in the new BI-RADS lexicon can help stratify the risk of malignancy in patients selected to undergo breast biopsy. We believe our results contribute additional clinical evidence showing that the BI-RADS lexicon represents a powerful clinical tool for mammographic reporting.

References

1. Sickles EA. Periodic mammographic follow-up of probably benign lesions: results in 3184 consecutive cases. *Radiology* 1991;179:463-468.
2. Varas X, Leborgne F, Leborgne JH. Nonpalpable, probably benign lesions: role of follow-up mammography. *Radiology* 1992;184:409-414.
3. Varas X, Leborgne JH, Leborgne F, Mezzera J, Jaumandreu S, Leborgne F. Revisiting the mammographic follow-up of BI-RADS category 3 lesions. *AJR Am J Roentgenol* 2002;179:691-695.
4. Vizcaino I, Gadea L, Andreo L, et al. Short-term follow-up results in 795 nonpalpable probably benign lesions detected at screening mammography. *Radiology* 2001;219:475-483.
5. American College of Radiology. Breast imaging reporting and data system (BI-RADS). 3rd ed. Reston, Va: American College of Radiology, 1998.
6. American College of Radiology. Breast imaging reporting and data system (BI-RADS). 4th ed. Reston, Va: American College of Radiology, 2003.
7. Berg WA, Arnoldus CL, Teferra E, Bhargavan M. Biopsy of amorphous breast

- calcifications: pathologic outcome and yield at stereotactic biopsy. *Radiology* 2001;221:495-503.
8. Berg WA, Campassi C, Langenberg P, Sexton MJ. Breast imaging reporting and data system: inter- and intraobserver variability in feature analysis and final assessment. *AJR Am J Roentgenol* 2000;174:1769-1777.
 9. Liberman L, Abramson AF, Squires FB, Glassman JR, Morris EA, Dershaw DD. The breast imaging reporting and data system: positive predictive value of mammographic features and final assessment categories. *AJR Am J Roentgenol* 1998;171:35-40.
 10. Swets JA, Getty DJ, Pickett RM, D'Orsi CJ, Seltzer SE, McNeil BJ. Enhancing and evaluating diagnostic accuracy. *Med Decis Making* 1991;11:9-18.
 11. Moskowitz M. The predictive value of certain mammographic signs in screening for breast cancer. *Cancer* 1983;51:1007-1011.
 12. Baker JA, Kornguth PJ, Floyd CE Jr. Breast imaging reporting and data system standardized mammography lexicon: observer variability in lesion description. *AJR Am J Roentgenol* 1996;166:773-778.
 13. Lev-Toaff AS, Feig SA, Saitas VL, Finkel GC, Schwartz GF. Stability of malignant breast microcalcifications. *Radiology* 1994;192:153-156.
 14. Chan EC. Promoting an ethical approach to unproven imaging tests. *J Am Coll Radiol* 2005;2:311-320.
 15. Hillman BJ. Informed and shared decision making: an alternative to the debate over unproven screening tests. *J Am Coll Radiol* 2005;2:297-298.