Using MRI to plan breast-conserving surgery following neoadjuvant chemotherapy for early breast cancer

M Bhattacharyya*1, D Ryan2, R Carpenter3, S Vinnicombe4 and CJ Gallagher1

1Department of Medical Oncology, St Bartholomew’s Hospital, West Smithfield, London EC1M 7BE, UK; 2Department of Histopathology, St Bartholomew’s Hospital, West Smithfield, London EC1M 7BE, UK; 3Department of Surgery, St Bartholomew’s Hospital, West Smithfield, London EC1M 7BE, UK; 4Department of Radiology, St Bartholomew’s Hospital, West Smithfield, London EC1M 7BE, UK

Contrast-enhanced magnetic resonance imaging (MRI) was used to monitor the response of patients undergoing neoadjuvant chemotherapy for breast cancer with the aim of undergoing breast-conserving surgery (BCS). Patients were prospectively recruited to undergo MRI as well as conventional methods of clinical examination, mammography (MM) and ultrasonography (USS) and response was assessed by each of these methods. Thirty-two patients with primary breast cancer were recruited. Magnetic resonance imaging correlation with histopathological size (r = 0.71) was superior to USS (r = 0.65) and to MM where tumour size was not measurable following chemotherapy in 71% of patients. Magnetic resonance imaging had 87.5% sensitivity (95% CI = 68–97%) and 50% specificity (95% CI = 16–84%) for a PPV (positive predictive value) of 99.8% and NPV (negative predictive value) of 80% for the detection of residual invasive cancer. Magnetic resonance imaging displayed 80% sensitivity (95% CI = 28.4–99.5%) and 89% specificity (95% CI = 71–98%) to detect pathological pCR in the breast. Eighty-four per cent of recruited patients were identified as potentially suitable candidates for BCS following chemotherapy and of those choosing to accept BCS, breast conservation was achieved in 90.5%, or 65.6% of all patients. Of those who proceeded to BCS, 9.5% required a re-do mastectomy because of positive margins; however, no residual tumour was found on histological examination of mastectomy specimens. Magnetic resonance imaging appears to be superior to conventional methods for assessing pathological response and the low rate of re-operation for positive margins indicates a valuable role in aiding the decision to undergo BCS or mastectomy.

British Journal of Cancer (2008) 98, 289 – 293. doi:10.1038/sj.bjc.6604171 www.bjcancer.com

Keywords: breast cancer; MRI; neoadjuvant chemotherapy; breast-conserving surgery

Pre-operative neoadjuvant chemotherapy has been an important development in the management of patients with early breast cancer. Although no more effective than post-operative treatment in improving survival, it has been shown to downstage large operable tumours, and increase the proportion of women who can be offered breast-conserving surgery (BCS), where previously a mastectomy would have been required (Hortobagyi et al, 1983). Neoadjuvant therapy also identifies the proportion of women achieving a complete pathological remission who are likely to have an excellent prognosis, and conversely, those for whom further treatment may be necessary (Feldman et al, 1986; Singletary et al, 2002).

Following neoadjuvant chemotherapy, accurate assessment of tumour size and location is necessary for planning the surgical management of the patient. There is a poor correlation between the histological appearances of the tumour and measurements obtained by physical examination, mammography (MM) or ultrasonography (USS). Radiological assessment is least accurate in younger women who most often desire BCS because their breast tissue is more dense making it more difficult to distinguish invasive cancer from residual in situ carcinoma and chemotherapy-induced fibrosis (Cocconi et al, 1984; Segel et al, 1988, Vinnicombe, 1996).

Limitations in tumour localisation may lead to a greater incidence of positive resection margins and the need for repeated excision or mastectomy in patients with a consequent failure to attain the desired goals of aesthetic breast conservation and optimum tumour control.

It has been suggested that breast magnetic resonance imaging (MRI) is more accurate in the diagnosis of primary breast cancer (Cocconi et al, 1984; Gilles et al, 1994; Abraham et al, 1996; Drew et al, 1999) and we therefore, wished to assess its use in the evaluation of tumour response and residual tumour size following chemotherapy when compared with conventional imaging. More accurate information may enable appropriate planning of surgery including BCS, minimising re-excision rates while maintaining the efficacy and possibility of cure.

Aims

This study was designed to assess the usefulness of MRI in measuring response to neoadjuvant chemotherapy and maximis-
patients who were judged potentially suitable for BCS, on the basis of clinical examination and radiological assessment. Of these, 21 proceeded with outcome surgery compared with the maximum tumour diameters observed with imaging, using the Pearson’s correlation coefficient.

RESULTS

Baseline characteristics

A total of 32 patients aged between 24 and 60 (median age 42 years) satisfied all inclusion criteria for the imaging study. Twenty-two (69%) were pre-menopausal and 10 (31%) were peri- or post-menopausal. Patients presented with Stage 1 (6%), Stage 2 (62%) and Stage 3 (31%) disease and median tumour size at presentation was 4.75 cm (range = 2–8 cm). Tumours were staged using the TNM classification (Singletary et al, 2002). All completed six cycles of anthracycline-based chemotherapy.

Response to chemotherapy

All 32 patients had MRI scans preceding neoadjuvant chemotherapy and at the completion of chemotherapy. Twenty-eight patients had mammograms and 30 had ultrasound scans pre- and post-chemotherapy. Pre- and post-chemotherapy measurements, for each imaging modality, are shown for each patient (Table 1). Response was assessed radiologically by RECIST criteria (Therasse et al, 2000) and clinical response, based on bi-dimensional measurement (Table 2). Mammography data were incomplete as it was not possible to measure the size of tumour after chemotherapy in 18 patients (56%) because the tumour margins were no longer assessable.

Correlation with histology

The pathological complete response rate (pCR) in the breast in this study was 12.5%. Seven patients had a complete radiological response as assessed by MRI. Pathological complete response was present in four of these patients and residual foci of invasive disease were seen in the remaining three patients measuring from 0.1 to 0.6 cm in diameter. Histological size and the size assessed by USS in these patients is shown (Table 3). It was therefore possible to detect pCR using MRI; however, MRI overestimated the rate of pCR.

The performance of the MRI scan in detecting residual invasive cancer was sensitivity 87.5% (95% CI = 67.6–97.3%), specificity 50% (95% CI = 15.7–84.2%) for a positive predictive value (PPV) of 99.8% and a negative predictive value (NPV) of 80%. For the detection of pCR the MRI scan performance was sensitivity 80% (95% CI = 28.4–99.5%), specificity 89% (95% CI = 70.8–97.6%) for a PPV of 56% and an NPV of 96%.

In four patients, the post-chemotherapy MRI residual tumour size was over 1 cm larger than pathological size. In each of these cases, histological evaluation revealed the presence of DCIS, which had an enhancement pattern on MRI that could not be differentiated from the invasive component (Table 3).

Overall, MRI correlation with histopathological size (r = 0.71) was superior to USS correlation (r = 0.65). Correlation could not be obtained for MM, as tumour size was not measurable in more than 50% of patients following chemotherapy.

Surgical outcome

Following neoadjuvant chemotherapy, 27 (84%) patients were judged potentially suitable for BCS, on the basis of clinical examination and radiological assessment. Of these, 21 proceeded...
to breast conservation and 4 patients changed their mind and chose to have mastectomy. Two patients who had no evidence of residual tumour on physical examination or radiological assessment underwent localisation biopsy and were therefore offered radiotherapy alone; however, localisation biopsy confirmed the absence of tumour.

Of the 21 patients who had BCS, 2 patients (10%) required subsequent mastectomy because of positive excision margins following the initial surgery. In one of these patients, the post-chemotherapy pre-operative MRI showed a partial response with a 3.6 by 2.7 cm area of gradual enhancement postero-lateral to the nipple thought likely to represent residual invasive disease whereas MM was normal and the USS showed a 0.3 cm hypoechoic lesion. Histology of the initial segmental mastectomy showed a 0.1-cm invasive tumour involving the margin and the patient proceeded to mastectomy, the histology of which showed no residual tumour. In the second patient, the MRI scan reported a partial response with an enhancing focus measuring 1.0 by 0.7 cm with no discernible tumour mass; the surrounding parenchyma displayed non-malignant enhancement, possibly due to chemotherapy-induced fibrosis or a residual intraduct component. In this patient, USS had shown a 1.7-cm mass. Histology of the segmental mastectomy showed a multifocal grade 2 infiltrating ductal carcinoma measuring 1.8 cm with associated low-grade cribriform DCIS with a tumour deposit in the medial en face surface. Histology from the mastectomy however showed no residual invasive cancer.

Nine patients had a mastectomy within this study. The reasons for proceeding to mastectomy are given and include patient’s choice, position of residual tumour and identification of residual multifocal tumour (Table 4).

In the three patients, who chose to have mastectomy, one had a complete response on MRI and histology and one had a small 1.5 cm tumour as predicted on MRI. However, in one patient, the post-chemotherapy tumour size on MRI was 5.6 cm preoperatively whereas the histology showed a 1.8-cm Grade 2 ductal carcinoma. In this patient, the MRI scan had not distinguished invasive tumour from the extensive DCIS seen on the histopathological specimen.

It was not possible to calculate the sensitivity and specificity of the MRI in predicting successful BCS as the MRI result was used to guide the decision; thus, no patients were considered for BCS in whom MRI was not thought to be favourable. This was further confounded by two patients who did not have surgery, and three patients who despite a favourable MRI result chose to have mastectomy.

The second and the third patients had a mastectomy within this study. The reasons for proceeding to mastectomy are given and include patient’s choice, position of residual tumour and identification of residual multifocal tumour (Table 4).

In the three patients, who chose to have mastectomy, one had a complete response on MRI and histology and one had a small 1.5 cm tumour as predicted on MRI. However, in one patient, the post-chemotherapy tumour size on MRI was 5.6 cm preoperatively whereas the histology showed a 1.8-cm Grade 2 ductal carcinoma. In this patient, the MRI scan had not distinguished invasive tumour from the extensive DCIS seen on the histopathological specimen.

It was not possible to calculate the sensitivity and specificity of the MRI in predicting successful BCS as the MRI result was used to guide the decision; thus, no patients were considered for BCS in whom MRI was not thought to be favourable. This was further confounded by two patients who did not have surgery, and three patients who despite a favourable MRI result chose to have mastectomy.

### Table 1

| Age (years) | Stage | Clinical diameter (cm) | MRI diameter (cm) | Mammo diameter (cm) | USS diameter (cm) | Surgery | Histology (cm) |
|------------|-------|------------------------|------------------|---------------------|-----------------|---------|----------------|
| 1          | 24    | T2N0                   | 5                | 4.5                 | NA              | 4.5     | BCS            |
| 2          | 41    | T3N0                   | 6                | 3                   | 3.5             | 2.8     | BCS            |
| 3          | 52    | T2N0                   | 4                | 3.5                 | 3               | 3.1     | BCS            |
| 4          | 48    | T2N0                   | 4                | 3.5                 | NA              | 3       | BCS            |
| 5          | 41    | T3N1                   | 5                | 4.5                 | 2               | 4       | BCS            |
| 6          | 55    | T3N1                   | 5                | 5                   | 5               | NA      | BCS            |
| 7          | 42    | T2N0                   | 5                | 2.3                 | 5               | NA      | BCS            |
| 8          | 43    | T2N0                   | 5                | 2.3                 | 5               | 5       | BCS            |
| 9          | 42    | T2N0                   | 5                | 2.7                 | NA              | 2.2     | BCS            |
| 10         | 40    | T2N0                   | 3                | 2                   | NA              | 2.3     | BCS            |
| 11         | 49    | T1N1                   | 2                | 2                   | NA              | 0.6     | Mastectomy     |
| 12         | 56    | T2N2                   | 3                | 2.3                 | 2               | 2       | BCS            |
| 13         | 35    | T2N0                   | 4.5              | 6                   | 6               | 4       | BCS            |
| 14         | 49    | T2N0                   | 3                | 3                   | 3               | 2.8     | BCS            |
| 15         | 55    | T3N1                   | 6                | 2                   | 6               | 3       | BCS            |
| 16         | 47    | T2N1                   | 5                | 2.3                 | NA              | NA      | BCS            |
| 17         | 60    | T2N1                   | 3                | 2.5                 | 2.5             | 2.5     | BCS            |
| 18         | 36    | T2N0                   | 4                | 2.4                 | 0               | 1.2     | BCS            |
| 19         | 50    | T2N2                   | 2                | 2.2                 | 2               | 2.1     | BCS            |
| 20         | 40    | T2N0                   | 2                | 2                   | 2               | 2.5     | BCS            |
| 21         | 35    | T3N1                   | 6                | 4.5                 | 3               | 4       | BCS            |
| 22         | 55    | T3N1                   | 5                | 5                   | NA              | 4       | BCS            |
| 23         | 33    | T2N0                   | 3.5              | 4                   | NA              | 3.7     | Mastectomy     |
| 24         | 37    | T3N1                   | 8                | 3.5                 | 4               | 3       | Mastectomy     |
| 25         | 35    | T1N2                   | 2                | 2.8                 | 2               | 2       | Mastectomy     |
| 26         | 47    | T3N1                   | 4                | 5                   | 4               | 3.9     | Mastectomy     |
| 27         | 53    | T3N1                   | 6                | 4                   | 3               | 2       | Mastectomy     |
| 28         | 33    | T2N0                   | 2                | 3.5                 | NA              | 3       | Mastectomy     |
| 29         | 33    | T3N1                   | 6                | 4                   | 5.5             | 5.2     | Mastectomy     |
| 30         | 25    | T3N0                   | 5                | 4                   | 5.5             | 5       | Mastectomy     |
| 31         | 31    | T3N1                   | 5                | 4                   | NA              | 4.5     | Mastectomy     |
| 32         | 45    | T2N0                   | 5                | 3                   | NA              | 3.7     | Mastectomy     |

**Table 2**

| Response to chemotherapy as measured clinically, by MRI, mammography and ultrasound, as assessed by RECIST criteria |
|---------------------------------------------------------------|
| Response           | Clinical diameter (cm) | MRI diameter (cm) | Mammo diameter (cm) | USS diameter (cm) |
| Complete response (CR) | 4 (12.5%)               | 7 (22%)           | 5 (16%)             | 5 (16%)          |
| Partial response (PR)    | 26 (81%)                | 17 (53%)          | 1 (3%)              | 17 (53%)        |
| Stable disease (SD)       | 2 (6%)                  | 8 (25%)           | 2 (6%)              | 4 (12.5%)       |
| Progressive disease (PD)  | 0                      | 0                 | 0                   | 0               |

Not measurable | 0 | 0 | 20 (62.5%) | 4 (12.5%) |

\(n = 32\) patients.
Clinical Studies

| Patient | MRI size (cm) | MRI report | Histology invasive cancer size (cm) | Histology report |
|---------|---------------|------------|------------------------------------|-----------------|
| 6       | 5.6           | Reduced tumour volume noted | 1.8 | Grade 2 infiltrating ductal carcinoma |
| 9       | 3             | Main tumour mass 3 cm, satellite areas and intraduct component | 1.4 | Grade 2 ductal carcinoma |
| 14      | 2             | 2 cm mass, striking surrounding distortion possible desmoplastic reaction or intraduct component | 0   | Residual DCIS only |
| 26      | 2.5           | Not all of mass enhances. Residual enhancing focus 10 mm. Enhancement of surrounding parenchyma either chemotherapy-induced fibrosis or residual intraductal component | 1.5 | Grade 3 infiltrating ductal carcinoma; surrounding high grade DCIS |

DISCUSSION

The use of breast MRI scanning in this group of women being considered for BCS after neoadjuvant chemotherapy led to a more accurate preoperative assessment of the response to MM or ultrasound. Magnetic resonance imaging detection of residual invasive disease in comparison with operative histology had a PPV of 99.8% and an NPV of 80%. However, as might be expected MRI did not perform as well in detecting complete pathological remissions with a PPV of 56% though the NPV was 96%.

The MRI correlation with histopathological size \( r = 0.71 \) is similar to that found previously with correlations of \( r = 0.75 \) (Rosen et al, 2003) and 0.72 (Martinich et al, 2004) reported. Other groups have reported correlations of \( r = 0.6 \) (Partridge et al, 2002) and \( r = 0.982 \) (Cheung et al, 2003).

Magnetic resonance imaging was superior to ultrasound for assessment of tumour size \( r = 0.61 \) and to physical examination. Mammography was found to be unreliable in the assessment of preoperative tumour size because of the inability to define the tumour margins.

All patients were fully informed about their treatment options and were supported by a breast care nurse so that they could participate in the decisions about their treatment. As a result of our policy of neoadjuvant chemotherapy (that excluded all T4 tumours) BCS was achieved in 19 out of 32 (59.4%) patients for whom mastectomy would have otherwise been necessary. Mastectomy was still required in eight (25%) patients to achieve optimum local tumour control. The remaining five patients (15.6%) were rendered suitable for BCS but chose mastectomy (three patients), or radiotherapy only (two patients).

Breast MRI has been found to be very sensitive for the detection of primary invasive breast cancer but less is known about the accuracy of MRI for detecting residual disease after chemotherapy as cytotoxic agents may affect the dynamics of contrast uptake (Gilles et al, 1994; Orel et al, 1995; Hunt et al, 1996; Fisher et al, 1998; Partridge et al, 2002; Bedrosian et al, 2003).

In breast conservation, positive margins are associated with an increased long-term risk of cancer recurrence in the ipsilateral breast (Fourquet et al, 1989; Anscher et al, 1993; Pfitzinger et al, 1994; Dewar et al, 1995; Gage et al, 1996; Wazer et al, 1998; Freedman et al, 1999; Cowen et al, 2000) and, therefore, patients with positive margins, following BCS, require further surgery. In our series, the re-operation rate was 9.5% (two patients) but no histological evidence of residual tumour was found on the mastectomy specimen.

Accurate assessment of tumour response to chemotherapy may correctly identify which patients are suitable candidates for BCS, minimising the rates of re-excision surgery, thereby minimising risk and distress to the patient caused by repeated surgical procedures. Physical examination and conventional imaging are unable to reliably predict the presence or extent of residual or recurrent disease.

Several studies have suggested that MRI is a more accurate method of delineating residual tumour following neoadjuvant chemotherapy than clinical, ultrasound or mammographic assessment (Boetes et al, 1995; Abraham et al, 1996; Drew et al, 1999, 2001; Fischer et al, 1999; Balu-Maestro et al, 2002; Rieber et al, 2002; Cheung et al, 2003; Rosen et al, 2003; Martinich et al, 2004; Warren et al, 2004). Chemotherapy-induced fibrosis has been shown to impair the evaluation of tumour by conventional radiological methods and physical examination (Cocconi et al, 1984; Segel et al, 1988). We also found that similar factors together with the presence of extensive DCIS limited to the interpretation of the MRI scans.

The final decision to undertake BCS is a complex mixture of surgical judgement and patient’s expectations and desires, so we were not able to assess in this study how much it had been advanced by MRI scanning. The low rate of re operation for positive margins (2 out of 21 9.52%) may be one measure of success and compares favourably with other reported series however longer term follow-up will be necessary to assess local recurrence rates and overall survival.

REFERENCES

Abraham DG, Jones RC, Jones SE, Cheek JH, Peters GN, Knox SM, Grant MD, Hampe DW, Savino DA, Harms SE (1996) Evaluation of neoadjuvant chemotherapeutic response of locally advanced breast cancer by magnetic resonance imaging. Cancer 78: 91 – 100

Anscher MS, Jones P, Prosnitz LR, Blackstock W, Hebert M, Reddick R, Tucker A, Dodge R, Leight Jr G, Iglehart JD et al. (1993) Local failure and margin status in early-stage breast carcinoma treated with conservation surgery and radiation therapy. Ann Surg 218: 22 – 28
Balu-Maestro G, Chapelleir C, Bleuse A, Chanale I, Chaurael C, Largillier R (2002) Imaging in evaluation of response to neoadjuvant breast cancer treatment benefits of MRI. Breast Cancer Res Treat 72: 145 – 152
Bedrosian I, Mick R, Orel SG, Schnall M, Reynolds C, Spitz FR, Callans LS, Bazby GP, Rosato EF, Fraker DL, Czerniecki BJ (2003) Changes in the surgical management of patients with breast carcinoma based on preoperative magnetic resonance imaging. Cancer 98: 468 – 473
Boetes C, Mus BD, Holland B, Barentsz JO, Strijp SP, Wobbes T, Hendriks JH, Ruys SH (1995) Breast tumors: comparative accuracy of MR imaging relative to mammography and US for demonstrating extent. Radiology 197: 743 – 747
Cheung YC, Chen SC, Su MY, See LG, Hsueh S, Chang HK, Lin YC, Tsai CS (2003) Monitoring the size and response of locally advanced breast cancers to neoadjuvant chemotherapy (weekly paclitaxel and epirubicin) with serial enhanced MRI. Breast Cancer Res Treat 78: 51 – 58
Cocconi G, Di Blasio B, Alberti G, Bisagni G, Botti E, Peracchia G (1984) Problems in evaluating response of primary breast cancer to systemic therapy. Breast Cancer Res Treat 4: 309 – 313
Cowen D, Hovuenaehgel B, Bardou V, Jacquemier J, Bautrant E, Conte M, Viens P, Largillier R, Puig B, Resbeut M, Maraninchi D (2000) Local and distant failures after limited surgery with positive margins and radiotherapy for node-negative breast cancer. Int J Radiat Oncol Biol Phys 47: 305 – 312
Dewar JA, Arriagada R, Benhamou S, Benhamou E, Brelet JJ, Pellae-Cosset B, Martin JL, Petit JJ, Contesso G, Sarrazin D (1995) Local relapse and contralateral tumor rates in patients with breast cancer treated with conservative surgery and radiotherapy (Institut Gustave Roussy 1970 – 1982). IGR breast cancer group. Cancer 76: 2260 – 2265
Drew PJ, Chatterjee S, Turnbull LW, Read J, Carleton PJ, Fox JN, Monson JR, Kerin MJ (1999) Dynamic contrast enhanced magnetic resonance imaging of the breast is superior to triple assessment for the pre-operative detection of multifocal breast cancer. Ann Surg Oncol 6: 599 – 603
Drew PJ, Kerin MJ, Mahapatra T, Malone C, Monson JR, Turnbull LW, Fox JN (2001) Evaluation of response to neoadjuvant chemoradiotherapy for locally advanced breast cancer with dynamic contrast-enhanced MRI of the breast. Eur J Surg Oncol 27: 617 – 620
Feldman LD, Hortobagyi GN, Buzdar AU, Ames FC, Blumenschein GR Jr AB, Hoehn JL, Lees AW, Dimitrov NV, Bear HD (1998) Effect of preoperative chemotherapy on the outcome of women with operable breast cancer. J Natl Cancer Inst 90: 1125 – 1131
Fischer U, Kopka L, Grabbe E (1999) Breast carcinoma: effect of primary breast cancer to systemic therapy. Eur J Surg Oncol 25: 627 – 628
Fouquet A, Campana F, Zafraeni B, Mosseri V, Viell P, Durand JC, Vilcoq JR (1989) Prognostic factors of breast recurrence in the conservative management of early breast cancer: a 25-year follow-up. Int J Radiat Oncol Biol Phys 17: 719 – 725
Gage I, Schnitt SJ, Nixon AJ, Silver B, Recht A, Troyan SL, Eberlein T, Love SM, Gelman R, Harris JR, Connolly JL (1996) Pathologic margin involvement and the risk of recurrence in patients treated with breast-conserving therapy. Cancer 78: 1921 – 1928
Gilles R, Guinebretiere JM, Toussaint C, Spielman M, Rietjens M, Petit JY, Contesso G, Masselot J, Vanel D (1994) Locally advanced breast cancer: contrast-enhanced subtraction MR imaging of response to preoperative chemotherapy. Radiology 191: 633 – 638
Hortobagyi GN, Blumenschein GR, Spanos W, Montague ED, Buzdar AU, Yap HY, Schell F (1983) Multimodal treatment of locoregionally advanced breast cancer. Cancer 51: 763 – 768
Hunt KK, Ames FC, Singletary SE, Buzdar AU, Hortobagyi GN (1996) Locally advanced noninflammatory breast cancer. Surg Clin North Am 76: 393 – 410
Martincich L, Montemurro F, De Rosa G, Marra V, Ponzone R, Cirillo S, Gatti M, Biglia N, Sarotto I, Sismendi P, Regge D, Aglietta M (2004) Monitoring response to primary chemotherapy in breast cancer using dynamic contrast-enhanced magnetic resonance imaging. Breast Cancer Res Treat 83: 67 – 76
Orel SG, Schnall MD, Powell CM, Hochman MG, Solin LJ, Fowble BL, Torosian MH, Rosato EF (1995) Staging of suspected breast cancer: effect of MR imaging and MR-guided biopsy. Radiology 196: 115 – 122
Partridge SC, Gibbs JE, Lu Y, Esserman LJ, Sudilovsky D, Hylton NM (2002) Accuracy of MR imaging for revealing residual breast cancer in patients who have undergone neoadjuvant chemotherapy. AJR Am J Roentgenol 179: 1193 – 1199
Pilttinger TP, Moronnic NC, Poulter CA, Peacock JL (1994) Importance of margin status in outcome of breast-conserving surgery for carcinoma. Surgery 116: 605 – 608; discussion 608-9
Rieber A, Brumbs HJ, Gabelmann A, Heilmann V, Kreienberg R, Kuhn T (2002) Breast MRI for monitoring response of primary breast cancer to neo-adjuvant chemotherapy. Eur Radiol 12: 1711 – 1719
Rosen EL, Blackwell KL, Baker JA, Soo MS, Bentley RC, Yu D, Samulski TV, Dewhirst MW (2003) Accuracy of MRI in the detection of residual breast cancer after neoadjuvant chemotherapy. AJR Am J Roentgenol 181: 1275 – 1282
Segel MC, Paulus DD, Hortobagyi GN (1988) Advanced primary breast cancer: assessment at mammography of response to induction chemotherapy. Radiology 169: 49 – 54
Singletary SE, Allred C, Ashley P, Bassett LW, Berry D, Bland KI, Borgen PI, Clark G, Edge SB, Hayes DF, Hughes LL, Hutter RV, Morrow M, Page DL, Recht A, Theriault RL, Thor A, Weaver DL, Wieden HS, Greene FL (2002) Revision of the American joint committee on cancer staging system for breast cancer. J Clin Oncol 20: 3628 – 3636
Therasse P, Arbuck SG, Eisenhauer EA, Wanders J, Kaplan RS, Rubinstein L, Verweij J, Van Glabbeke M, van Oosterom AT, Christian MG, Gwyther SG (2000) New guidelines to evaluate the response to treatment in solid tumors. European organization for research and treatment of cancer, national cancer institute of the United States, national cancer institute of Canada. J Natl Cancer Inst 92: 205 – 216
Vinnicombe S (1996) Primary breast cancer; mammographic changes after neoadjuvant chemotherapy with pathological correlation. Radiology 198: 331 – 340
Warren RM, Bobrow LG, Earl HM, Britton PD, Gopalani D, Purushotham AD, Wishart GC, Benson JR, Hollingworth W (2004) Can breast MRI help in the management of women with breast cancer treated by neoadjuvant chemotherapy? Br J Cancer 90: 1349 – 1360
Wazer DE, Schmidt-Ullrich RR, Ruthazer R, Schmid GH, Graham R, Safaai H, Rothschild J, McGrath J, Erban JK (1998) Factors determining outcome for breast-conserving irradiation with margin-directed dose escalation to the tumor bed. Int J Radiat Oncol Biol Phys 40: 851 – 858