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Contrast-enhanced CT Evaluation of Clinically and Mammographically Occult Multiple Breast Tumors in Women with Unilateral Early Breast Cancer

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Background: Magnetic resonance imaging mammography is performed to determine the extent of lesions and to detect occult lesions, but preoperative diagnosis by breast computed tomography (CT) is less common.
Methods: We performed a retrospective study of detection of mammographically occult multiple lesions using breast CT. The subjects were 407 female patients (median age: 56 years old; median tumor size: 1.9 cm) with breast cancer who underwent preoperative, contrast-enhanced breast CT.
Results: CT detected 73 incidental-enhanced breast nodules (median size: 0.8 cm) in 73 patients that were undetectable by conventional methods. Age, size of the main lesion or laterality of lesions did not differ between patients with and without incidental nodules, but the frequency of mastectomy was significantly higher in those with incidental nodules. Of the 73 incidental nodules, 22 (30%) were in the same quadrant as the main lesion, 26 (36%) were in other quadrants and 25 (34%) were in the opposite breast. On qualitative diagnosis by CT, 48 were suspected to be malignant (66%), 17 benign (23%) and eight non-specific (11%). In histological evaluation of 44 of the 48 nodules suspected to be malignant, 24 were malignant (invasive carcinoma: 22, non-invasive carcinoma: 2); of seven of the 17 nodules suspected to be benign, all were benign; and of three of the eight non-specific nodules, one was non-invasive carcinoma. The discovery rate of clinically and mammographically occult multiple lesions by preoperative breast CT was 6%.
Conclusion: We conclude that breast CT is useful for the detection of occult lesions and choice of surgical procedure.

Key words: breast CT – preoperative – occult lesion – IEBN – MRI – malignancy

INTRODUCTION

The sensitivity of magnetic resonance imaging (MRI) for detection of breast cancer is high (94–100%) (1,2), and staging MRI mammography is performed in addition to preoperative evaluation by conventional methods (palpation, mammography and ultrasonography (US)) to determine the extension of the lesion and to detect mammographically occult multifocal or multicentric lesions. In contrast, there have only been a few evaluations of preoperative computed tomography (CT) for breast cancer, and these have been performed in a relatively small number of patients. Development of multidetector-row CT has markedly improved the temporal and spatial resolutions of breast CT, and our facility has performed preoperative staging breast CT in patients indicated for breast preservation surgery since April 2003. Here, we report a retrospective investigation of CT detection of clinically and mammographically occult multiple lesions in these patients.

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PATIENT AND METHODS

Protocol of Preoperative Diagnosis

Malignancy or benignity of masses is diagnosed by inspection and palpation of the breast, mammography, breast echography, fine needle aspiration cytology and needle biopsy. In mammography, images of the bilateral breast are acquired from two directions: medio-lateral oblique and cranio-caudal views. In mammary gland echography, the extension was determined by focusing on the main lesion and the opposite breast was screened at the same time. When breast cancer was diagnosed or strongly suspected based on these tests, the patient underwent resection or biopsy. Breast CT was performed in patients for whom breast-conserving surgery (BCS) was judged applicable based on findings from palpation, mammography and US. CT was not performed in patients indicated for mastectomy by palpation, mammography and US; i.e. the presence of a wide calcified lesion or multiple lesions over several regions was apparent and mastectomy was desirable. CT was also not performed when the patient requested mastectomy, even though BCS was applicable. The surgical procedure (BCS or mastectomy) was finally decided by discussing with the patient based on the assumed resection area and the the extension of the main lesion on breast CT.

Breast CT Technique

The patients were kept in the prone position and scanned for 0.5 s using four-slice MDCT (Aquilion^{TM} 32; Toshiba Medical Systems Co., Tokyo, Japan). Bilateral whole breast scanning was performed within a single breath-hold with 1-mm detector raw collimation and a helical pitch of 27:1 after pre-enhanced scanning of the whole thoracic area (400−500 mm) for breast cancer screening. This was followed by a contrast-enhanced scan with biphasic helical CT scanning, for which 100 ml of non-ionic contrast material [Iopamilone $^{®}$370 (Iopamidol), Bayer Schering Pharma Co., Ltd., Oosaka, Japan] was injected intravenously at a flow rate of 3.0 ml/s. The delay between the initiation of injection and evaluation of contrast enhancement was 75 s for early phase imaging and 180 s for late phase imaging.

Qualitative Diagnosis of Incidental-Enhanced Breast Nodules by CT

The breast CT findings were judged by two expert radiologists. Nodular shadows near to or connected with the main lesion via cord-like shadows were judged to be daughter shadows. Enhanced nodular shadows that were located away from the main lesion without continuity and undetectable by palpation, mammography or US were regarded as incidental-enhanced breast nodules (IEBNs). When an IEBN was detected, re-examination by mammary gland echography and evaluation of the nodule were generally performed. IEBNs were divided into three groups based on the contrast pattern and shape: nodules suspected to be malignant, including those with early enhancement and an unclear tumor boundary with a margin that was fluffy or serrate; nodules suspected to be benign, including those with weak enhancement and a clear boundary and rough and large calcified nodules; and non-specific nodules that were not classifiable as malignant or benign, including nodular shadows that were very small or weakly enhanced and were difficult to evaluate.

Histological Examination

IEBNs suspected to be malignant by CT were examined histologically. For those suspected to be benign or judged non-specific, the decision to perform biopsy was made with reference to the findings of a second examination by mammary gland echography. Histological examination was performed when the patient requested biopsy, even if the nodules were found to be benign in the second echography examination. The excised specimen was sliced into 5 mm sections and stained with haematoxylin-eosin stain. The final judgment of malignancy or benignity of the IEBN was made based on the histological examination. IEBNs judged to be malignant were classified into multifocal lesions, multicentric lesions and intra-breast metastases, based on pathological continuity with the main lesion, the histologic type and localization in the breast. Multifocal lesions were defined as IEBNs with pathological continuity with the main lesion due to vascular invasion or advancement into the lactiferous ducts or IEBNs present in the same quadrant as the main lesion, with the same histologic type as the main lesion. Multicentric lesions were defined as IEBNs present in quadrants other than that of the main lesion and showing unclear continuity with the main lesion, or IEBNs present in the same quadrant as the main lesion but not continuous, with a different histologic type compared to the main lesion. Intra-breast metastases were defined as IEBNs that were not continuous with the main lesion, but in which vascular invasion by the main lesion was severe, with a histologic type that was the same as that of the main lesion and accompanied by no intra-ductal component.

Data Collection and Analysis

Of patients who underwent breast CT before surgery for breast cancer after April 2003, those with unilateral breast cancer for which BCS was judged applicable by mammography and US were included in the study. Patients were excluded for the following reasons: if bilateral breast cancer was diagnosed by conventional methods (palpation, mammography and US); if multiple lesions were apparent over multiple quadrants of the same breast on examination by conventional methods; if a widely extended main lesion was present for which mastectomy was desirable based on conventional methods; if lesions forming no mass due to calcification alone were discovered by mammography; if preoperative chemotherapy had been performed; and if no main lesion was present in biopsy at the time breast CT was performed.

Table 1. Patient characteristics

	Number of patients (%) Median (range)			*P* value
	All cases ($n = 407$)	IEBNs		
		Abcent ($n = 3347$)	Present ($n = 73$)	
Age	56 (21–84)	56 (26–84)	54 (21–80)	0.11
Size of primary tumor (cm)	1.9 (0.5–6)	1.9 (0.7–6)	1.7 (0.5–4.5)	0.12
Lateriality				
Right	184 (46)	158 (47)	28 (38)	0.16
Left	221 (54)	176 (53)	45 (62)	
Surgical procedure				
Mastectomy	103 (25	77 (23)	26 (36)	0.025
BCS	304 (75)	257 (77)	47 (64)	
(Bilateral BCS)	6 (2)		6 (8)	
Daughter nodule				
Present	38 (9)	25 (7)	13 (18)	0.013
Absent	369 (91)	309 (93)	60 (82)	
Characteristics of IEBNs				
Localization				
Same quadrant			22 (30)	
Other quadrant			26 (36)	
Opposite breast			25 (34)	
Size of IEBNs (cm)			0.8 (0.3–2)	

IEBNs, incidental-enhanced breast nodules; BCS, breast conversing surgery.

A χ^2 test or *t*-test was used for statistical analysis, with differences with $P < 0.05$ considered significant.

RESULTS

There were 407 patients eligible for analysis between April 2003 and June 2007 (Table 1). All subjects were female. The median age was 56 years old (21–84 years old) and the median tumor size was 1.9 cm (0.5–6 cm). The main lesion was localized on the right side in 186 patients and on the left side in 221 patients. The chosen surgical procedure was mastectomy in 103 patients and BCS in 304 patients (bilateral surgery in six patients). Preoperative palpation, US and mammography detected nodules near the main lesion in 38 cases (9%), and these were judged to be daughter nodules continuous with the main lesion by CT. Other than these daughter nodules, 73 IEBNs without continuity with the main lesion were detected only by preoperative breast CT. A comparison of the clinical background of the 334 cases without IEBNs and the 73 cases with IEBNs on preoperative CT is shown in Table 1. There was no significant difference in age, size of the main lesion, or laterality of the lesion between the two groups. For patients without an IEBN, the chosen surgical procedure was BCS in 257 cases (77%) and mastectomy in 77 (23%), whereas in the group with an IEBN, BCS was performed in 47 cases (64%) and mastectomy in 26 cases (36%), showing a significantly higher frequency of mastectomy in patients with an IEBN ($P = 0.025$). In cases with daughter nodules adjacent to the main lesion, the frequency of detection of an IEBN by CT was significantly higher ($P = 0.013$). The median size of the IEBN was 0.8 cm (0.3–2 cm), with localization in the same quadrant as the main lesion in 22 cases (30%), in other quadrants in 26 cases (36%) and in the opposite breast in 25 cases (34%).

Qualitative and Pathological Diagnoses of IEBNs by CT

On qualitative diagnosis of the 73 IEBNs, 48 were suspected to be malignant (66%), 17 were suspected to be benign (23%) and eight were non-specific (11%). Comparison of clinical background with CT findings showed no significant difference in age, localization, size of the main lesion, or size of the IEBN among the groups (Table 2). The detection rate by repeated US was 33% for nodules judged to be non-specific, which was significantly lower than those for nodules suspected to be malignant and benign. Of the 48

Table 2. CT diagnosis and clinico-pathological findings of IEBNs

	CT diagnosis of IEBNs Numbers of patients (%), Median (range)			*P* value
	Suspicious malignant ($n = 48$)	Suspicious benign ($n = 17$)	Non-specific ($n = 8$)	
Age	54.5 (21–80)	52 (32–69)	56 (437–71)	0.87
Localization				
Same quadrant	16 (33)	5 (29)	1 (13)	0.18
Other quadrant	20 (42)	4 (24)	2 (25)	
Opposite breast	12 (25)	8 (47)	5 (63)	
Size of primary tumor	1.7 (0.5–31)	1.6 (0.9–4.5)	2 (1.3–2.6)	0.8
Size of IEBNs	0.8 (0.5–2)	1 (0.5–1.8)	0.7 (0.5–1.5)	0.74
US detection				
Yes	44 (92)	16 (94)	3 (33)	0.0001
No	4 (8)	1 (6)	5 (67)	
Histological examination				
Yes	44 (92)	7 (41)	3 (38)	
No	4 (8)	10 (59)	5 (62)	
Method of biopsy				
Mastectomy	19	4		
Partial resection (ipisi-lateral)	11	3	1	
Partial resection (contra-lateral)	12		2	
US-guided mammotomc	2			
Histology				
Non-specific	11	4	1	
Fibrocysitc disease	4			
Fibroadenoma	3	2		
Ductal hyperplasia		1	1	
Lobar hyperplasis	2			
Non-invasive carcinoma	2		1	
Invasive carcinoma	22			

CT, computed tomography.

nodules suspected to be malignant, 44 (92%) were detectable by repeated echography. Identification of the other four nodules was difficult, although they were closely examined by echography. Of the 44 nodules suspected to be malignant and detectable by echography, 42 were excised during surgery for the main lesion and examined histologically: 19 were incidental nodules excised during mastectomy, 11 were obtained by partial resection on the same side as the main lesion (including extended resection of the main lesion in BCS) and 12 were obtained by partial resection on the side opposite to the main lesion. The other two nodules were obtained by echo-guided mammotome biopsy after surgery. The pathological diagnosis of the 44 nodules was non-specific in 11, fibrocystic disease in 4, fibroadenoma in 3, lobar hyperplasia in 2, non-invasive carcinoma in 2 and invasive carcinoma in 22. Seven of the 17 nodules suspected to be benign by CT were also examined histologically, and the diagnosis was non-specific in 4, fibroadenoma in 2 and ductal hyperplasia in 1. Histological examination of three of the eight nodules diagnosed as non-specific in CT resulted in a diagnosis of non-specific, ductal hyperplasia and non-invasive carcinoma in one case each.

Clinicopathology of Multiple Malignant Nodules Discovered by Preoperative Breast CT

Of the 407 cases examined by preoperative breast CT, 73 IEBNs were detected in 73 cases. Of these, 54 nodules were examined histologically, of which 25 (6% of all cases) were diagnosed as malignant and 29 as benign. The discovery rate of clinically and mammographically occult multiple lesions by preoperative breast CT was 6% (same breast:

Table 3. Histological diagnosis and clinical findings of IEBNs

	Histological diagnosis of IEBNs Number of patients(%)/median (range)		*P* value
	Malignant ($n = 25$)	Benign ($n = 25$)	
Age	51 (34–78)	57 (31–80)	0.88
Size of primary tumor	1.7 (0.5–3)	1.7 (0.9–3.1)	0.13
Size of IEBNs	0.9 (0.5–2)	0.75 (0.4–1.8)	0.31
Daughter nodule			
Present	6 (24)	4 (14)	0.34
Absent	19 (76)	25 (86)	
Localization			
Same quadrant	9 (36)	11 (38)	0.82
Other quadrant	10 (40)	13 (45)	
Opposite breast	6 (24)	5 (17)	
CT finding			
Suspicious malignant	24 (96)	20 (69)	0.024
Suspicious benign		7 (240)	
Non-specific	1 (4)	2 (7)	
Size of invasive carcinoma ($n = 22$)	0.6 (0.1–2.3)		
Size of non-invasive carcinoma ($n = 3$)	1 (1–3)		
Classification			
Multifocal lesion	6		
Multicentric lesions	17		
Intrabreast metastasis	2		

4.5%, opposite breast: 1.5%). Of the 25 nodules judged to be malignant, 22 were invasive carcinoma and three were non-invasive carcinoma. A comparison of the background factors between the lesions confirmed histologically to be malignant and benign is shown in Table 3. There were no significant differences in age, size of the main lesion, size of IEBN, presence or absence of daughter nodules, or localization between the two groups. CT findings differed between the two groups, and 20 of the 44 nodules suspected to be malignant by CT were histologically benign. Multiple malignant nodules were localized in the same quadrant as the main lesion in 9 cases, in other quadrants on the same side in 10 cases and in the opposite breast in 6 cases. The median pathological tumor size of invasive carcinoma ($n = 22$) was 0.6 cm (0.1–2.3 cm) and that of non-invasive carcinoma ($n = 3$) was 1 cm (1–3 cm). On pathological comparison with the main lesions, 6 nodules were diagnosed as multifocal lesions related to the main lesion, 2 as intra-breast metastases from the main lesion and 17 (11 in the same side as the main lesion and 6 in the opposite breast) as multicentric lesions.

Observation of the course of 19 of the 73 IEBNs was performed without histological examination. The median duration of follow-up was 28.7 months (10.9–53.0 months) and no nodule was diagnosed as malignant by histological examination or surgery during this period. The sensitivity, specificity and positive and negative accuracy of CT for detection of clinically or mammographically negative multiple lesions were 96.0, 93.7, 50.0 and 99.7%, respectively, where detection of IEBNs suspected to be malignant by CT is defined as positive, and detection of no IEBN, IEBNs suspected to be benign or non-specific IEBNs by CT is defined as negative.

DISCUSSION

The main reason for performing staging MRI mammography in addition to preoperative evaluation of breast cancer by conventional methods is to determine the extension of the lesion accurately. The presence of extended intraductal components (EICs) proximal to the resected stump in breast-conserving therapy and exposure of the resected stump are significant risk factors for local recurrence (3,4). Thus, determination of the resection boundary required to obtain a negative stump before BCS and a switch of the surgical

procedure to mastectomy for an expanded lesion are important for local control. MRI is more effective for determining extension of lesions accurately and detecting EICs compared to mammography and US (5–7), and this improves selection of patients for BCS and reduces the need for further mammary glandectomy and mastectomy in wide stump-positive cases (2,8).

There have been only a few reports on preoperative evaluation of lesion extension by breast CT, and these have been performed in a relatively small number of patients. Therefore, use of CT as a basis for navigation in surgery has not been examined extensively compared to MRI. The recent introduction of multidetector-row CT has markedly improved the performance of breast CT, and the sensitivity and specificity for detection of EICs by contrast-enhanced CT are now reported to be 82–88 and 75–89%, respectively (9–12), and those for detection of EICs and multiple lesions are 76–91% and 89–91, respectively, showing improved performance compared to mammography alone (10,11). Nakahara et al. (13). reported a comparative study of three-dimensional (3D) MRI and 3D helical CT for evaluation of lesion extension in breast cancer: in 50 cases of Tis-T2 primary breast cancer, the sensitivity, specificity and accuracy of 3D CT for detecting intraductal spread or DCIS were 71.9, 83.3 and 76.0%, respectively, and those for 3D MRI were 87.5, 61.1 and 78.0%, respectively. Three cases were overestimated by CT (6.0%) and seven by MRI (14.0%) and nine cases were underestimated by CT (18.0%) and 4 by MRI (8.0%). Therefore, Nakahara et al. (13) concluded that 3D helical CT may be an alternative to 3D MRI for preoperative assessment of breast cancer.

The second purpose of MRI mammography is the detection of multiple lesions that are undetectable by conventional methods. Additional malignant lesions were detected in the same breast in about 63% of patients with breast cancer diagnosed as solitary either clinically or by mammography in a pathological study reported by Holland et al. (14). The rates of mammographically and clinically occult multifocal or multicentric lesions identified by MRI have ranged from 16 to 38% (2,15–20). In a study conducted by the International Breast MRI Consortium (IBMC 6883), the detection rate of multiple lesions located more than 2 cm from the index lesion was investigated as a practical evaluation method, assuming that the surgical margin in BCS is 2 cm (21). In 426 patients with primary breast cancer, lesions located more than 2 cm from the index lesion were additionally detected by mammography in 7.5% of cases and by MRI in 18% of cases. Furthermore, occult lesions of breast cancer have been detected on the opposite side by MRI in 5–24% of patients diagnosed with a solitary breast tumor or a high-risk lesion (22–24).

There has been no systematic report on the detection of multiple lesions by breast CT. In our study, multiple clinically and mammographically occult lesions were detected in 6% of patients, with the lesions present in the same breast as the main lesion and on the opposite side in 4.5 and 1.5% of cases, respectively. These rates are lower than those detected by MRI, which may simply be due to the lower sensitivity of CT compared with MRI. However, the frequency of simultaneous multiple lesions varies depending on background factors (hereditary breast cancer, familial history and the presence of lobar carcinoma *in situ* on mammary gland biopsy), and results have varied even among studies by MRI. Therefore, a comparative study in the same subjects is required to conclude whether MRI or CT is superior for detecting mammographically occult lesions.

There are several pitfalls associated with MRI for staging of breast cancer. In addition to tumors, many benign lesions and normal breast tissue may show enhancement after administration of contrast material. Therefore, histological confirmation of suspected multifocal disease is required before a treatment decision is made. This may lead to an increase in breast biopsies of enhanced lesions that subsequently prove to be benign, and may compromise cosmetic results after breast conservation surgery. These concerns also apply to breast CT, since we found that only 55% of IEBNs suspected to be malignant by CT were histologically malignant, indicating that judgment of benignity or malignancy based on CT findings alone is inadequate and histological examination is also required. However, this results in almost half of patients undergoing an unnecessary biopsy. Detection of IEBNs by breast CT regardless of the presence or absence of multiple lesions also has a considerable mental effect on patients in deciding the surgical procedure. This is reflected by the mastectomy rate in patients with IEBNs being 13% higher than in those with no IEBN, compared to the 4.5% rate of discovery of occult lesions in the same breast by breast CT.

Our findings are also important with regard to avoidance of unnecessary mastectomy. Our data show that IEBNs suspected to be malignant can be detected by preoperative breast CT, but the accuracy is only 50%. Therefore, when such IEBNs are detected, medical staff should explain to the patient that the lesions are histologically benign in about half of cases detected by CT to avoid making the patient too anxious, and calmly recommend histological examination to avoid unnecessary mastectomy.

Performing breast MRI or CT in addition to conventional preoperative methods is useful for navigation in surgery with regard to local control of cancer, but it also has a negative aspect. Accurate determination of the extension of the lesion, maintenance of negativity of the stump and detection of occult lesions for removal by primary resection all increase the efficacy of treatment and theoretically decrease the local recurrence rate. However, postoperative irradiation and chemoendocrine therapy also affect local recurrence, and the scientific basis of use of breast MRI and CT to improve local control remains to be clarified (25). The advantages of CT over MRI are the far shorter time required for the examination and the capability of acquiring images in the supine position close to the posture in surgery, which allows surgeons to more easily view the resection procedure.

However, breast CT may be inferior to MRI in terms of radiation exposure. Berrington de González et al. (26). investigated the influence of diagnostic X-rays on carcinogenesis, mainly using epidemiological data from Japanese atomic bomb survivors, and found that the attributable risk of diagnostic X-rays was the highest (3.2%) in cancer patients in Japan, where the frequency of CT is high. This is a theoretical value, and there are many opposing arguments, but it is likely that the radiation dose in common CT studies increases the risk of cancer (27).

Overall, our findings show that performing breast CT in addition to conventional methods increases the rate of discovery of occult lesions. To establish the true significance of preoperative breast CT, it will be necessary to investigate its influence on local control, which is expected to be the most important advantage, and on esthetics, economic costs and long-term effects of X-ray exposure on carcinogenesis.

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Conflict of interest statement

None declared.

References

1. Esserman L, Hylton N, George T, Weidner N. Contrast-enhanced magnetic resonance imaging to assess tumor histopathology and angiogenesis in breast carcinoma. *Breast J* 1999;5:13–21.
2. Esserman L, Hylton N, Yassa L, Barclay J, Frankel S, Sickles E. Utility of magnetic resonance imaging in the management of breast cancer: evidence for improved preoperative staging. *J Clin Oncol* 1999;17:110–9.
3. Voogd AC, Peterse JL, Crommelin MA, Rutgers EJ, Botke G, Elkhuizen PH, et al. Histological determinants for different types of local recurrence after breast-conserving therapy of invasive breast cancer. Dutch Study Group on local Recurrence after Breast Conservation (BORST). *Eur J Cancer* 1999;35:1828–37.
4. Park CC, Mitsumori M, Nixon A, Recht A, Connolly J, Gelman R, et al. Outcome at 8 years after breast-conserving surgery and radiation therapy for invasive breast cancer: influence of margin status and systemic therapy on local recurrence. *J Clin Oncol* 2000;18:1668–75.
5. Amano G, Ohuchi N, Ishibashi T, Ishida T, Amari M, Satomi S. Correlation of three-dimensional magnetic resonance imaging with precise histopathological map concerning carcinoma extension in the breast. *Breast Cancer Res Treat* 2000;60:43–55.
6. Van Goethem M, Schelfout K, Kersschot E, Colpaert C, Verslegers I, Biltjes I, et al. MR mammography is useful in the preoperative locoregional staging of breast carcinomas with extensive intraductal component. *Eur J Radiol* 2007;62:273–82.
7. Berg WA, Gutierrez L, NessAiver MS, Carter WB, Bhargavan M, Lewis RS, et al. Diagnostic accuracy of mammography, clinical examination, US, and MR imaging in preoperative assessment of breast cancer. *Radiology* 2004;233:830–49.
8. Zhang Y, Fukatsu H, Naganawa S, Satake H, Sato Y, Ohiwa M, et al. The role of contrast-enhanced MR mammography for determining candidates for breast conservation surgery. *Breast Cancer* 2002;9:231–9.
9. Hiramatsu H, Enomoto K, Ikeda T, Mukai M, Furuta T, Hattori H, et al. Three-dimensional helical CT for treatment planning of breast cancer. *Radiat Med* 1999;17:35–40.
10. Akashi-Tanaka S, Fukutomi T, Miyakawa K, Uchiyama N, Tsuda H. Diagnostic value of contrast-enhanced computed tomography for diagnosing the intraductal component of breast cancer. *Breast Cancer Res Treat* 1998;49:79–86.
11. Uematsu T, Sano M, Homma K, Shiina M, Kobayashi S. Three-dimensional helical CT of the breast: accuracy for measuring extent of breast cancer candidates for breast conserving surgery. *Breast Cancer Res Treat* 2001;65:249–57.
12. Nishino M, Hayakawa K, Yamamoto A, Nakamura Y, Morimoto T, Mukaihara S, et al. Multiple enhancing lesions detected on dynamic helical computed tomography-mammography. *J Comput Assist Tomogr* 2003;27:771–8.
13. Nakahara H, Namba K, Wakamatsu H, Watanabe R, Furusawa H, Shirouzu M, et al. Extension of breast cancer: comparison of CT and MRI. *Radiat Med* 2002;20:17–23.
14. Holland R, Veling SH, Mravunac M, Hendriks JH. Histologic multifocality of Tis, T1-2 breast carcinomas. Implications for clinical trials of breast-conserving surgery. *Cancer* 1985;56:979–90.
15. Orel SG, Schnall MD, Powell CM, Hochman MG, Solin LJ, Fowble BL, et al. Staging of suspected breast cancer: effect of MR imaging and MR-guided biopsy. *Radiology* 1995;196:115–22.
16. Boetes C, Mus RD, Holland R, Barentsz JO, Strijk SP, Wobbes T, et al. Breast tumors: comparative accuracy of MR imaging relative to mammography and US for demonstrating extent. *Radiology* 1995;197:743–7.
17. Fischer U, Kopka L, Grabbe E. Breast carcinoma: effect of preoperative contrast-enhanced MR imaging on the therapeutic approach. *Radiology* 1999;213:881–8.
18. Mumtaz H, Hall-Craggs MA, Davidson T, Walmsley K, Thurell W, Kissin MW, et al. Staging of symptomatic primary breast cancer with MR imaging. *AJR Am J Roentgenol* 1997;169:417–24.
19. Krämer S, Schulz-Wendtland R, Hagedorn K, Bautz W, Lang N. Magnetic resonance imaging and its role in the diagnosis of multicentric breast cancer. *Anticancer Res* 1998;18:2163–4.
20. Weinstein SP, Orel SG, Heller R, Reynolds C, Czerniecki B, Solin LJ, et al. MR imaging of the breast in patients with invasive lobular carcinoma. *AJR Am J Roentgenol* 2001;176:399–406.
21. Schnall MD, Blume J, Bluemke DA, Deangelis GA, Debruhl N, Harms S, et al. MRI detection of distinct incidental cancer in women with primary breast cancer studied in IBMC 6883. *J Surg Oncol* 2005;92:32–8.
22. Liberman L, Morris EA, Kim CM, Kaplan JB, Abramson AF, Menell JH, et al. MR imaging findings in the contralateral breast of women with recently diagnosed breast cancer. *AJR Am J Roentgenol* 2003;180:333–41.
23. Lehman CD, Gatsonis C, Kuhl CK, Hendrick RE, Pisano ED, Hanna L, et al., ACRIN Trial 6667 Investigators Group.MRI evaluation of the contralateral breast in women with recently diagnosed breast cancer. *N Engl J Med* 2007;356:1295–303.
24. Pediconi F, Catalano C, Roselli A, Padula S, Altomari F, Moriconi E, et al. Contrast-enhanced MR mammography for evaluation of the contralateral breast in patients with diagnosed unilateral breast cancer or high-risk lesions. *Radiology* 2007;243:670–80.
25. Fischer U, Zachariae O, Baum F, von Heyden D, Funke M, Liersch T. The influence of preoperative MRI of the breasts on recurrence rate in patients with breast cancer. *Eur Radiol* 2004;14:1725–31.
26. Berrington de González A, Darby S. Risk of cancer from diagnostic X-rays: estimates for the UK and 14 other countries. *Lancet* 2004;363:345–51.
27. Brenner DJ, Hall EJ. Computed tomography-an increasing source of radiation exposure. *N Engl J Med* 2007;357:2277–84.