Surgery Today
Jpn J Surg (1993) 23:704–710

SURGERY TODAY

A Comparison Between Ultrasonography and Mammography, Computed Tomography and Digital Subtraction Angiography for the Detection of Breast Cancers

NORIYUKI TOHNOSU, KAZUAKI OKUYAMA, YOSHIO KOIDE, TOSHIYUKI KIKUCHI, TOMOTAKA AWANO, HIROMASA MATSUBARA, TOMOAKI SANO, HITOSHI NAKAICHI, YUTAKA FUNAMI, KAZUYUKI MATSUSHITA, and KAICHI ISONO

The Second Department of Surgery, School of Medicine, Chiba University, 1-8-1 Inohana, Chuo-ku, Chiba, 260 Japan

Abstract: Ultrasound (US) was compared with mammography (MMG), computed tomography (CT), and digital subtraction angiography (DSA) in its effectiveness to detect breast cancer masses and metastatic axillary nodes. Forty-seven breast cancer patients who all underwent MMG, US, CT, and DSA preoperatively in our institution between 1986 and 1990 were studied. US was able to detect tumors in all cases regardless of tumor size, whereas DSA detected T1-size tumors and MMG detected T2-size tumors in 40% and 64.7% of cases, respectively, being specifically inferior to US. It was found that MMG was least likely to detect papillotubular carcinoma, although microcalcification alone without a tumor mass on MMG improved detectability from 46.2% to 76.9%, according to the histological type. CT was found to be most sensitive to axillary node metastases (81.8%), followed by US (72.7%), but DSA was significantly unfavorable (42.9%). Thus, we concluded that US was superior to MMG, CT, and DSA for detecting breast cancer masses, but that CT was more advantageous than US, while DSA was of little value for evaluating axillary nodal status.

Key Words: ultrasound, mammography, computed tomography, digital subtraction angiography, breast cancer

Introduction

New imaging techniques including Doppler ultrasound have recently become available for evaluating the blood supply to tumors in the diagnosis of breast diseases.[1] In order to determine the appropriate operative procedure for breast cancer, it is important not only to detect the tumor, including the extent of spread, but also to evaluate the status of axillary nodes before surgery. In this paper, the effectiveness of conventional ultrasound (US) was determined and compared with mammography (MMG), computed tomography (CT), and intravenous digital subtraction angiography (DSA) in the detectability of breast cancers and metastatic axillary nodes.

Reprint requests to: N. Tohnosu, Department of Surgery, Funabashi Municipal Medical Center, Kanasugibashi 1-21-1, Funabashi, Chiba, 273 Japan
(Received for publication on Mar. 13, 1992; accepted on Nov. 13, 1992)

Materials and Methods

Forty-seven breast cancer patients who all underwent US, MMG, CT, or DSA preoperatively at Chiba University Hospital between 1986 and 1990 were included in this study. The US equipment used was a real-time, electronic linear array scanner (Toshiba SSA-90A) with 5.0 or 7.5 MHz linear transducers. The other equipment used for MMG, CT, and DSA included a Senographe 500-T (GE), a GE-9800, and a Toshiba DEF-03A, respectively. Craniocaudal and mediolateral projections were obtained routinely on MMG, with spot MMG being added in some cases. US images were obtained by scanning manually in both longitudinal and transverse planes of the breast, axillary, and subclavian regions. Rounded hypoechoic lesions over 10 mm in size along the axillary and subclavian vessels were regarded as metastatic nodes. CT studies were done on a 1-cm slice of breast or axillary node tissue without the use of contrast material. In the transverse plane, axillary nodes measuring over 1 cm and/or showing irregular margins were considered metastatic. DSA was performed by the Seldinger technique using a FG 5 catheter inserted through an antecubital vein and positioned in the superior vena cava. Thirty milliliters of 60% sodium diatrizoate was injected through the catheter to view image exposures in real time. When a mass became stained even slightly in the axilla, it was determined as being metastatic. If US, CT, and DSA did not detect an image in the axillary nodes, it was regarded as being negative. Detectability was assessed by determining the fraction

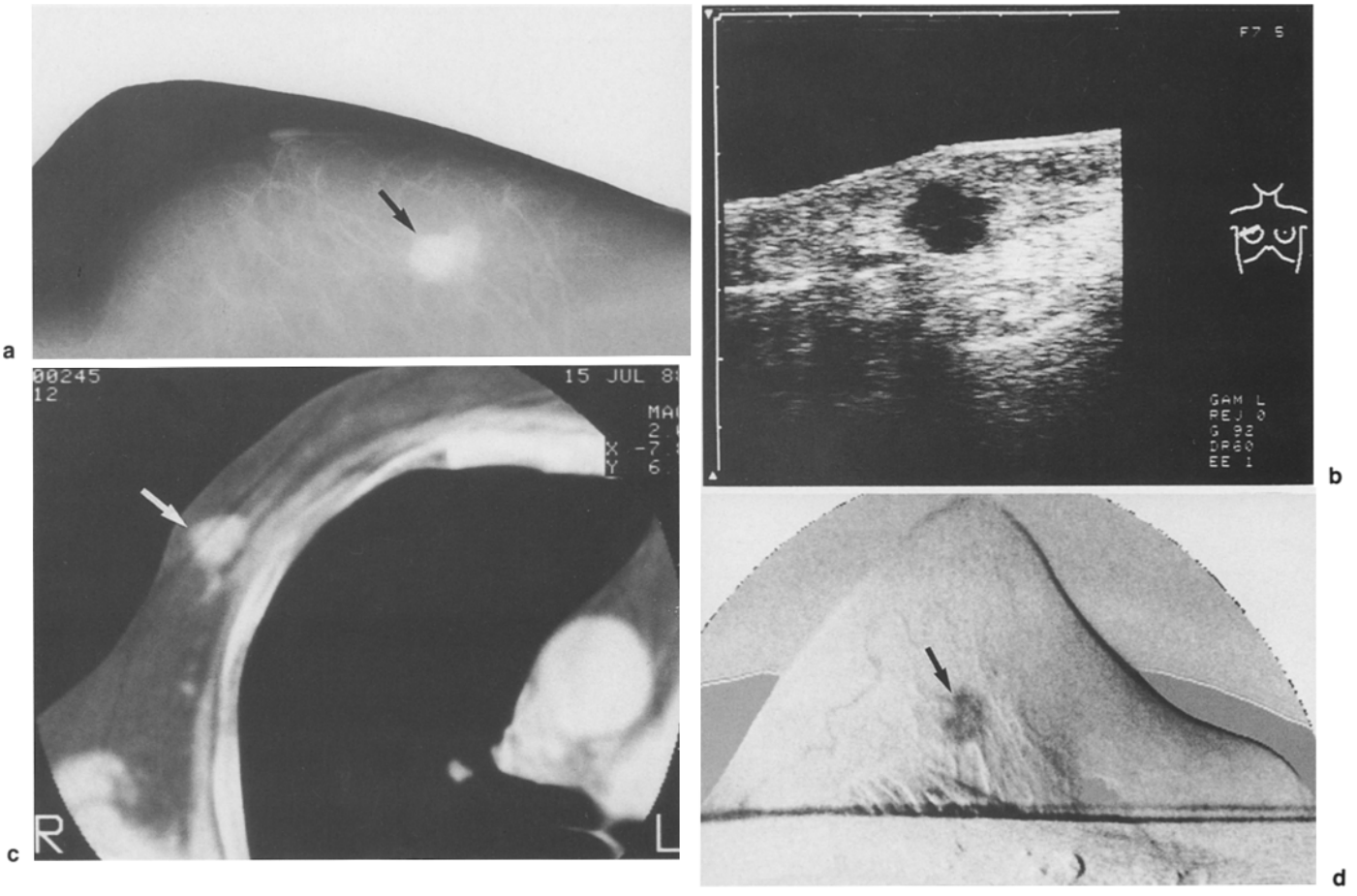

Fig. 1a–d. Images of breast cancer by mammography, ultrasound, computed tomography, and digital subtraction angiography in a 71-year-old woman with a tumor, 2.1 × 1.8 cm in size, on palpation. **a** A spiculate tumor without calcification is visualized on mammography (*black arrow*); **b** a jagged tumor is clearly imaged on ultrasound in the lateral upper quadrant of the right breast; **c** a high-density mass is seen on CT (*white arrow*); and **d** a tumor with a feeding vessel is demonstrated on DSA (*black arrow*)

of the number of patients with identified masses by the number of all patients examined by each imaging technique. Sensitivity was calculated by the fraction of true positives (TP)/TP + false negatives (FN), whereas specificity was calculated by the fraction of true negatives (TN)/TN + false positives (FP). Accuracy was calculated by: TP + TN/TP + FN + TN + FP.

The detectability of tumors in the breast by MMG, US, CT, and DSA was then compared and the accuracy for visualizing metastatic axillary nodes by US, CT, and DSA was also assessed. The images obtained by each technique were interpreted by the same physician.

Results

The images obtained by MMG, US, CT, and DSA in a 71-year-old woman with a tumor 2.1 × 1.8 cm in size on palpation are shown in Fig. 1. MMG clearly depicts a spiculate tumor without calcification; US shows a jagged tumor clearly imaged in the lateral upper quadrant of the right breast; CT demonstrates a high density mass; and DSA depicts a tumor with a feeding vessel. US was able to detect the tumors in all cases regardless of age, although the detectability of MMG on patients under 40 years of age was only 42.9%, which was low compared to the 71.4% for both CT and DSA. The detectability of MMG and CT improved in proportion to age, being 87.5% for MMG and 100% for CT on patients over 60 years of age. However, no characteristic improvement by age was seen for DSA even though it detected all tumors in patients over 60 years of age (Table 1). The detectability of tumor contours in T1-sized tumors was as unfavorable as 40%, especially for DSA, while in T2 tumors, MMG was inferior to the other imaging techniques at 64.7%. In fact, US was found to be most favorable in detectability, regardless of tumor size (Table 2). Figure 2

Table 1. Detectability by age distribution

Age	1986–1990 Chiba University MMG	US	CT	DSA
<40	3/7 (42.9%)	7/7 (100)	5/7 (71.4)	5/7 (71.4)
40≦	11/19 (57.9)	19/19 (100)	17/19 (89.5)	13/19 (68.4)
50≦	10/13 (76.9)	13/13 (100)	13/13 (100)	10/13 (76.9)
60≦	7/8 (87.5)	8/8 (100)	8/8 (100)	8/8 (100)

MMG, Mammography; *US*, ultrasound; *CT*, computed tomography; *DSA*, digital subtraction angiography

Table 2. Detectability by tumor size

Tumor size	1986–1990 Chiba University MMG	US	CT	DSA
T1	3/5 (60%)	5/5 (100)	5/5 (100)	2/5 (40)
T2	22/34 (64.7)	34/34 (100)	32/34 (94.1)	28/34 (82.4)
T3 + T4	6/8 (75)	8/8 (100)	7/8 (87.5)	6/8 (75)

For explanation of abbreviations see Table 1

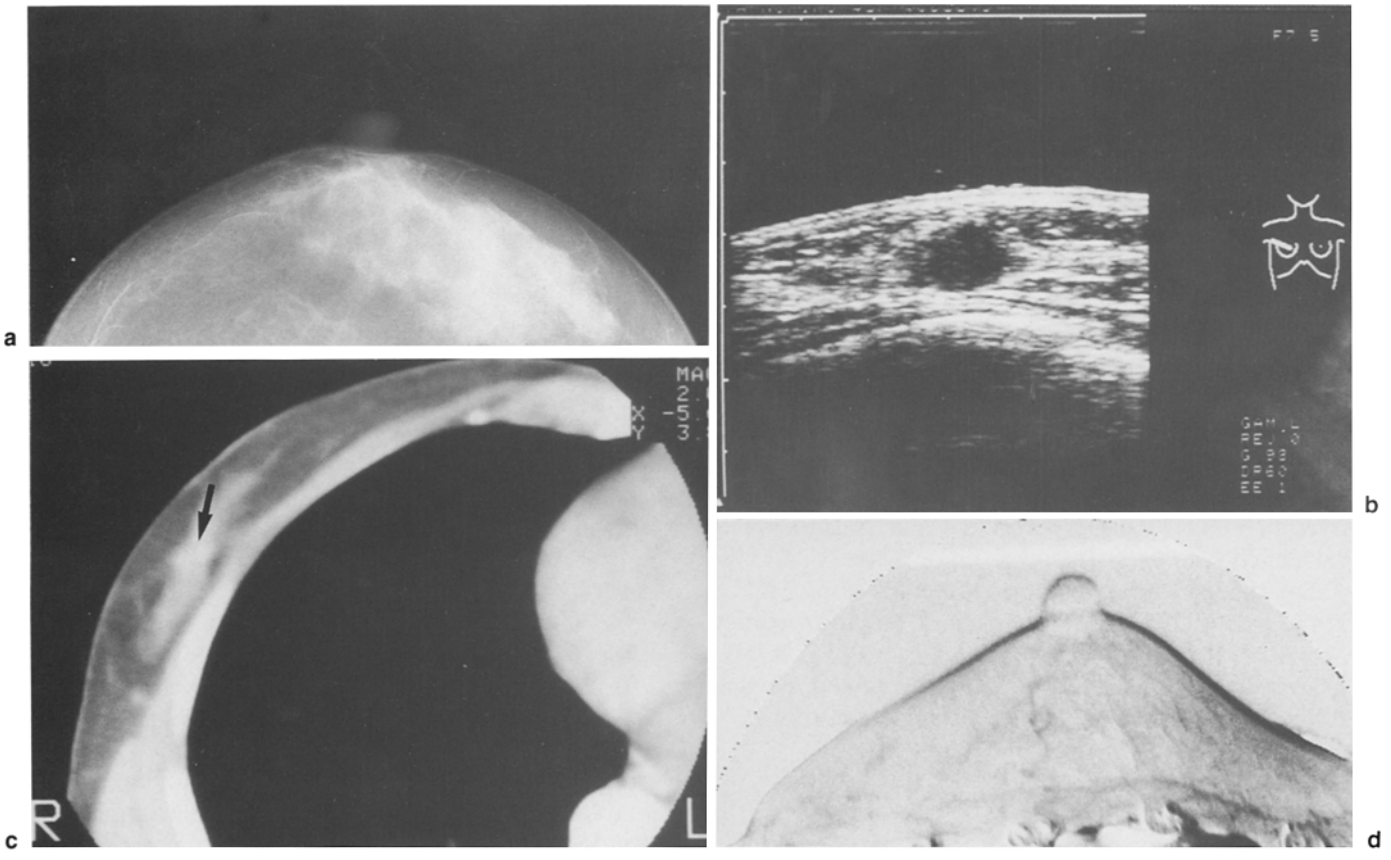

Fig. 2a–d. Images of breast cancer by mammography, ultrasound, CT, and DSA in a 46-year-old patient with a tumor, 1.7 × 1.6 cm in size, on palpation. **a** A tumor is not imaged on mammography; **b** a tumor is clearly seen on ultrasound; **c** a tumor is slightly visualized on CT (*black arrow*); and **d** no tumor is demonstrated on DSA

Table 3. Detectability by histological type

Histological type	1986–1990 Chiba University MMG	US	CT	DSA
Pap tub ca	6/13 (46.2%)	13/13 (100)	10/13 (76.9)	10/13 (76.9)
Solid tub ca	13/18 (72.2)	18/18 (100)	18/18 (100)	16/18 (88.9)
Scirrhous ca	8/11 (72.7)	11/11 (100)	11/11 (100)	7/11 (63.6)
Special type	4/5 (80)	5/5 (100)	5/5 (100)	3/5 (60)

Pap tub, papillotubular; *ca*, carcinoma
For explanation of abbreviations see Table 1

shows the MMG, US, CT, and DSA of a 46-year-old female with a T1 tumor, 1.7 × 1.6 cm in size. It can be seen that only US detected the tumor clearly (Fig. 2b).

Detectability according to the histological types of the Japanese Breast Cancer Society classification was unfavorable, specifically in papillotubular carcinoma for MMG at 46.2%, and in scirrhous carcinoma or special type for DSA at 63.6%, and 60%, respectively (Table 3). Thus, the detectability of MMG had a tendency to be unfavorable compared to US and CT, although it detected microcalcification alone without a tumor mass which improved its detectability from 64.7% to 79.4% in T2 tumors (Table 4). According to histological type, the detectability of MMG was raised from 46.2% to 76.9% for papillotubular carcinoma, and from 72.7% to 81.8% for scirrhous carcinoma (Table 5). Similarly, the number of cases correctly diagnosed as cancer by MMG increased from 30 to 35 cases due to the presence of microcalcification alone. The diagnostic accuracy of MMG and US was thus 74.5% and 91.5%, respectively (Table 6). Axillary nodal status was also examined by US, CT, and DSA and the metastatic axillary nodes found by each imaging technique are demonstrated in Fig. 3. US detects right axillary nodes 9 mm and 6 mm in size but the image does not give sharp contrast to the surrounding, relatively thick, fatty tissue. However, CT clearly depicts nodes even as small as 3 mm in size, while the imaging on DSA is markedly inferior even to US. In assessing the sensitivity of axillary node metastases, CT at 81.8% was more favorable than US at 72.7%, while DSA at 42.9% had little diagnostic value (Table 7).

Table 4. Improved detectability for MMG due to microcalcification without a tumor mass, by tumor size

Tumor size	1986–1990 Chiba University Tumor(+)	Tumor(−), calcification(+)
T1	3/5 (60%)	—
T2	22/34 (64.7)	27/34 (79.4)
T3 + T4	6/8 (75)	—

For explanation of abbreviations see Table 1

Table 5. Improved detectability for MMG due to microcalcification without a tumor mass, by histological type

Histological type	1986–1990 Chiba University Tumor(+)	Tumor(−), calcification(+)
Pap tub ca	6/13 (46.2%)	10/13 (76.9)
Solid tub ca	13/18 (72.2)	—
Scirrhous ca	8/11 (72.7)	9/11 (81.8)
Special type	4/5 (80)	—

Pap tub, papillotubular; *ca*, carcinoma
For explanation of abbreviations see Table 1

Table 6. Accuracy of MMG and US

Imaging technique	1986–1990 Chiba University Accuracy
MMG	35[a]/47 (74.5%)
US	43/47 (91.5)

[a] The number of cases detected increased due to the presence of microcalcification
For explanation of abbreviations see Table 1

Table 7. Accuracy for axillary node metastases

Imaging technique	1986–1990 Chiba University Sensitivity	Specificity	Accuracy
US	16/22 (72.7%)	18/25 (72.0)	34/47 (72.3)
CT	17/22 (81.8%) *	22/25 (88.0)	39/47 (83.0)
DSA	9/21 (42.9%)	24/26 (92.3)	33/47 (70.2)

* $P < 0.05$
For explanation of abbreviations see Table 1

Discussion

Many imaging techniques have been utilized in the diagnosis of breast cancer. In order to determine the most appropriate operative procedure, including breast conserving surgery, a combination of the commonly used techniques is indispensable because each modality is supplementary in detecting lesions. MMG has long

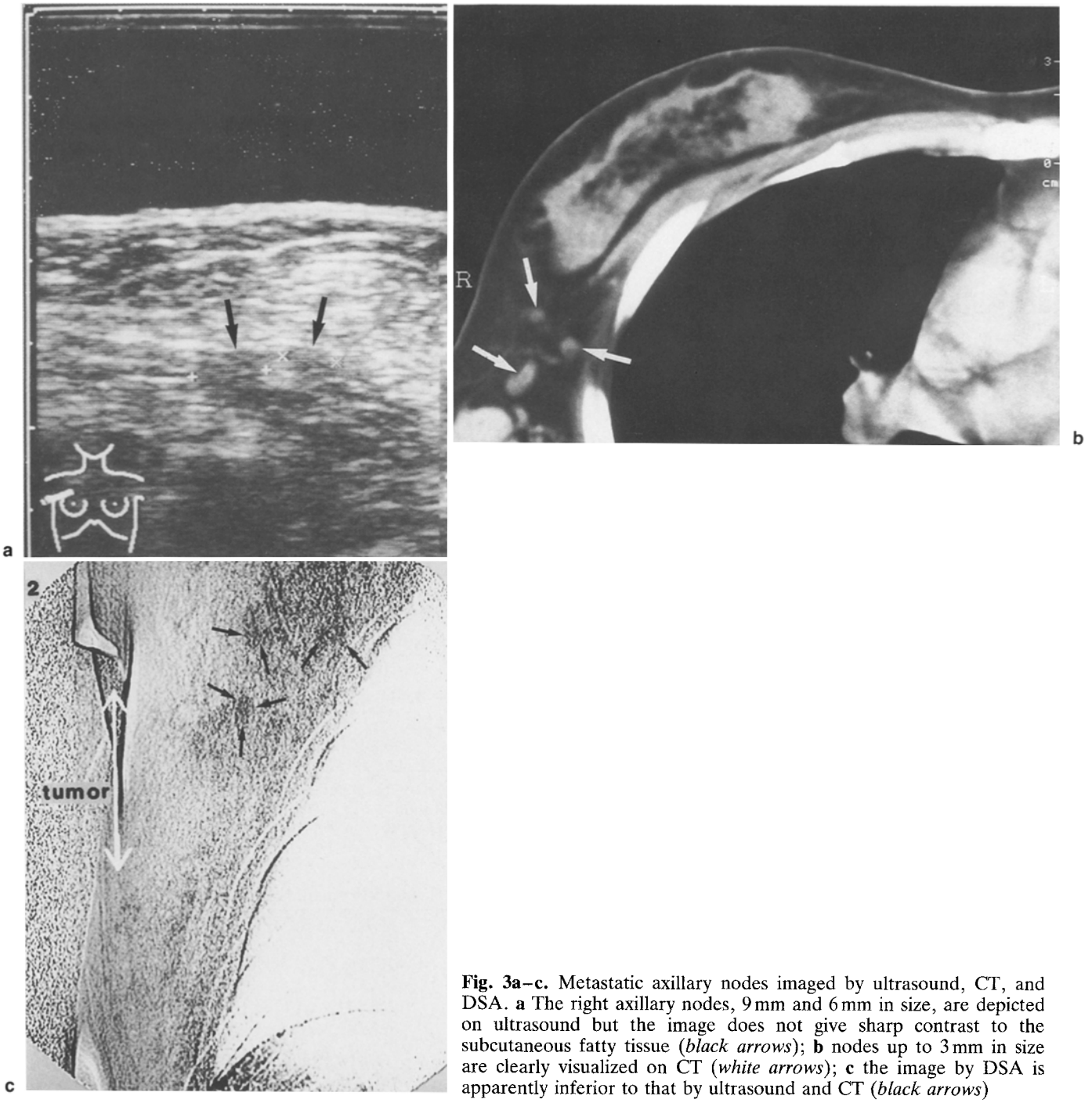

Fig. 3a–c. Metastatic axillary nodes imaged by ultrasound, CT, and DSA. **a** The right axillary nodes, 9 mm and 6 mm in size, are depicted on ultrasound but the image does not give sharp contrast to the subcutaneous fatty tissue (*black arrows*); **b** nodes up to 3 mm in size are clearly visualized on CT (*white arrows*); **c** the image by DSA is apparently inferior to that by ultrasound and CT (*black arrows*)

been used for diagnosing breast cancer, especially that with microcalcification.[2–4] However, dense or dysplastic young breast tissue is difficult to interpret by MMG even if a tumor is palpable. In comparing US to MMG, many authors[5–9] advocate the superiority of US; Guyer et al.[9] stating that no tumor mass was missed by US in 68 breast cancer patients, as in our experience. However, with advances in interpreting techniques and instruments, especially transducers with improved resolution, US has also often come to play an important role not only in detecting microcalcification,[8,10] but also in diagnosing the intraductal spread of cancer, particularly in Japanese women.[11,12]

Ellen et al.[13] reported that mammographic features of breast cancer patients younger than 35 years of age, detected masses only in 35.1% of 74 patients. Similar findings were obtained in our series for patients under 40 years of age. Harper,[14] Feig,[15] and Rosner[16] there-

fore recommend sonography as the imaging technique of choice for women younger than 30 years. To compare the ability of US and MMG, one study showed detection rates of 58% and 97% of 64 cancers, respectively.[17] On the contrary, Guyer et al.[9] stress the superiority of US over MMG by reporting the detectability of 68 cancers by MMG and US as 79.4% and 98.5%, respectively, in accordance with our experience.

Concerning the detectability by tumor size of cancers smaller than 1 cm, only 8% were detected by US while 90% were detected by MMG.[17] However, according to reports by Japanese investigators[18,19] sonography has detected as many as 88.5%–100% of cancers under 1 cm in some studies, though there were no such cases in our series. The detection of T2 tumors by MMG was unfavorable in our series but this may possibly have been improved if spot MMG had been routinely added.

According to histological type, papillary carcinoma, which occurs in less than 2% of all malignant breast tumors, has a tendency toward revealing a specific multinodular pattern of increased density in a segmental distribution to involve more than one quadrant of the breast.[20] This may explain why papillotubular carcinoma is poorly visualized on MMG according to the Japanese histological classification, as seen in our series. Mitnick et al.[20] also stated that the multinodular lesions of papillary carcinoma may have associated microcalcifications, which were observed in 6 of 18 patients in their study. Our series similarly showed that most of the patients with microcalcifications alone without a tumor mass were those with papillotubular carcinoma, which was more frequently detected than scirrhous carcinoma. According to the report of Ellen et al.,[13] the number of patients aged under 35 years with a well defined mass was almost the same as that of those with calcifications alone, according to MMG, but the detectability of cancer was raised from 35.1% to 83.8% by adding the latter finding;[13] this being similar to our results regardless of age distribution.

Rosner et al.[16] reported the diagnostic accuracy of MMG and US to be 84% and 73%, respectively, showing no significant difference, while an analysis by Cole-Beuglet et al.[17] showed the accuracy of MMG and US to be 74% and 69%, respectively, but that the latter improved to 79% with the knowledge of clinical data. Kobayashi[22] recorded 85% cancer detectability with US and 83% with MMG, whereas another paper[9] reported mammographic and sonographic accuracies to be 80.9% and 91.2%, respectively, revealing similar results to our own.

In a report by Chang et al.,[23] the superiority of a CT scan with intravenous contrast medium enhancement over MMG for detecting cancer in dense breasts was demonstrated, being 94% versus 77%, respectively. They stated that even malignant microcalcification without an associated mass can be identified. Conversely, Gisvold et al.[24] reported that conventional MMG was more favorable than CT without contrast material for detecting malignancies, being 90% versus 68.3%, respectively, but that the detectability by CT improved to 81.8% when contrast material was used. We were able to detect a tumor mass by CT without contrast material much more easily than by MMG, although it was so difficult to differentiate malignant lesions from benign ones that its diagnostic accuracy could not be compared to the other techniques.

DSA is useful for evaluating the vascularity of tumors.[25,26] Watt et al.[26] stress that DSA achieves excellent resolution of the iodine-containing vessels and can be used in dense breasts, unlike MMG. Tsurumi[25] states that intra-arterial DSA is superior in detectability to intravenous DSA, showing results of 81% versus 64%, but that detectability is correlated to tumor size. However, there have few reports which advocate the advantage of DSA specifically in detectability. In our series, we found DSA inferior to other techniques for scirrhous and special type carcinomas, maybe because of the poorer vascularity in the tissue around the tumor.[27]

As axillary node status is important in the prognosis of breast cancer, preoperative clinical examinations with US, CT, or magnetic resonance imaging (MRI) have been employed to detect metastatic axillary lymph nodes. The sensitivity of US is reported as 66%–72.7%,[28–30] concurrent with our study. US studies the nodes by tracing along the axillary or subclavian vessels in real time, but it is often difficult to perform depending on the thickness of the subcutaneous fatty tissue. On the other hand, CT and MRI are more effective in diagnosing metastatic axillary nodes than assessing breast lesions[31–33] because they provide excellent discrimination of a small solid mass from fatty tissue in the axilla. The sensitivity for detecting metastatic axillary nodes according to the literature is 76%,[32] similar to our findings. However, Kawakami et al.[32] stress that images at 3-mm intervals must be obtained, so that axillary nodes are not missed, but are more clearly visualized for interpretation. Conversely, March[34] and Fossel[35] strictly stated that CT does not provide an accurate assessment of axillary node status primarily because of its inability to exclude micrometastatic involvement of nonenlarged nodes.

In conclusion, US is superior to MMG, CT, or DSA in detecting breast cancer masses. CT is more advantageous than US or DSA for evaluating axillary nodal status, while DSA has little diagnostic value compared to US and CT.

References

1. Jellins J (1988) Combining imaging and vascularity assessment of breast lesions. Ultrasound Med Biol 14[Suppl. 1]:121–130
2. Gallager HS, Martin JE (1969) The study of mammary carcinoma by mammography and whole organ sectioning. Cancer 23(4):855–873
3. Egan RL, McSweeney MB, Sewell CW (1980) Intramammary calcifications without an associated mass in benign and malignant diseases. Radiology 137:1–7
4. Colbassani HJ, Feller WF, Cigtay OS, Chun B (1982) Mammographic and pathologic correlation of microcalcification in disease of the breast. Surg Gynecol Obstet 155:689–696
5. Teixidor HS, Kazam E (1977) Combined mammographic and sonographic evaluation of breast masses. Am J Roentgenol 128: 409–417
6. Maturo VG, Zusmer NR, Gilson AJ, Bear B (1982) Ultrasonic appearances of mammary carcinoma with a dedicated whole breast scanner. Radiology 142:713–718
7. Fleicher AC, Muhletaler CA, Reynolds VH, Marchin JE, Thieme GA, Bundy AL, Winfield AC, Everette JA (1983) Palpable breast masses: Evaluation by high-frequency, handheld real-time sonography and xeromammography. Radiology 148:813–817
8. Harper AP, Kelly-Fry E (1980) Ultrasound visualization of the breast in symptomatic patients. Radiology 137:465–469
9. Guyer PB, Dewbury KC (1985) Ultrasound of the breast in the symptomatic and X-ray dense breast. Clinical Radiology 36: 69–76
10. Kasumi F (1988) Can microcalcifications located within breast carcinomas be detected by ultrasound imaging? Ultrasound Med Biol 14[Suppl. 1]:175–182
11. Tsunoda H, Ueno E, Tohno E, Akisada M (1990) Echogram of ductal spreading of breast carcinoma (in Japanese with English abstract). Jpn J Med Ultrasonics 17(1):44–49
12. Kamio T (1990) Ultrasonographic diagnosis of nonpalpable breast tumor (in Japanese with English abstract). Jpn J Med Ultrasonics 17(3):81–95
13. Ellen SP, Luisa PM, Bernard VE (1990) Breast cancers in 35 years of age and younger: Mammographic findings. Radiology 177:117–119
14. Harper AP, Kelly-Fry E, Noe S (1981) Ultrasound breast imaging: The method of choice for examining the young patient. Ultrasound Med Biol 7:231–237
15. Feig SA (1989) The role of ultrasound in a breast imaging center. Semin Ultrasound CT MR 10:90–105
16. Rosner D, Blaird D (1985) What ultrasonography can tell in breast masses that mammography and physical examination cannot. J Surg Oncol 28:308–313
17. Cole-Beuglet C, Goldberg BB, Kurz AB, Rubin CS, Patchefsky AS, Shaber GS (1981) Ultrasound mammography: A comparison with radiographic mammography. Radiology 139: 693–698
18. Sickles EA, Filly RA, Callen PW (1983) Breast cancer detection with sonography and mammography: Comparison using state-of-the-art equipment. AJR 140:843–845
19. Tokunaga K, Marukawa T, Hosoki T, Hori S, Yoshioka H, Kuroda C, Kozaka T, Morimoto K, Miyata Y, Takatsuka Y, Kawahara T (1987) Ultrasonography of the breast (in Japanese with English abstract). Rinsho Hoshasen (Jpn J Clin Radiol) 32(1):1–13
20. Ishikawa T, Miyamoto Y (1989) Sonographic diagnosis in breast carcinoma by 7.5 MHz high-resolution electric linear array transducer (in Japanese with English abstract). Nippon Igaku Hoshasen Gakkai Zasshi (Jpn J Med Radiol) 49(1):15–22
21. Mitnick JS, Vazquez MF, Harris MN, Schecher S, Roses DF (1990) Invasive papillary carcinoma of the breast: Mammographic appearance. Radiology 177:803–806
22. Kobayashi T (1977) Gray-scale echography for breast cancer. Radiology 122:207–214
23. Chang CHJ, Sibala JS, Fritz SL, Dwyer SJ III, Templeton AW, Lin F, Jewell WR (1980) Computed tomography in detection and diagnosis of breast cancer. Cancer 46:939–946
24. Gisvold JJ, Karsell PR, Reese DF, McCullough EC (1977) Clinical evaluation of computerized tomographic mammography. Mayo Clin Proc 52:181–185
25. Tsurumi K, Okuyama N (1987) Digital subtraction angiography for breast cancer. Keio J Med 36:262–270
26. Watt AC, Ackerman LV, Windham JP, Shetty PC, Burke MW, Flynn MJ, Grodinsky C, Fine G, Wilderman SJ (1986) Breast lesions: Differential diagnosis using digital subtraction angiography. Radiology 159:39–42
27. Samejima N, Yamazaki K (1988) A study on the vascular proliferation in tissues around the tumor in breast cancer. Jpn J Surg 18(3):235–242
28. Tate JJT, Lewis V, Archer T, Guyer PG, Royle GT, Taylor I (1989) Ultrasound detection of axillary lymph node metastases in breast cancer. Europ J Surg Oncol 15:139–141
29. Bruneton JN, Caramella E, Héry M, Aubanel D, Manzino JJ, Picard JL (1986) Axillary lymph node metastases in breast cancer: Preoperative detection with US. Radiology 158:325–326
30. Pamilo M, Soiva M, Lavast EM (1989) Real-time ultrasound, axillary mammography and clinical examination in the detection of axillary lymph node metastases in breast cancer patients. J Ultrasound Med 8:115–120
31. Fisher B, Wolmark N, Bauer M, Redmond C, Gebhardt M (1981) The accuracy of clinical nodal staging and of limited axillary dissection as a determinant of histologic nodal status in carcinoma of the breast. Surg Gynecol Obstet 152:765–772
32. Kawakami Y, Fujita M, Watanabe K, Ryu M, Honda I, Watanabe S, Sakamoto K, Takeuchi O, Shinohara Y (1989) CT diagnosis of metastases in regional nodes of the breast (in Japanese with English abstract). Nippon Rinsho Gekai Gakkai Zasshi (J Jpn Soc Clin Surg) 50(10):2107–2111
33. Hanh H, Hoeffken W (1985) Computerized tomography of breast cancer and regional lymph nodes. Diag Imag Clin Med 54:165–169
34. March DE, Wechsler RJ, Kurtz AB, Rossenberg AL, Needleman L (1991) CT: Pathologic correlation of axillary nodes in breast carcinoma. J Comput Assist Tomogr 15(3):440–444
35. Fossel ET, Brodsky G, Delayre JL, Wilson RE (1983) Nuclear magnetic resonance for the differentiation of benign and malignant breast tissues and axillary lymph nodes. Ann Surg 198(4): 541–545