Wei Tse Yang, FRCR
Constantine Metreweli, FRCR, FRCP
Peggo K. W. Lam, MPhil
Jenny Chang, MD, MRCP

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[1] From the Department of Diagnostic Radiology and Organ Imaging (W.T.Y., C.M.) and the Center for Clinical Trials and Epidemiological Research (P.K.W.L.), Chinese University of Hong Kong, Prince of Wales Hospital, Shatin, NT, Hong Kong; and the Breast Care Center, Baylor College of Medicine, Houston, Tex (J.C.). Received September 18, 2000; revision requested November 2; final revision received March 15, 2001; accepted March 19. Supported in part by the University Grants Council Direct Grant for Research, Chinese University of Hong Kong, project code 2040753 and a research grant from Schering, Berlin, Germany. **Address correspondence to** W.T.Y. (e-mail: *weitsetan@cuhk.edu.hk*).

Author contributions:
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Benign and Malignant Breast Masses and Axillary Nodes: Evaluation with Echo-enhanced Color Power Doppler US[1]

PURPOSE: To evaluate microbubble contrast enhancement in distinguishing malignant from benign breast masses and malignant from benign axillary nodes in patients with breast cancer.

MATERIALS AND METHODS: Eighty-six patients with 86 breast masses and 32 patients with breast cancer (subgroup of 86 patients) with 32 axillary nodes underwent color power Doppler ultrasonography with and without contrast material. Vascular features and contrast material transit times were recorded. Nodal enhancement was compared with corresponding primary breast cancer enhancement in the subset of 32 patients.

RESULTS: Pathologic analysis revealed 58 breast carcinomas and 28 benign breast lesions and 20 malignant and 12 benign axillary nodes in the 32 patients with breast cancer. Breast cancers had a greater total number and greater number of peripheral vessels than did benign lesions before and after contrast material administration ($P < .001$). Malignant nodes had a greater total number and greater number of peripheral vessels at baseline and after contrast enhancement ($P < .05$), and a longer enhancement duration ($P = .004$) compared with benign nodes. Malignant nodes enhanced more than did corresponding primary breast cancers. Postcontrast number of peripheral vessels was an independent predictor of primary breast cancer ($P < .05$), and increased number of peripheral vessels after contrast enhancement and enhancement duration were independent predictors of nodal malignancy ($P < .05$).

CONCLUSION: Primary breast cancers and malignant axillary nodes had a greater total number and greater number of peripheral vessels compared with benign breast masses and axillary nodes, respectively.

Increased tumor vascularity has been described as a characteristic feature of malignancy and has been used to distinguish primary breast cancer from benign lesions at Doppler ultrasonography (US), a noninvasive form of angiography (1–4). The introduction of intravascular contrast agents such as SH U 508A (Levovist; Schering, Berlin, Germany), a galactose-based medium that contains microbubbles small enough to be maintained in the pulmonary vasculature, has been shown to improve the detection of blood flow through small systemic vessels and thereby allow more complete delineation of the vascular anatomy of microvessels (5,6). Microbubble-enhanced color Doppler US has been used to evaluate primary breast masses and is reported to have 100% sensitivity and accuracy in distinguishing malignant from benign breast disease (7).

With the growing use of sentinel node biopsy, the necessity of full axillary dissection in all patients with breast cancer is becoming increasingly controversial (8,9). Alternative noninvasive methods for accurate prediction of lymph node metastases may enable better identification of likely positive nodes for sampling and thus the selection of patients who would benefit from axillary node dissection. Such methods would be useful adjuncts to the

accurate staging of disease in patients (10–12). Despite numerous reports (13–17) in the literature describing the role of Doppler US in differentiating between malignant and benign superficial regional lymph nodes, to our knowledge the usefulness of microbubble-enhanced color power Doppler US in the diagnosis of axillary metastases has not yet been studied. We undertook this study to evaluate the usefulness of microbubble contrast enhancement in distinguishing malignant from benign breast masses and in differentiating between malignant and benign axillary nodes.

MATERIALS AND METHODS

Eighty-six breast masses in 86 consecutive patients were prospectively examined by using gray-scale and color power Doppler US with microbubble enhancement. After imaging, the diagnoses of all breast masses were confirmed by means of core biopsy (Monopty; Bard Urological, Covington, Ga), excision biopsy, or mastectomy. In this same patient group, axillary nodes were visible in 62 (72%) patients. Forty (69%) of 58 patients suspected of having primary breast cancer at imaging had visible axillary nodes at gray-scale US and were recruited for microbubble-enhanced color power Doppler US of the axillary node. Four patients declined to undergo further contrast material–enhanced color power Doppler US of the axillary node; in three patients, contrast-enhanced color power Doppler US of the axillary node could not be completed owing to age and hemiplegia; and in one patient, the data captured at microbubble-enhanced color power Doppler US of the axillary node were inadvertently erased.

Therefore, a subset of 32 patients with visible axillary nodes and suspected primary breast cancer at US underwent microbubble-enhanced color power Doppler US of 32 axillary lymph nodes. All 32 of these patients were confirmed to have primary breast cancer at pathologic analysis. The pathologic diagnosis of all axillary lymph nodes studied was obtained by using fine-needle aspiration cytology with US guidance, followed by axillary dissection in all patients. The mean age of the patients was 56 years (range, 19–84 years). The mean size of all 86 breast masses was 2.5 cm (range, 0.6–10.0 cm). The mean size of the 32 axillary lymph nodes was 1.6 cm (range, 0.6–3.2 cm). This study received local ethics committee approval, and written informed consent was obtained from all patients.

US was performed by one breast radiologist (W.T.Y.), who was blinded to the clinical diagnoses of the patients. Each breast mass and each axillary node was scanned by using a US imaging unit (HDI 3000 or HDI 5000; Advanced Technology Laboratories, Bothell, Wash) with a 12–5-MHz linear-array transducer. With a Doppler operating frequency of 6 MHz for the transducer, the machine settings used for color power Doppler US imaging were aimed at optimizing sensitivity for the detection of low-velocity and low-volume blood flow. The video output of the scanner was tape recorded, starting a few seconds prior to injection and continuing until the strength of the color power Doppler US signals was subjectively judged to have returned to baseline. The color power Doppler US images were stored on magneto-optical disks and hard-copy laser images for review.

At baseline color power Doppler US, the morphologic vessel characteristics studied in the 86 breast masses were vessel number and distribution (ie, central, peripheral, and side-branching vessels); these characteristics were modified after previously published criteria (3). The definitions for vessel distribution were as follows: *(a)* Peripheral vessels were defined as one or more vessels coursing along the margin of a mass. *(b)* Central vessels were defined as one or more color signals within the mass that did not extend to the periphery. *(c)* Side-branching vessels were defined as one or more color signals arising from peripheral or central vessels in a branching pattern that were smaller in caliber than the primary vessel. For large masses, the area with the greatest vascularity was selected for study.

The recommended dose of 10 mL of a 300-mg solution of SH U 508A was injected through a 19-gauge cannula in the cubital fossa at a rate of 2 mL/sec and flushed through with 10 mL of saline. The dynamic features of the contrast material bolus—namely, time to peak enhancement and duration of enhancement (ie, time to return to baseline)—were recorded in seconds. The degree of enhancement was determined on the basis of the change in the number of vessels after contrast material administration.

In 32 patients suspected of having breast cancer on the basis of mammographic and US findings, color power Doppler US of a single axillary node was performed before and after contrast material administration. The morphologic and contrast material transit features of each of the 32 nodes were documented. The number and distribution (ie, central, central perhilar, and peripheral, on the basis of previously published criteria [10]) of vessels were studied at baseline and after contrast material administration. The morphologic vascular findings of malignant and benign axillary nodes at color power Doppler US were then compared with those of the corresponding primary breast cancer in the same patient before and after contrast material administration.

One-way analysis of variance for repeated measures was performed to assess *(a)* differences between the baseline and postcontrast vascular parameters of malignant and benign breast masses and axillary nodes, *(b)* differences in vascular parameters between the malignant and benign breast masses and axillary nodes, and *(c)* differences in vessel number increases between the malignant and benign breast masses and axillary nodes. Within-patient comparisons of vascular enhancement between the primary breast cancer and the axillary node were performed similarly by using one-way analysis of variance for repeated measures. Stepwise logistic regression analysis was performed to determine the significant independent predictors of breast malignancy and nodal malignancy (18). By using a statistical software package (SPSS for Windows, version 10.0; SPSS, Chicago, Ill), receiver operating characteristic analysis of these variables was subsequently performed to evaluate the overall diagnostic usefulness of the criteria on the basis of the area under the curve.

RESULTS

Primary Breast Lesions

Of the 86 primary breast lesions studied, 58 (67%) were malignant and 28 (33%) were benign at pathologic analysis. The pathologic diagnoses of the benign breast lesions were fibroadenoma ($n = 13$), phyllodes tumor ($n = 1$), benign papilloma ($n = 3$), inflammatory change ($n = 3$), and benign proliferation ($n = 8$). The pathologic diagnoses of the breast cancers were infiltrating ductal cancer not otherwise specified ($n = 49$), mucinous carcinoma ($n = 3$), medullary carcinoma ($n = 1$), infiltrating lobular cancer ($n = 3$), and ductal carcinoma in situ ($n = 2$). The mean size of the malignant masses was 2.5 cm (range, 0.6–8.0 cm); and that of the benign masses, 2.5 cm (range, 0.6–10.0 cm). The tumor stages and corresponding axillary lymph node statuses of the 58 breast cancers are listed in Table 1. The histopathologic correla-

TABLE 1
Tumor Stage and Corresponding Pathologic Lymph Node Status of 58 Primary Breast Cancers

Parameter	T1	T2	T3	Total
No. of cancers	25 (43)	30 (52)	3 (5)	58 (100)
Lymph node status*				
Metastasis	7 (28)	17 (57)	2 (67)	26 (45)
No metastasis	18 (72)	13 (43)	1 (33)	32 (55)

Note.—Stage 1 cancers were smaller than 2 cm; stage 2, 2–5 cm; and stage 3, larger than 5 cm. All numbers in parentheses are percentages.
* Data are numbers of cancers.

TABLE 2
Correlation of US Visualization of Axillary Nodes with Pathologic Lymph Node Status in 58 Patients with Histopathologically Proved Primary Breast Cancer

Finding	Axillary Node Status		
	Positive	Negative	Total
Axillary node seen at gray-scale US and characterized at CPD US	20	12	32
Axillary node seen at gray-scale US and not characterized at CPD US	4	4	8
Axillary node not seen at gray-scale US and not characterized at CPD US	3	15	18

Note.—CPD = color power Doppler.

tions between the axillary lymph nodes seen and those not seen at US are shown in Table 2.

In the primary breast lesions, the baseline vascularities of the malignant and benign masses were significantly different: The mean total vessel number in the malignant masses was 8.1 ± 7.8 (SD), and that in the benign masses was 3.5 ± 3.2 (P = .001). The mean peripheral vessel number in the malignant masses was 2.8 ± 2.5, and that in the benign masses was 1.0 ± 1.5 ($P < .001$). The mean total postcontrast vessel number also was significantly greater in the malignant breast lesions than in the benign lesions (15.9 ± 12.0 vs 8.0 ± 6.9; P = .001) (Table 3).

In addition, the breast cancers were found to have a significant global increase in all vessels, including the peripheral, central, and side-branching vessels, after contrast material administration (Fig 1). The benign lesions showed a vessel increase predominantly in the central and peripheral vessels after contrast enhancement, without a significant change in the number of side-branching vessels (Fig 2). The transit features of the malignant and benign breast masses were not significantly different. The mean times to peak enhancement were 24.0 seconds ± 7.6 and 23.9 seconds ± 8.0, respectively, and the mean durations of enhancement were 428.2 seconds ± 204.8 and 400.5 seconds ± 183.6, respectively (Table 4).

Axillary Lymph Nodes

Of the 32 axillary lymph nodes studied, 20 (62%) were malignant and 12 (38%) were benign at pathologic analysis. At baseline, a significant difference in vessel number between the malignant and benign nodes was noted: The mean total vessel numbers were 4.3 ± 3.9 and 3.3 ± 2.5 (P = .032), respectively, and the mean peripheral vessel numbers were 1.4 ± 1.3 and 0.4 ± 0.7 ($P < .001$), respectively (Table 3). Significant global enhancement involving the peripheral, central, and central perhilar vessels was seen in both the malignant and benign nodes after contrast material administration (Figs 3, 4a, 4b). However, the overall degree of enhancement was greater in the malignant nodes than in the benign nodes. The postcontrast vessel numbers in the malignant nodes were significantly greater than those in the benign nodes: The mean total vessel numbers were 15.6 ± 7.1 and 9.4 ± 5.7 (P = .032), respectively, and the mean peripheral vessel numbers were 4.8 ± 2.6 and 1.6 ± 1.7 ($P < .001$), respectively (Table 3). The mean times to peak enhancement for malignant and benign nodes were similar: 22.6 seconds ± 11.1 and 25.7 seconds ± 10.0 (P = .433), respectively. The malignant nodes enhanced for a greater duration than did the benign nodes: 378.9 seconds ± 175.7 and 203.7 seconds ± 108.1, respectively (P = .004) (Table 4).

Axillary Lymph Nodes versus Primary Breast Cancers

The vascular pattern of each axillary node was compared with that of the corresponding primary breast cancer in a subset of 32 patients. The malignant node enhanced more than did the corresponding primary breast cancer in the same patient, whereas the enhancement in the benign node was similar to that in the corresponding primary breast cancer (Table 5) (Fig 4). Differences in within-patient enhancement between the malignant and benign nodal groups tended to be significant (P = .053) (Table 5).

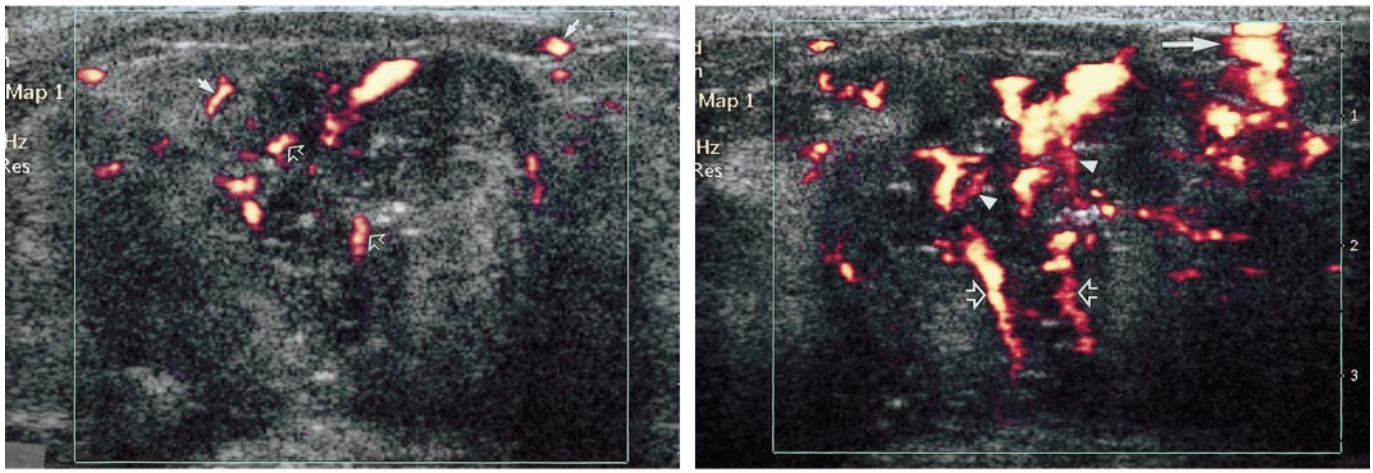
Logistic Regression Analysis

In the primary breast masses, only the postcontrast peripheral vessel number was a significant independent predictor of malignancy, according to logistic regression data (Table 6). Receiver operating characteristic analysis of the postcontrast peripheral vessel numbers in breast masses was performed. The area under the curve was 0.77 (Fig 5a). The cutoff value of four postcontrast peripheral vessels indicated a sensitivity of 67% (39 of 58) and a specificity of 79% (22 of 28).

For axillary lymph nodes, the significant independent predictors of lymph node malignancy at logistic regression analysis were increase in peripheral vessel number after contrast material administration and duration of enhancement (Table 6). A score that incorporated both these variables was derived at logistic regression analysis by using the stepwise procedure and was defined by the equation, score = −3.4252 + 0.0105 (duration of enhancement) + 0.5643 (increase in peripheral vessel number) (18). Receiver operating characteristic analysis of the combined score for the significant variables in the axillary nodes was performed as defined above. The area under the curve was 0.86 (Fig 5b). The cutoff score of 0.41 indicated a sensitivity of 80% (16 of 20 nodes) and a specificity of 92% (11 of 12 nodes).

DISCUSSION

The general consensus is that patients with breast cancer who have node-positive disease proved by performing either sentinel node biopsy or US-guided biopsy require level 2 axillary dissection as the standard of care (19). The main focus of



a. b.

Figure 1. **(a)** Precontrast radial color power Doppler US image of a primary breast cancer shows central (open arrows) and peripheral (solid arrows) vessels. **(b)** Postcontrast radial color power Doppler US image of the same lesion as in **a** shows an increase in central (open arrows), peripheral (solid arrow), and side-branching (arrowheads) vessels.

TABLE 3
Comparison of Vessel Number between Benign and Malignant Breast Masses and Axillary Lymph Nodes

Analyzed Vessels	Benign Masses or Nodes*		Malignant Masses or Nodes*		Baseline vs Postcontrast Vessel Numbers†‡	Vessel Numbers in Benign vs Malignant Masses or Nodes†	Vessel Number Increases in Benign vs Malignant Masses or Nodes†
	Baseline	Postcontrast	Baseline	Postcontrast			
Primary breast masses (n = 86)							
All vessels§	3.5 ± 3.2	8.0 ± 6.9	8.1 ± 7.8	15.9 ± 12.0	<.001	.001	.016
Peripheral vessels	1.0 ± 1.5	2.1 ± 2.4	2.8 ± 2.5	5.6 ± 4.2	<.001	<.001	.101
Central vessels	2.1 ± 2.6	4.5 ± 6.0	3.7 ± 4.6	7.1 ± 7.7	<.001	.078	.277
Side-branching vessels	0.4 ± 1.3	1.3 ± 4.1	1.6 ± 3.9	3.2 ± 5.4	.034	.048	.487
Axillary lymph nodes (n = 32)							
All vessels‖	3.3 ± 2.5	9.4 ± 5.7	4.3 ± 3.9	15.6 ± 7.1	<.001	.032	.022
Peripheral vessels	0.4 ± 0.7	1.6 ± 1.7	1.4 ± 1.3	4.8 ± 2.6	<.001	<.001	.013
Central vessels	1.0 ± 1.1	5.2 ± 5.3	1.9 ± 3.1	7.7 ± 5.0	<.001	.154	.362
Central perhilar vessels	1.8 ± 1.6	2.7 ± 1.9	1.0 ± 0.9	2.5 ± 2.8	.003	.389	.354

Note.—Breast cancers and malignant nodes had a greater total number of vessels and greater number of peripheral vessels than did benign masses and nodes, both at baseline and after contrast material administration.

* Data are mean numbers of vessels plus or minus SDs. Of the 86 primary breast masses, 28 were benign and 58 were malignant. Of the 32 axillary lymph nodes, 12 were benign and 20 were malignant.

† Data are *P* values.

‡ Within-patient comparison.

§ Sum of peripheral, central, and side-branching vessels.

‖ Sum of peripheral, central, and central perhilar vessels.

this study was to identify those patients with malignant axillary lymph nodes by performing US and to provide diagnostic criteria for detecting nodal malignancy. The described US determinants of nodal malignancy could serve as useful adjuncts to the accurate staging and planning of appropriate surgical and medical treatment of patients with breast cancer. Patients with node-positive breast cancer proved at US-guided biopsy may then be spared sentinel node biopsy and proceed directly to axillary dissection.

TABLE 4
Comparison of Contrast Material Transit Parameters between Benign and Malignant Breast Masses and Axillary Lymph Nodes

Parameter	Benign*	Malignant*	*P* value†
Primary breast masses (n = 86)			
Time to peak enhancement	23.9 ± 8.0	24.0 ± 7.6	.530
Duration of enhancement	400.5 ± 183.6	428.2 ± 204.8	.536
Axillary lymph nodes (n = 32)			
Time to peak enhancement	25.7 ± 10.0	22.6 ± 11.1	.433
Duration of enhancement	203.7 ± 108.1	378.9 ± 175.7	.004

* Data are mean times (in seconds) plus or minus SDs, as assessed in 28 benign and 58 malignant primary breast masses and in 12 benign and 20 malignant axillary lymph nodes.

† *P* values obtained by performing Student *t* test.

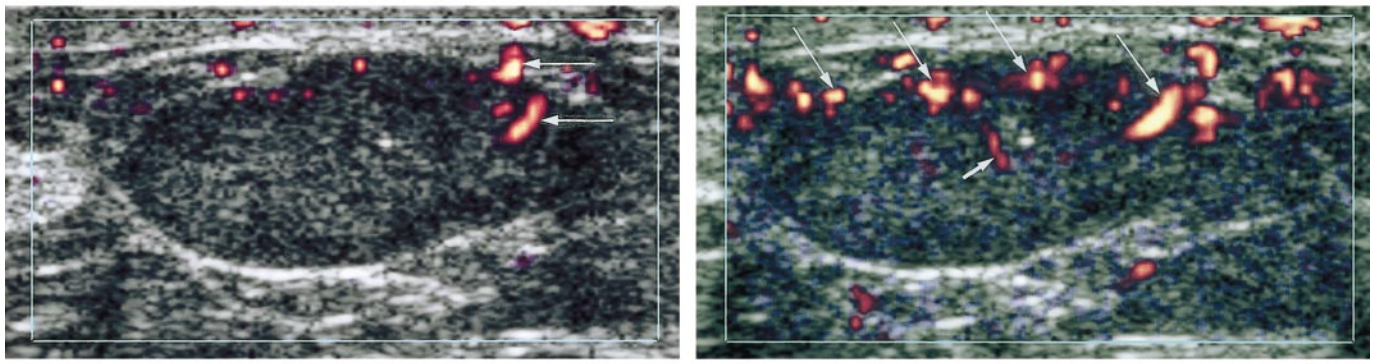


Figure 2. **(a)** Precontrast antiradial color power Doppler US image of a benign fibroadenoma shows sparse peripheral vessels (arrows). **(b)** Postcontrast antiradial color power Doppler US image of the same lesion as in **a** shows an increase in peripheral (long arrows) and central (short arrow) vessels.

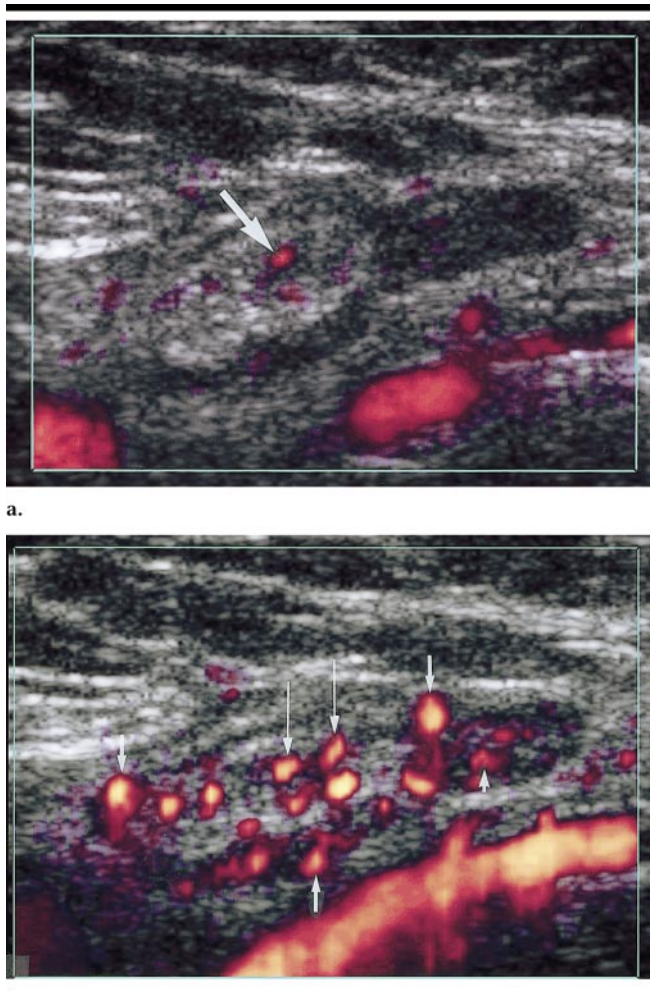


Figure 3. **(a)** Precontrast radial color power Doppler US image of a benign axillary node shows a single central perhilar vessel (arrow). **(b)** Postcontrast radial color power Doppler US image of the same lesion as in **a** shows an increase in central perhilar (long thin arrows), central (short arrow), and peripheral (long thick arrows) vessels.

Earlier investigations indicate that microbubble contrast materials improve the detection of the characteristic vascular morphologic features of primary breast lesions by enhancing the signal strength in small vessels (7). Microbubble Doppler US has been reported to be a reliable tool for distinguishing malignant from benign primary breast masses, with a sensitivity of 100% and an accuracy of 100% (7). Our study findings confirm earlier results (7) that malignant and benign breast lesions show a significant increase in the number of tumor vessels after contrast material administration. Malignant breast lesions enhanced significantly more than did benign lesions. A significant increase in the number of side-branching vessels was seen in primary breast cancers after contrast material administration. In addition, malignant breast masses had significantly more peripheral vessels at baseline and after contrast material administration than did benign breast masses. This finding was found to be an independent predictor of primary breast cancer at logistic regression analysis.

We extended the application of color power Doppler US to the study of axillary lymph nodes in patients with breast cancer. To our knowledge, this was the first attempt at demonstrating the reliability of color power Doppler US, with and without echo enhancement, in differentiating between malignant and benign nodal disease in patients with breast cancer. The diagnosis of every node imaged at color power Doppler US was confirmed at pathologic analysis after imaging in this study. The results show that the vascularity of malignant axillary nodes is different from that of benign nodes. Malignant nodes enhance more than benign nodes do after contrast material administration. In addition, there is a significantly higher peripheral vessel distribution in malignant nodes both at both

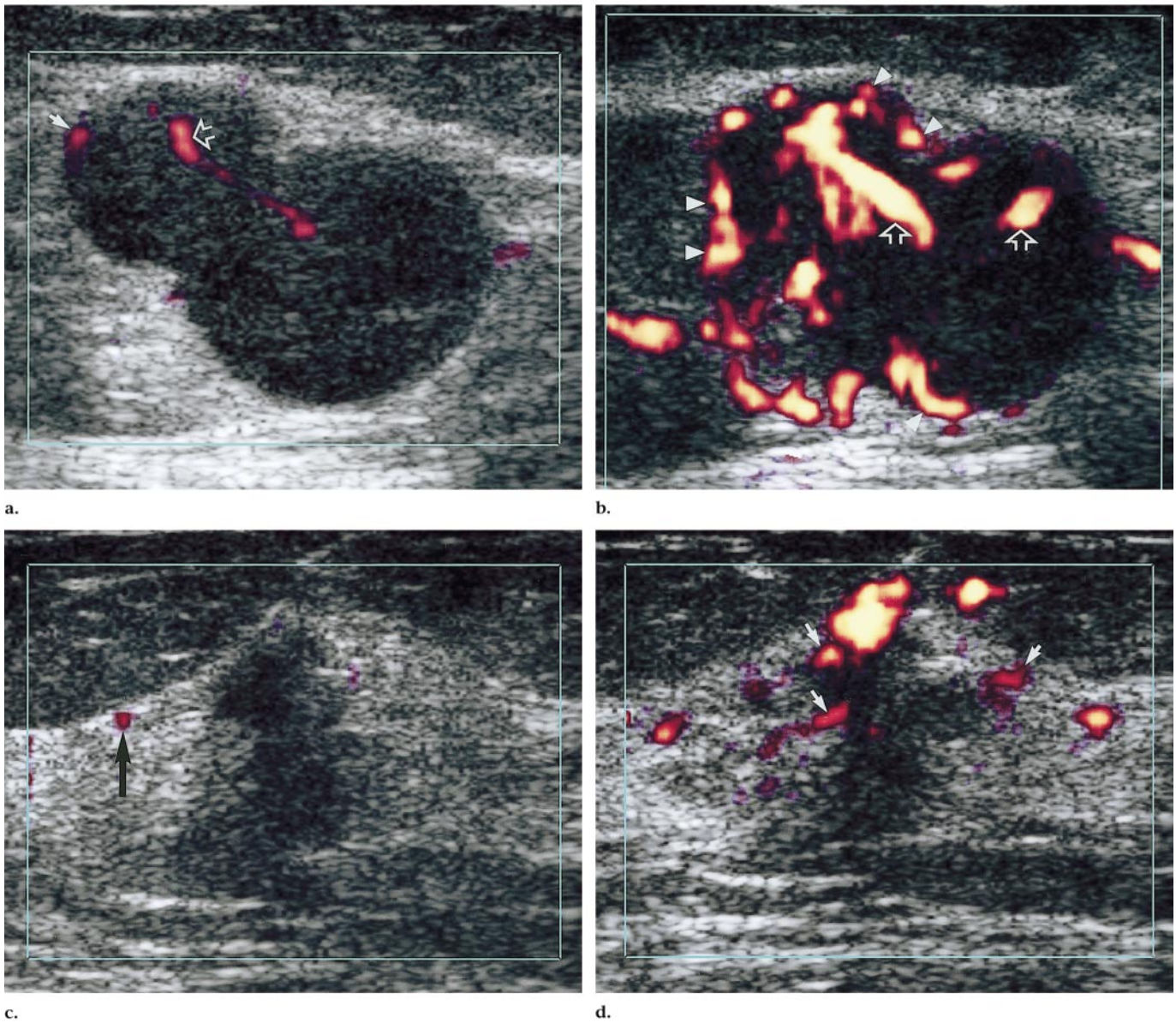


Figure 4. **(a)** Precontrast radial color power Doppler US image of a malignant axillary node shows central (open arrow) and peripheral (solid arrow) vessels. **(b)** Postcontrast radial color power Doppler US image of the same lesion as in **a** shows a florid increase in central (arrows) and peripheral (arrowheads) vessels. **(c)** Precontrast radial color power Doppler US of the corresponding breast cancer in the same patient as in **a** shows a solitary tiny vessel (arrow) outside of the lesion. **(d)** Postcontrast radial color power Doppler US image of the same lesion as in **c** shows a moderate increase in the number of peripheral vessels (arrows). This increase is markedly lower than the increase in peripheral vessel number in the axillary node seen in **b**.

baseline and after contrast material administration, as compared with benign nodes. This finding is similar to previous Doppler US reports (14,15) on cervical lymph nodes in head and neck cancers. Logistic regression analysis revealed increase in peripheral vessel number after contrast material administration and duration of enhancement to be independent predictors of nodal malignancy.

Results of histopathologic studies (20,21) in patients with breast cancer show a strong correlation between vessel number and presence of metastatic disease. The findings of previous Doppler studies on breast masses, as well as the results of the present study, show increased breast tumor vascularity to be a feature of primary breast malignancy (2). In this study, we further documented the differential change in enhancement between axillary nodes and the corresponding primary breast cancer, which is, to our knowledge, a finding not previously described. We report our preliminary observation that malignant nodes enhance significantly more than do the corresponding primary breast cancers, whereas benign nodes do not. This finding may reflect the separate vascular morphologic features and dynamics of nodal metastases, as compared with those of primary breast cancers. The reasons behind this observation may warrant further investigation of the biologic features and vascular architecture of axillary metastases.

The described findings confirm earlier reports (3) that color power Doppler US is

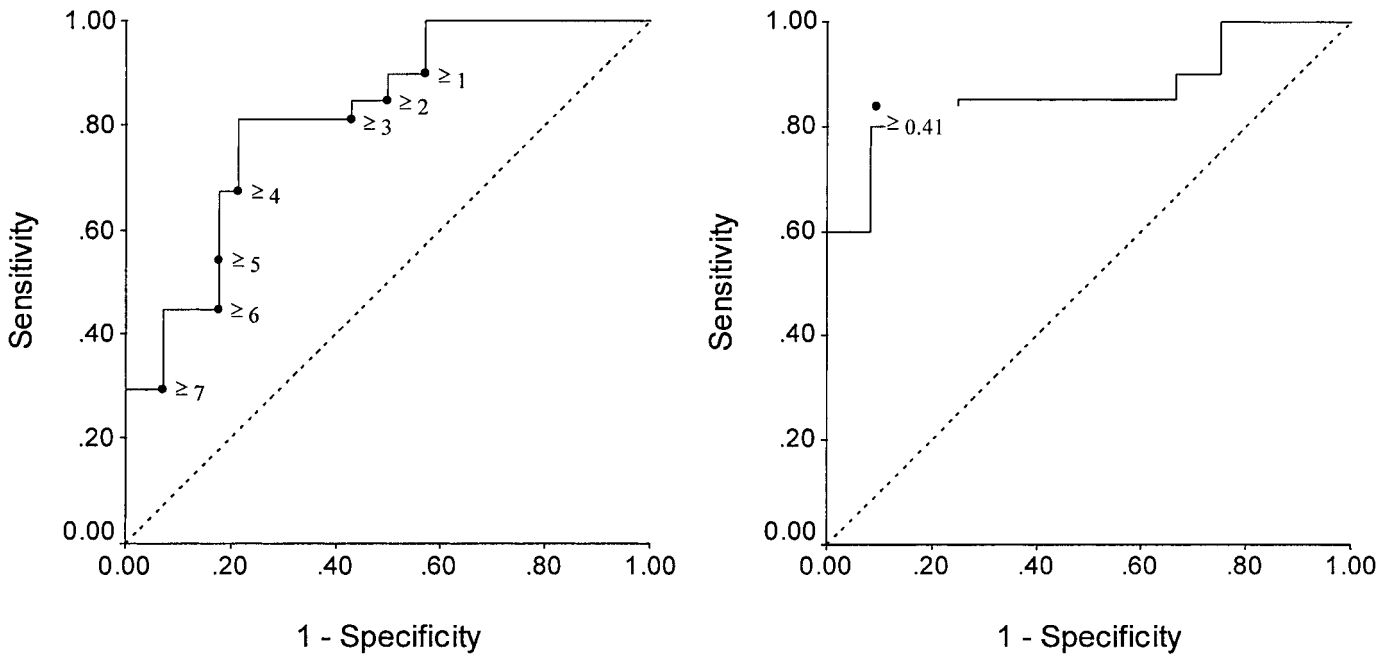


Figure 5. **(a)** Graph illustrates results of receiver operating characteristic analysis of the postcontrast peripheral vessel numbers in 86 breast masses, for classification of benign and malignant disease. The area under the curve is 0.77, and the optimal cutoff value is four postcontrast peripheral vessels. **(b)** Graph illustrates results of receiver operating characteristic analysis of the combined score for increase in peripheral vessel number and duration of enhancement in 32 axillary lymph nodes, for classification of benign and malignant disease. The area under the curve is 0.86, and the optimal score is 0.41.

TABLE 5
Comparison of Vessel Number Increase in Axillary Lymph Nodes and Corresponding Primary Breast Cancer within Patients

	Benign Nodes (n = 12)*			Malignant Nodes (n = 20)*			
Analyzed Vessels	Primary Breast Cancer	Axillary Lymph Nodes	Difference†	Primary Breast Cancer	Axillary Lymph Nodes	Difference†	P value‡
All§	7.8 ± 8.3	6.2 ± 4.9	−1.6 ± 10.1	7.3 ± 3.9	11.4 ± 6.4	4.1 ± 6.2	.053
Peripheral	0.6 ± 2.5	1.2 ± 1.3	0.6 ± 2.7	2.2 ± 2.0	3.4 ± 2.7	1.3 ± 2.7	.504
Central	5.3 ± 5.2	4.2 ± 5.3	−1.1 ± 6.1	4.9 ± 3.7	5.9 ± 4.8	1.0 ± 6.1	.354

Note.—Malignant lymph nodes showed a greater increase in vessel number than did the corresponding primary breast cancer. This was not observed with benign lymph nodes.

* Data are mean increases in vessel number (in number of vessels) plus or minus SDs.

† Increase in vessel number in axillary lymph node minus increase in vessel number in primary breast cancer in the same patient.

‡ For difference in vessel number increase between each axillary node and the corresponding primary breast cancer in the benign and malignant node groups.

§ For primary breast cancers, "all vessels" refers to the sum of peripheral, central, and side-branching vessels. For axillary lymph nodes, "all vessels" refers to the sum of peripheral, central, and central perhilar vessels.

TABLE 6
Logistic Regression Analysis of Significant Variables in Primary Breast Masses and Axillary Lymph Nodes

Factor	Odds Ratio	95% CI	P value
Postcontrast peripheral vessel number: primary breast masses (n = 86)	1.431	1.174, 1.744	.004
Axillary lymph nodes (n = 32)			
Increase in peripheral vessel number	1.758	1.056, 2.927	.030
Duration of enhancement	1.010	1.001, 1.020	.027

useful in distinguishing malignant from benign breast masses. More important, the application of this technique to axillary nodes may also have a role in distinguishing malignant from benign nodal disease in patients with breast cancer. The finding of greater differential enhancement of an axillary lymph node compared with that of the corresponding primary breast cancer in the same patient

may provide a clue to the diagnosis of regional axillary metastasis. Initial data suggest that this technique deserves further study for the evaluation of the pathologic status of axillary lymph nodes in breast cancer.

We acknowledge that the modest number of benign and malignant breast masses and axillary nodes limited our data. This study was further limited by the relatively large size of the breast lesions with likely positive nodes, so the effect of the technique on small, likely node-negative cancers could not be assessed. The results obtained need to be confirmed with prospective analysis in larger numbers of women. If the results are confirmed, the potential of contrast-enhanced color power Doppler US in the staging and treatment of small breast cancers can be further evaluated. This is especially pertinent, given the dramatic evolution of breast cancer management in recent decades. With diagnoses of earlier stage breast cancer increasing, there has been a paradigm shift away from radical surgery and full axillary dissection to breast conservation and sentinel node biopsy (22–28). The use of sentinel node biopsy for accurate tumor staging in patients with breast cancer is gradually gaining acceptance in clinical practice (8,29,30). The described US determinants of nodal malignancy could serve as useful adjuncts to sentinel node biopsy, because patients with node-positive breast cancer proved by performing US-guided biopsy might be able to proceed directly to axillary dissection.

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