Ultrasound in Med. & Biol., Vol. 32, No. 9, pp. 1299–1306, 2006

0301-5629/06/$–see front matter

ELSEVIER

doi:10.1016/j.ultrasmedbio.2006.05.018

● *Original Contribution*

SONOGRAPHIC FEATURES OF NONPALPABLE BREAST CANCER: A STUDY BASED ON ULTRASOUND-GUIDED WIRE-LOCALIZED SURGICAL BIOPSIES

See-Ying Chiou,*† Yi-Hong Chou,*† Hong-Jen Chiou,*† Hsin-Kai Wang,*† Chui-Mei Tiu,*† Ling-Ming Tseng,†‡ and Cheng-Yen Chang*†

*Department of Radiology, Taipei Veterans General Hospital, 201, Section 2, Taipei 112, Taiwan; †School of Medicine, National Yang-Ming University, 155, Section 2, Peitou Taipei 112, Taiwan; ‡Department of Surgery, Taipei Veterans General Hospital, 201, Section 2, Taipei 112, Taiwan

(*Received* 2 *October* 2005, *revised* 11 *May* 2006, *in final form* 19 *May* 2006)

Abstract—The purpose of this study is to investigate the correlation between surgicopathological findings and ultrasonic images of nonpalpable breast lesions. The study was composed of 220 nonpalpable breast lesions from 193 patients. The breast lesions were classified into soft tissue type (185 lesions) and calcification type (35 lesions). Of the 220 lesions, 62 (28%) were malignant. For soft tissue type lesions, the sonographic features of sound attenuation ($p < 0.001$) and irregular border ($p < 0.001$) were significantly associated with the malignant diagnosis. For soft tissue-type and calcification-type lesions, the presence of increased vascularity ($p < 0.001$) or calcification ($p < 0.001$) was significantly associated with the malignant diagnosis. Of the 164 breast lesions with corresponding mammograms, 37 of 74 mammographically identifiable lesions were pathologically malignant, as compared with 16 of 90 lesions with negative mammograms ($p < 0.001$). In our study, the more sensitive sonographic features for predicting malignancy were irregular border and increased vascularity (sensitivity 88% and 82%, respectively), whereas the features of sound attenuation and presence of calcifications were more specific (specificity 88% and 80%, respectively). In conclusion, ultrasound-guided wire localization of breast lesions is not only useful in assisting surgical biopsy, but the sonographic findings obtained by this procedure correlate with pathologic diagnosis. (E-mail: yhchou@vghtpe.gov.tw)

Key Words: **Breast cancer, Sonography, Ultrasound, Surgery.**

INTRODUCTION

Presurgical wire localization for nonpalpable breast lesions has been used since the 1980s. This localization procedure is generally done in conjunction with special techniques, such as ultrasound and stereotaxis, in the last few years (Homer et al. 1992; Meyer et al. 1984; Tiu et al. 1991). Recently, preliminary results have been obtained with wire localization guided by magnetic resonance imaging. Among these guidance procedures, ultrasound-guided wire localization is the most convenient and best-tolerated method. The recent advances in high-resolution ultrasound have improved the detection rate of nonpalpable breast malignancies by screening ultrasound (Buchberger et al. 2000; Gordon 2002). For such nonpalpable breast lesions with suspicious sonographic features, ultrasound-guided interventional procedures, including percutaneous fine needle aspiration cytology (FNAC), core needle biopsy, vacuum-assisted mammotomy and presurgical localization, play an important role in the approach of tissue diagnosis. Here, we report our experience using the ultrasound-guided wire method for localizing and biopsying nonpalpable breast lesions, and assess the correlation between sonographic features and pathologic results, as well as the sensitivity, specificity and positive and negative predictive values of these sonographic characters.

MATERIALS AND METHODS

From 2000 through 2003, 193 patients with 220 nonpalpable breast lesions were surgically biopsied. Preoperatively, an ultrasound-guided metallic wire was inserted percutaneously to localize the tissue for biopsy.

Address correspondence to: Yi-Hong Chou, Department of Radiology, Taipei Veterans General Hospital, 201, Section 2, Shih-Pai Road, Taipei 112, Taiwan. E-mail: yhchou@vghtpe.gov.tw

The ultrasound-guided procedure was performed within 3 h before the surgical procedure. The ultrasound equipments that we used included LOGIQ 700MR (GE Medical Systems, Milwaukee, WI, USA), Sequoia (Acuson-Siemens, Mountain View, CA, USA), Voluson 730 (GE Medical Systems, Milwaukee, WI, USA) and HDI 5000 (Advanced Technology Laboratories, Bothell, WA, USA). The ultrasound transducers had frequencies of 7 to 12 MHz. Both gray-scale and color Doppler images were used to evaluate the breast lesions. If the patients had mammograms taken within the last three months or if the lesion had calcified component, the mammography images were reviewed to check whether the breast lesions could be demonstrated on mammogram and to evaluate the pattern of calcifications. The sonographic images were available for the reviewer to make comparison and correlation between mammograms and sonograms for complete preoperative film interpretation.

The breast lesions were divided into two types: the soft-tissue type (type 1) and the calcification type (type 2). Type 1 lesions appeared chiefly as focal, space-occupying masses (Fig. 1a) and type 2 lesions appeared as calcifications or microcalcifications in the breast parenchyma (Fig. 1b) rather than as focal soft-tissue masses.

The ultrasonographic characteristics of the breast lesions were evaluated and recorded, including the type, echopattern, lesion shape, sound transmission of the lesions, vascularity on Doppler imaging and the presence of calcifications or ductal dilation surrounding or adjacent to the lesions.

Free-hand ultrasound guidance was performed under local anesthesia in the ultrasound examination room. The needle carrying the hook wire was inserted percutaneously, penetrating the lesion and finally passing through the lesion with the needle tip about 1.5-cm beyond the far margin of the lesion (Fig. 2). The needle cannula was then removed with the wire kept in place. The wire used for presurgical localization had a hooked tip that could be fixed in the breast tissue. For all type-2 lesions and some type-1 lesions with calcifications, post-localization mammogram was performed to confirm the position of the wire. Specimen mammogram was also taken for type-2 lesions to make sure that the calcifications had been removed.

The histopathological results and the preoperative sonographic features of the breast lesions were analyzed. The evaluation of sonographic features was performed in a blinded fashion, with the investigator not knowing the histopathological results.

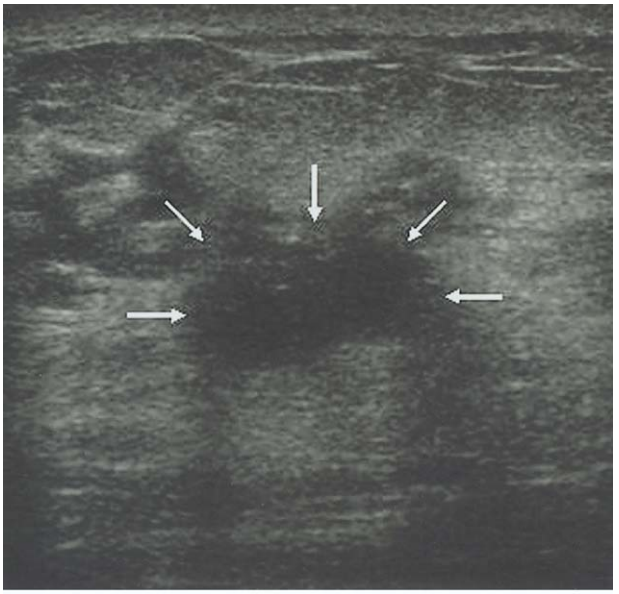


Fig. 1. (a) Example of type-1 lesion (soft-tissue type), presenting as a hypoechoic soft-tissue mass in the breast parenchyma (arrows). (b) Example of type-2 lesion (calcification type) with multiple tiny echogenic spots in the breast parenchyma without evident soft-tissue component. The tiny echogenic spots (arrows) represent microcalcifications.

RESULTS

Our study enrolled 193 female patients aged 18- to 85-y-old, with a mean of 49.9 y. The mean age of the benign cases was 48.4 y and that of the malignant cases was 53.5 y. Each patient had one to four breast lesions and there was a total of 220 lesions. All the lesions were clinically nonpalpable. Of the 220 lesions, 185 (84%) were of type-1 and 35 (16%) were of type-2.

The histopathological studies of the 220 representative specimens revealed 158 benign lesions (72%), including epithelial hyperplasias, fibroadenomas, non-proliferative benign disease, intraductal papillomas, stromal fibrosis lesions, sclerosing adenosis, lipomas and other borderline benign lesions, such as papillomatosis lesions and atypical ductal hyperplasias. Sixty-two lesions (28%) were malignant, including 31 infiltrating

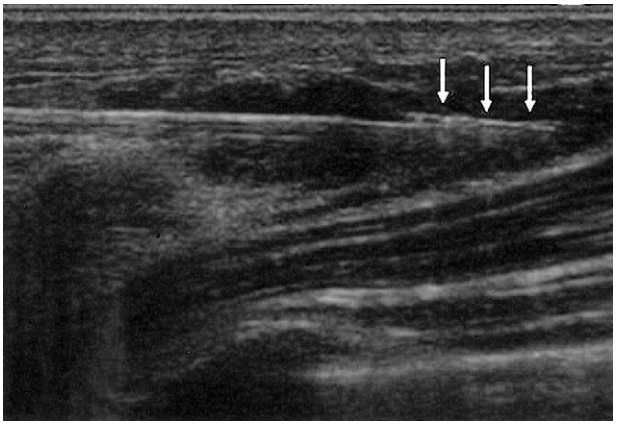


Fig. 2. After wire deployment, the hooked tip of the wire can be identified (arrows), which helps to make a fixation of the wire in the breast parenchyma.

ductal carcinomas (50%), four infiltrating lobular carcinomas (7%), 10 ductal carcinomas *in situ* (DCIS) with microinvasion (16%) and 17 DCIS without microinvasion (27%). There was no statistical difference in the malignancy rate between the type-1 and the type-2 groups ($p = 0.381$) (Table 1).

The sonographic characteristics of the 185 type-1 lesions were evaluated. The echo pattern of the lesion was based on the difference in the echogenicities of the lesion and subcutaneous fatty tissue. Lesions with similar echogenicity to the subcutaneous fatty tissue echogenicity (*i.e.*, isoechoic lesions) were identified in eight of the 185 lesions (4%). Lesions with less than (*i.e.*, hypoechoic) and more than (*i.e.*, hyperechoic) subcutaneous fatty tissue echogenicity were identified in 170 and one, respectively, of the 185 lesions (92% and 1%). Six lesions had mixed echogenicity (3%). The echo patterns of type-1 lesions and their pathologic findings are listed in Table 2.

The sound transmission pattern (Fig. 3), border characters (Fig. 4) and presence of regional ductal dilation (Fig. 5) in type-1 lesions were also evaluated. The pathologic findings of type-1 lesions and sonographic characteristics of these lesions are listed in Table 3.

Of the 220 lesions, all the type-2 lesions and some type-1 (soft tissue) lesions had calcifications (Fig. 6).

Table 1. Type-1 and type-2 lesions and their pathologic results

	Final histopathological results		
Ultrasound types	Benign	Malignant	*n* (%)
Type-1 (Soft-tissue type)	135	50	185 (84%)
Type-2 (Calcification type)	23	12	35 (16%)
Total, *n* (%)	158 (72%)	62 (28%)	220 (100%)

Table 2. Echopatterns of the 185 type-1 lesions and their pathologic results

Echopatterns	Benign	Malignant	*n*
Hypoechoic	123	47	170
Isoechoic	8	0	8
Hyperechoic	1	0	1
Mixed echogenicity	3	3	6
Total	135	50	185

Doppler imaging showed the vascularity in all 220 lesions. The presence of increased color flow signals in the lesion or in the pathologic area was considered to indicate hypervascularity (Fig. 7). The pathologic findings relating to lesions with calcification or vascularity are listed in Table 4.

For lesions with sound attenuation and lesions with irregular border, sonographic characteristics were significantly associated with malignant phenotype ($p < 0.001$). Calcification and hypervascularity were also significant predictors of malignant phenotype ($p < 0.001$). However, regional ductal dilation was not a significant predictor of malignancy ($p = 0.469$). The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) data of those sonographic characters are listed in Table 5.

Recent mammograms (within three months) were available for 164 of the 220 lesions. Only 74 of the 164 lesions (45%) could be identified on the mammograms (Fig. 8) and 37 of the 74 lesions were malignant. Among the other 90 lesions not visible on mammograms, 16 were malignant. Of the 164 lesions, 132 were type-1, including 42 malignant lesions, 26 of which were visible and 16 invisible on mammograms (Table 6). These results suggested that lesions (either type-1 or any lesion) visible on mammograms tend to be malignant ($p < 0.001$).

DISCUSSION

Ultrasound is most often used to assess palpable and nonpalpable masses detected by screening mammography (Bassett and Limme-Smith 1991; Buchberger et al. 2000; Durfee et al. 2000; Gordon 2002; Jackson et al. 1993). The recent progress in imaging technology has greatly increased the detection rate of small or nonpalpable breast lesions. Imaging-guided procedures play an important role in the diagnosis of nonpalpable breast lesions. The procedures include FNAC, core needle biopsy, minimally invasive vacuum–assisted biopsy and wire-localized surgical biopsy. When open biopsy is necessary for nonpalpable breast lesions, presurgical wire localization has been the preferred procedure, either under ultrasound or stereotactic guidance.

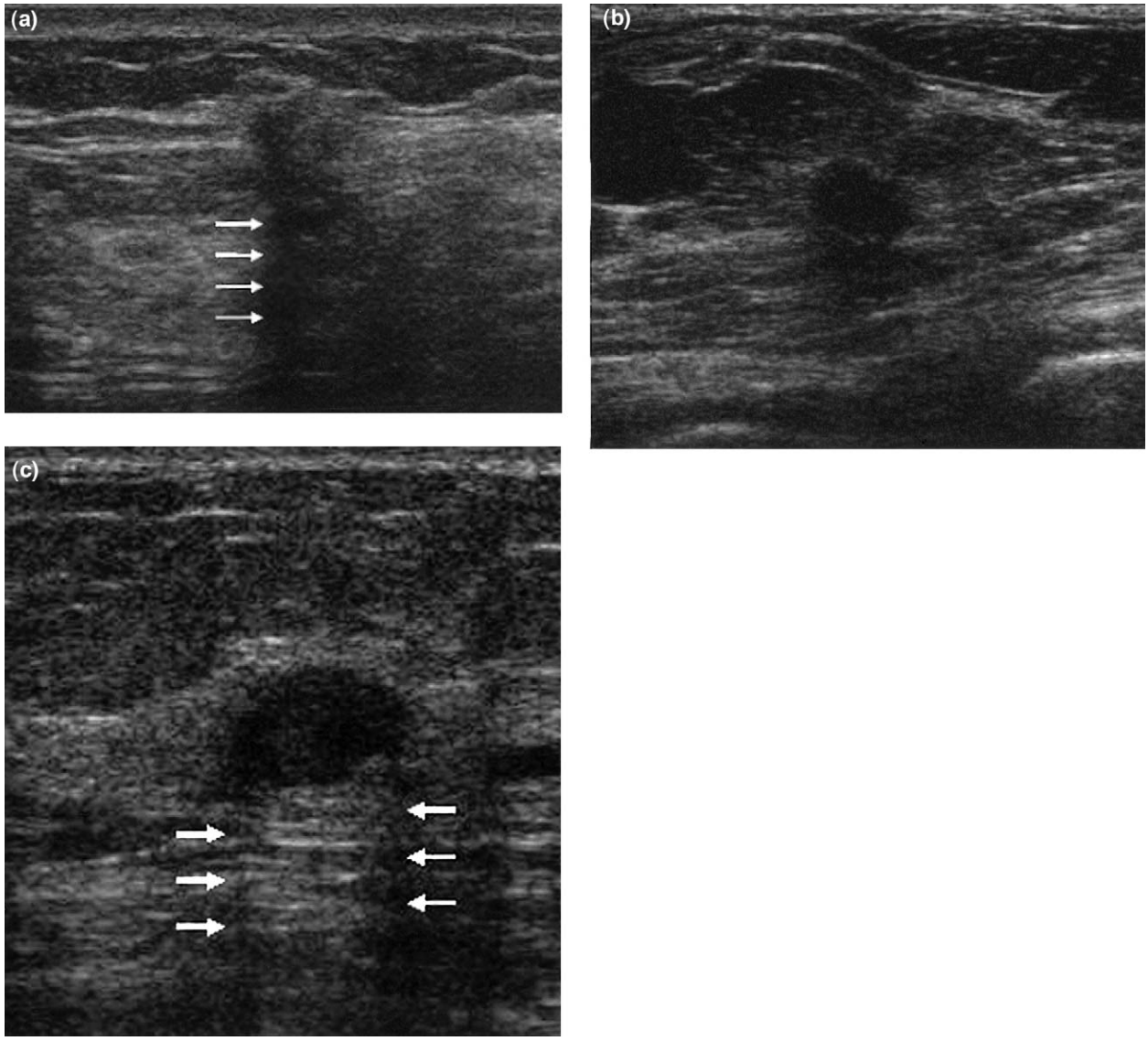


Fig. 3. Examples of lesions with different sound transmission. (a) Lesion with distal sound attenuation (arrows), infiltrating ductal carcinoma. (b) Lesion shows no significant alternation of sound transmission behind it, fibroadenoma. (c) Lesion with distal sound enhancement (arrows), epithelial hyperplasia.

Although mammography is the only widely accepted imaging modality used for screening early or occult breast cancers, with the recent advances in ultrasound technology, some studies have shown the potential of high-resolution sonography in the detection of nonpalpable breast cancers with improved detection rate, especially in dense breasts (Buchberger et al. 2000; Gordon and Goldenberg 1995; Parker et al. 1993; Weinstein et al. 1995). One of the most common uses of ultrasound (primarily gray-scale imaging but also Doppler ultrasound) is to help distinguish benign from malignant breast disease. Another common use is to provide guidance for interventional procedures (Mehta 2003). As many as 50% of nonpalpable breast lesions are visible on ultrasound (Potterton et al. 1994) and sometimes calcifications or microcalcifications can be depicted by using ultrasound (Huang et al. 1999).

Recently, detection of mammographically isolated microcalcifications has been improved by high-resolution sonography. Microcalcifications were more often detected by ultrasound if they were located in the territory of a hypoechoic mass (Gufler et al. 2000; Ranieri et al. 1997; Stavros et al. 1995). However, in our study, when the background of the breast lesion with calcifications or microcalcifications was hypoechoic (indicating soft tissue) or of mixed echo texture, the lesion was classified as type 1 with calcifications, rather than as type 2.

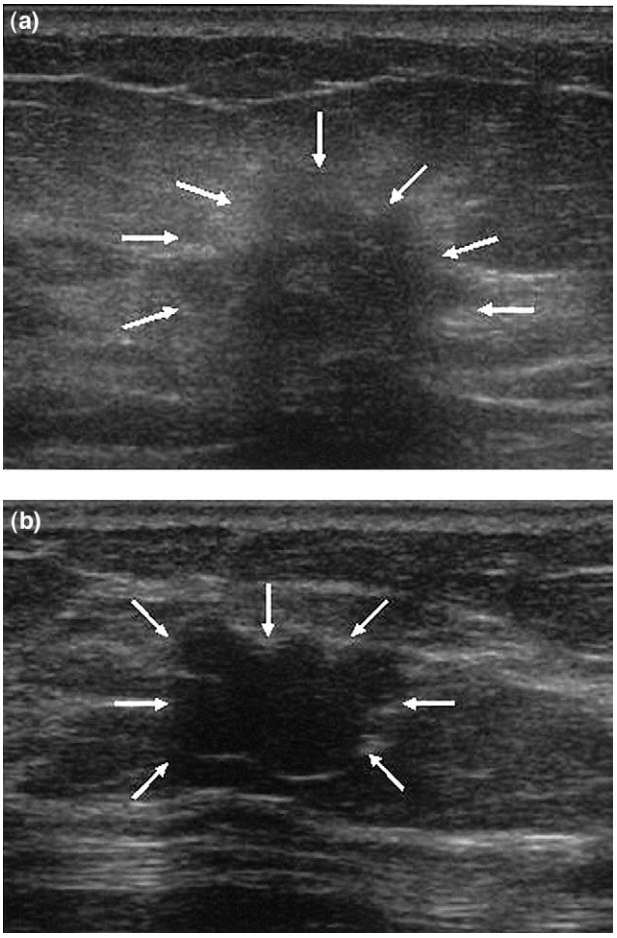


Fig. 4. Borders of a lesion. (a) Lesion with irregular and ill-demarcated border (arrows), infiltrating lobular carcinoma. (b) Lesion with smooth and well-defined border (arrows), fibroadenoma.

Many reports have described the sonographic features of malignant and benign breast lesions and the distinctions between them (Buchberger et al. 2000; Rahbar et al. 1999; Skaane et al. 1998; Stavros et al. 1995; Zonderland et al. 1999; Zonderland et al. 2000). Ultrasonographic characteristics of malignancy include spiculation, microlobulation, angular margin, taller-than-wide shape, acoustic shadowing, branch pattern, duct extension, marked hypoechogenicity, thick echogenic rim (or echogenic halo) and distortion of the surrounding tissue. In our study, we found that sound attenuation behind the lesions and irregular shape of the lesions are significantly associated with diagnosis of malignancy. These findings are compatible with those of previous reports. However, in our study, the presence of regional ductal dilation was not a significant predictor of malignancy. In the 17 patients with regional ductal dilation, intraductal papilloma occurred in 11, fibrocystic change in one, DCIS without microinvasion in three, DCIS with microinvasion in one and infiltrating ductal carcinoma in one. Over half of the lesions with regional ductal dilation turned out to be intraductal papillomas, which were often associated with the clinical symptom of nipple discharge, an indication for excisional biopsy.

The echo patterns of most breast lesions (92%) were mainly hypoechoic. On the other hand, the echo patterns of most (36 of the 38) malignant lesions were hypoechoic. The other two malignant lesions had mixed echogenicity. None of the isoechoic or hyperechoic lesions was malignant. The above findings are consistent with our knowledge of breast cancers.

Sickles (1982) reported that 35% to 45% of nonpalpable breast cancers detected at screening present as clusters of microcalcifications on mammography, and some series also mentioned the higher incidence of invasive cancer if microcalcifications are seen associated with a mass on ultrasound (Ranieri et al. 1997; Stavros et al. 1995). In our study, calcifications or microcalcifications without or with associated soft-tissue mass were significant predictors of malignancy. Of the 12 cases of malignant (type-2) lesions, eight were DCIS and, of the 50 cases of malignant (type-1) lesions, 18 were DCIS. Although the tendency to be DCIS seems to be higher in type-2 than in type 1-lesions, the difference was not significant.

The vascularity of breast lesions is another important issue. Many studies have shown that the number of detectable vessels is significantly higher in malignant than in benign lesions (Adler et al. 1990; Kedar et al. 1996; Madjar et al. 1997; McNicholas et al. 1993). Others have reported that spectral Doppler imaging re-

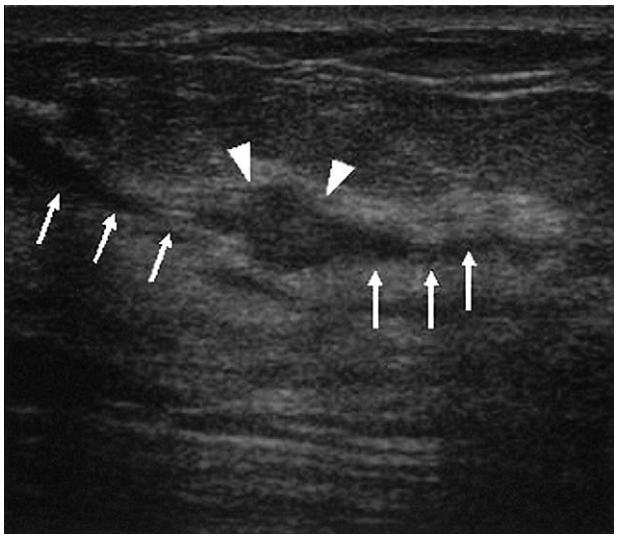


Fig. 5. A hypoechoic nodular lesion (arrowheads) located in a dilated duct (arrows). The pathologic result was ductal carcinoma *in situ*.

Table 3. Pathologic results of 134 type 1 lesions with different sonograhpic characters and the *p* value according to Pearson chi-square test

	Sonographic characters	Benign	Malignant	Total	*p* value
Sound transmission	Sound attenuation	16	17	33	
	Unchanged sound transmission	98	28	126	
	Distal enhancement	21	5	26	
Sound attenuation	Presence	16	17	33	<0.001
	Absence	119	33	152	
Border	Smooth, well-defined	65	6	71	<0.001
	Irregular, ill-demarcated	70	44	114	
Regional ductal dilatation	Presence	22	6	28	0.469
	Absence	113	44	157	

vealed that the high resistance index (RI) of intralesional arterial vessels is a malignancy indicator (Hollerweger et al. 1997; Peters-Engl et al. 1995) and that the vasculature of malignant tumors is more likely to have a penetrating vascular pattern (Kook et al. 1999; Raza and Baum 1997; Rizzatto et al. 1997). In our study, the vascular pattern and RI were not determined, but the presence of increased color flow signals in the lesion or in the pathologic area were found significantly to associate with diagnosis of malignancy, which is compatible with the previous report.

The correlation of sonographic and mammographic findings has been another interesting issue. Ultrasound does find some palpable or nonpalpable breast cancers that cannot be found by mammography (Buchberger et al. 1999; Buchberger et al. 2000; Durfee et al. 2000; Gordon and Goldenberg 1995; Kolb et al. 1998; Weinstein et al. 1995). In our study, of the 164 lesions for which mammograms were available, 37 of 53 malignant lesions could be identified on the mammogram, which means that about 30% (16 of 53) of nonpalpable breast cancers were only visible on ultrasound. Our result is a little bit higher than that of the previous study of Buchberger et al. (2000), who found the proportion of sonographically detected cancers to the total number of nonpalpable cancers was 22%. Kolb et al. (1998) reported that ultrasound had increased the number of breast cancers detected solely with imaging from 30 to 41 tumors in a group of 3626 women. In their study, about 27% (11 of the 41) nonpalpable breast cancers were only visible by ultrasound, which is similar to our result (30%).

The results of our study suggest that type-1 or type-2 lesions identified on mammograms had a statistically significant tendency to be malignant. However, for type-2 lesions, the evaluation of calcifications or microcalcifications should be based on mammographic findings. Mammographic identification of type-1 lesions was also a significant predictor of malignancy, regardless of other sonographic features.

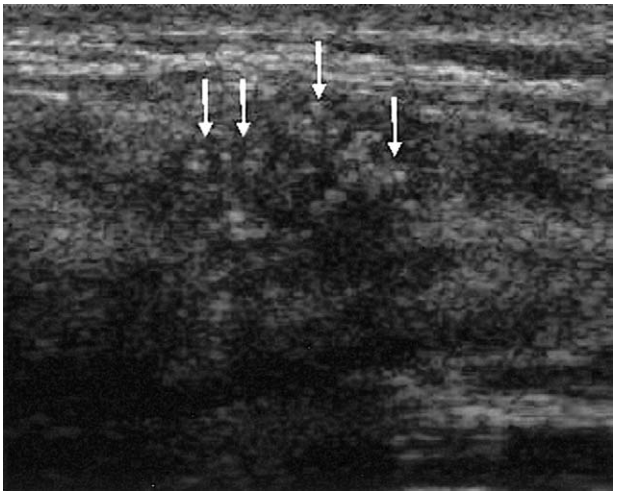


Fig. 6. A lesion with multiple microcalcifications, presenting as multiple tiny echogenic spots (arrows), which was ductal carcinoma *in situ* with microinvasion.

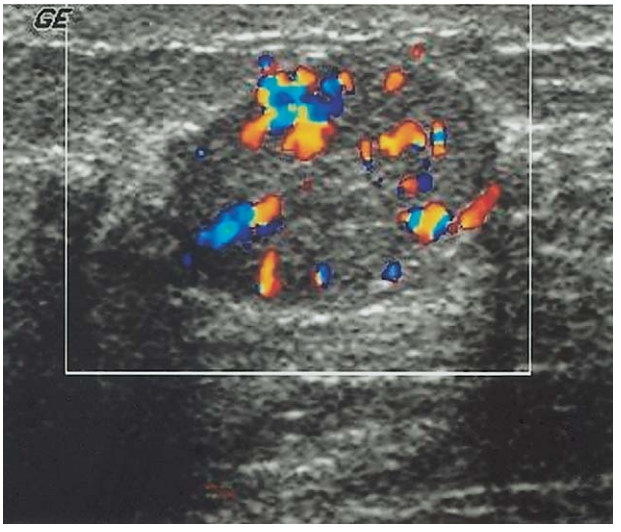


Fig. 7. An isoechoic nodular lesion with smooth border, distal enhancement and prominent intralesional color flow signals at color Doppler study, which was an introductal papilloma.

Table 4. Pathologic results of the 168 lesions with vascularity or calcification and the *p* value according to Pearson chi-square test.

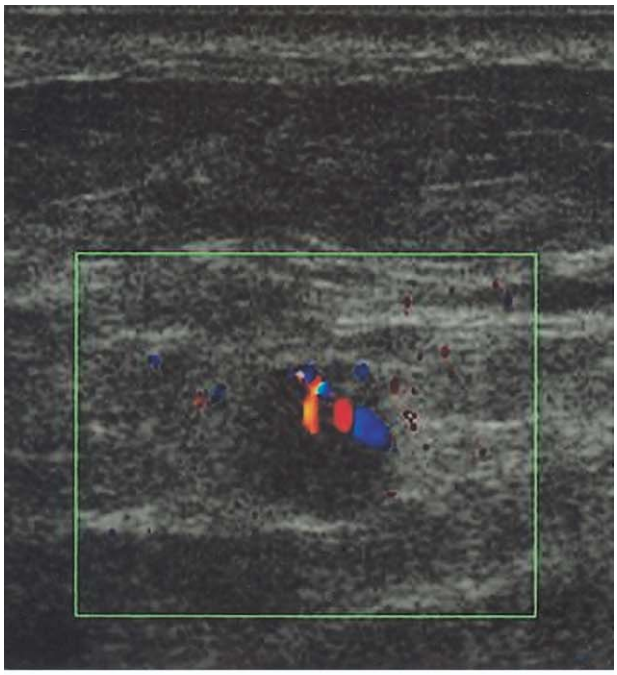
		Benign	Malignant	Total	*p* value
Vascularity	Presence	67	51	118	<0.001
	Absence	91	11	102	
Calcification	Presence	32	31	63	<0.001
	Absence	126	31	157	

Most previous reports have suggested the use of ultrasound as an adjunct to screening mammography. With the recent advances in ultrasound technology and the development of the high-frequency transducer, more nonpalpable or small breast lesions can now be detected by ultrasound. Ultrasound also provides a more comfortable and convenient way to provide guidance in interventional breast procedures. Ultrasound-guided FNAC and large-core needle biopsy have achieved some clinical benefit and improved the preoperative diagnosis of breast cancer (Liberman 2002; Rubin et al. 2001). Nevertheless, surgeons sometimes prefer excisional biopsy. Ultrasound is excellent for guidance of preoperative or intraoperative localization of breast lesions. Percutaneous needle or wire localization has been used since the 1980s (Homer et al. 1992; Meyer et al. 1984; Tiu et al. 1991). If a breast lesion could be demonstrated by both ultrasound and mammography, ultrasound usually provided the shorter route to approach the lesion. That is why we used to do presurgical localization under radiographical guidance for type-2 lesions. However, for the type-2 lesions, it is necessary to review the preprocedural and postprocedural mammogram, as well as the specimen mammogram, to assure adequate removal of microcalcifications.

In conclusion, in our study of 220 nonpalpable breast lesions surgically removed with the aid of presurgical ultrasound-guided wire localization, the malignancy rate was 28%. The ultrasonographic features that were significantly associated with malignancy include sound attenuation behind the lesions, irregular margin of

Table 5. The sensitivity, specificity, positive predictive value (PPV) and negative predictive value (NPV) of the sonographic characters

	Sensitivity	Specificity	PPV	NPV
Sound attenuation	34%	88%	52%	78%
Irregular or ill-demarcated border	88%	48%	39%	92%
Regional ductal dilatation	12%	84%	21%	72%
Vascularity	82%	58%	43%	89%
Calcification	50%	80%	49%	80%



(a)

(b)

Fig. 8. Example of a type-1 lesion visible on both sonogram and mammogram. (a) Ultrasound demonstrated a hypervascular hypoechoic nodular lesion, (b) Which appears as a nodular soft-tissue density on mammography (arrows). The pathologic result was a ductal carcinoma *in situ*.

Table 6. The proportion of benign and malignant results for the 164 lesions with mammogram available with consideration of different types of lesions

	Ultrasound types	Benign	Malignant	Total
Not visible on mammogram	Type 1	74	16	90
	Type 2	0	0	0
	Type 1 + 2	74	16	90
Visible on mammogram	Type 1	16	26	42
	Type 2	21	11	32
	Type 1 + 2	37	37	74

the lesions, presence of color flow signals and presence of calcifications in the lesions. Ultrasound-guided wire localization of breast lesions is not only useful in assisting surgical biopsy but also can reveal sonographic features that correlate with pathologic diagnosis. Simultaneous evaluation by both mammography and sonography may better predict diagnosis.

REFERENCES

Adler DD, Carson PL, Rubin JM, et al. Doppler ultrasound color flow imaging in the study of breast cancer: preliminary findings. Ultrasound Med Biol 1990;16:553–556.

Bassett LW, Limme-Smith C. Breast sonography. AJR Am J Roentgenol 1991;156:449–455.

Buchberger W, Dekoekkoek-Doll P, Springer P, et al. Incidental findings on sonography of the breast: clinical significance and diagnostic workup. AJR Am J Roentgenol 1999;173:921–927.

Buchberger W, Niehoff A, Obrist P, et al. Clinically and mammographically occult breast lesions: detection and classification with high-resolution sonography. Seminar in Ultrasound, CT, and MRI 2000;21:325–336.

Durfee SM, Selland DLG, Smith DN, et al. Sonographic evaluation of clinically palpable breast cancers invisible on mammography. The Breast J 2000;6:247–251.

Gordon PB, Goldenberg SL. Malignant breast masses detected only by ultrasound. Cancer 1995;76:626–630.

Gordon PB. Ultrasound for breast cancer screening and staging. Radiol Clin N Am 2002;40:431–441.

Gufler H, Buitrago-Tellez CH, Madjar H, et al. Ultrasound demonstration of mammographically detected microcalcifications. Acta Radiol 2000;41:217–221.

Hollerweger A, Rettenbacher T, Macheiner P, et al. New signs of breast cancer: high resistance flow and variations in resistive indices evaluation by color Doppler sonography. Ultrasound Med Biol 1997;23:851–856.

Homer MJ, Smith TJ, Safaii H. Prebiopsy needle localization: methods, problems, and expected results. Radiol Clin N Am 1992;30:139–153.

Huang CS, Wu CY, Chu JS, et al. Microcalcifications of non-palpable breast lesions detected by ultrasonography: correlation with mammography and histopathology. Ultrasound Obstet Gynecol 1999; 13:431–436.

Jackson VP, Hendrick RE, Feig SA, et al. Imaging of the radiographically dense breast. Radiology 1993;188:297–301.

Kedar RP, Cosgrove D, McCready VR, et al. Microbubble contrast agent for color Doppler US: effect on breast masses. Work in progress. Radiology 1996;198:679–686.

Kolb TM, Lichy J, Newhouse JH. Occult cancer in women with dense breasts: detection with screening US – diagnostic yield and tumor characteristics. Radiology 1998;207:191–199.

Kook S, Park H, Lee Y, et al. Evaluation of solid breast lesions with power Doppler sonography. J Clin Ultrasound 1999;27:231–237.

Liberman L. Percutaneous image-guided core breast biopsy. Radiol Clin N Am 2002;40:483–500.

Madjar H, Sauerbrei W, Prompeler HJ, et al. Color Doppler and duplex flow analysis for classification of breast lesions. Gynecol Oncol 1997;64:392–403.

McNicholas MMJ, Mercer PM, Miller JC, et al. Color Doppler sonography in the evaluation of palpable breast mass. AJR Am J Roentgenol 1993;161:765–771.

Mehta TS. Current uses of ultrasound in the evaluation of the breast. Radiol Clin N Am 2003;41:841–856.

Meyer JE, Kopans DB, Stomper PC, et al. Occult breast abnormalities: percutaneous preoperative needle localization. Radiology 1984; 150:335–337.

Parker SH, Jobe WE, Dennis MA, et al. US-guided automated large core breast biopsy. Radiology 1993;187:507–511.

Peters-Engl C, Medl M, Leodolter S. The use of colour-coded and spectral Doppler ultrasound in the differentiation of benign and malignant breast lesions. Br J Cancer 1995;71:137–139.

Potterton AJ, Peakman DJ, Young JR. Ultrasound demonstration of small breast cancers detected by mammographic screening. Clin Radiol 1994;47:337–338.

Rahbar G, Sie AC, Hansen GC, et al. Benign versus malignant solid breast masses: US differentiation. Radiology 1999;213:889–894.

Ranieri E, E'Andrea MR, D'Alessio A, et al. Ultrasound in the detection of breast cancer associated with isolated clustered microcalcifications, mammographically identified. Anticancer Res 1997;17: 2831–2836.

Raza S, Baum JK. Solid breast lesions: evaluation with power Doppler US. Radiology 1997;203:164–168.

Rizzatto G, Chersevani R, Abbona M, et al. High-resolution sonography of breast carcinoma. Eur J Radiol 1997;24:11–19.

Rubin E, Mennemeyer ST, Desmond RA, et al. Reducing the cost of diagnosis of breast carcinoma: impact of ultrasound and imaging-guided biopsies on a clinical breast practice. Cancer 2001;91:324–332.

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

Skaane P, Engedal K. Analysis of sonographic features in the differentiation of fibroadenoma and invasive ductal carcinoma. AJR Am J Roentgenol 1998;170:109–114.

Stavros AT, Thickman D, Rapp CL, et al. Solid breast nodules: use of sonography to distinguish between benign and malignant lesions. Radiology 1995;196:123–134.

Tiu CM, Chou YH, Chen CM, et al. Preoperative ultrasound- guided wire-localization of nonpalpable solid breast lesions. Chin J Radiol 1991;16:321–325.

Weinstein BJ, Phillips G, Kumari-Subaiya S, et al. Ultrasound detection of non-palpable non-mammographically visible breast cancer [abstract]. J Ultrasound Med 1995;15 (Suppl):117.

Zonderland HM, Coerkamp EG, van de Vijver MJ, et al. Diagnosis of breast cancer: contribution of US as an adjunct to mammograhpy. Radiology 1999;213:413–422.

Zonderland HM, Hermans J, Coerkamp EG. Ultrasound variables and their prognostic value in a population of 1103 patients with 272 breast cancers. Eur Radiol 2000;10:1562–1568.