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Use of Magnetic Resonance Imaging for Evaluating Residual Breast Tissue After Robotic-Assisted Nipple-Sparing Mastectomy in Women With Early Breast Cancer

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Objective: Prospective studies on postoperative residual breast tissue (RBT) after robotic-assisted nipple-sparing mastectomy (R-NSM) for breast cancer are limited. RBT presents an unknown risk of local recurrence or the development of new cancer after curative or risk-reducing mastectomies. This study investigated the technical feasibility of using magnetic resonance imaging (MRI) to evaluate RBT after R-NSM in women with breast cancer.

Materials and Methods: In this prospective pilot study, 105 patients, who underwent R-NSM for breast cancer at Changhua Christian Hospital between March 2017 and May 2022, were subjected to postoperative breast MRI to evaluate the presence and location of RBT. The postoperative MRI scans of 43 patients (age, 47.8 ± 8.5 years), with existing preoperative MRI scans, were evaluated for the presence and location of RBT. In total, 54 R-NSM procedures were performed. In parallel, we reviewed the literature on RBT after nipple-sparing mastectomy, considering its prevalence.

Results: RBT was detected in 7 (13.0%) of the 54 mastectomies (6 of the 48 therapeutic mastectomies and 1 of the 6 prophylactic mastectomies). The most common location for RBT was behind the nipple-areolar complex (5 of 7 [71.4%]). Another RBT was found in the upper inner quadrant (2 of 7 [28.6%]). Among the six patients who underwent RBT after therapeutic mastectomies, one patient developed a local recurrence of the skin flap. The other five patients with RBT after therapeutic mastectomies remained disease-free.

Conclusion: R-NSM, a surgical innovation, does not seem to increase the prevalence of RBT, and breast MRI showed feasibility as a noninvasive imaging tool for evaluating the presence and location of RBT.

Keywords: Robotic-assisted nipple-sparing mastectomy (R-NSM); Breast magnetic resonance imaging (MRI); Residual breast tissue (RBT); Breast cancer; Local recurrence

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INTRODUCTION

Although the association between residual breast tissue (RBT) and disease recurrence has not been proven till date, the amount of residual glandular tissue as detected by conservative mastectomy (e.g., skin- or nipple-sparing mastectomy [NSM]) has become a growing research topic [1-4]. Recurrence after therapeutic or prophylactic mastectomies has been attributed to substantial amounts of RBT; therefore, avoiding RBT may be crucial for the effectiveness of mastectomies [5-7].

With advances in the da Vinci surgical system (Intuitive Surgical), the robotic-assisted NSM (R-NSM) is equipped with three-dimensional (3D) imaging and instrument flexibility, resulting in a small and inconspicuous scar with a good cosmetic outcome [8-11]. Recent studies have also shown that R-NSMs are safe and feasible for patients with early breast cancer [11-15]. Despite the increasing number of R-NSM procedures performed worldwide [13,16], few studies have investigated the risk of RBT occurrence in patients receiving R-NSM. In addition, the outcome of R-NSM, in terms of breast tissue clearance, remains understudied. Thus, this prospective study investigated the technical feasibility of magnetic resonance imaging (MRI) in evaluating RBT after R-NSM for breast cancer.

MATERIALS AND METHODS

To evaluate the risk of RBT after R-NSM, this prospective pilot study, which aimed to examine at least 50 breasts, after R-NSM, using breast MRI was conducted at Changhua Christian Hospital in Taiwan. Following its approval by the Institutional Review Board of Changhua Christian Hospital (No. 201242), patients who had undergone R-NSM for breast cancer at our institute were invited to undergo postoperative breast MRI to evaluate the presence and location of RBT. Written informed consent for using clinical records was obtained from each participant.

To assess the presence of RBT after R-NSM, preoperative and postoperative breast MRI scans were carefully compared and analyzed. The preoperative MRI establishes the baseline characteristics of the patient's fibroglandular tissue. The clinicopathological characteristics of the patients, presence of RBT on MRI, any disease recurrence or distant metastasis, and survival status at the last follow-up, which ended on March 31, 2023, were collected by specially trained nurses and subsequently confirmed by the principal investigator.

Between March 2017 and May 2022, we enrolled 105 R-NSM procedures were performed at Changhua Christian Hospital. Finally, 40 disease-free patients (51 mastectomies) and 3 patients (three mastectomies) with local recurrence. The study design and patient allocation are shown in Figure 1.

Robotic-Assisted NSM Technique

The inclusion and exclusion criteria for N-RSM were based on the current breast cancer treatment guidelines [10,11,14,15]. The surgical technique used for R-NSM in the present study is described in previous studies by our experienced breast surgeon (HWL) [10,17]. Common incisions for R-NSM, including axillary or lateral chest incisions, were made as per the case requirement. Breast reconstruction after R-NSM can be performed using an implant (cohesive gel implant or tissue expander) or autologous tissues with a latissimus dorsi flap or abdominal flap, according to the patient's needs.

MRI Protocol

All pre- and postoperative breast MRI scans were performed using a Siemens MAGNETOM Verio 3.0 Tesla MRI machine (Siemens Health Care). All patients were imaged in the prone position, with both breasts placed in a dedicated 16-channel breast coil. The preoperative and postoperative breast MRI protocols are given elsewhere [18]. To assess the presence of RBT after R-NSM, the postoperative MRI protocols additionally included the acquisition of 3D T1-weighted sequences with the GeneRalized Autocalibrating Partial Parallel Acquisition technique, a 1-mm slice thickness with no gap, and without fat suppression (repetition time/echo time [TR/TE], 4.8/2.37 ms; field of view, 320 mm; matrix, 381 x 448; voxel size, 0.6 x 0.6 x 1; number of excitations, 1).

Image Analysis

All MRI examinations were subsequently processed using a commercially available workstation (DynaCAD; Invivo) to generate multivendor 3D multiplanar reformatted, subtracted, and maximum-intensity projection images. Postoperative T1-weighted images were evaluated for RBT owing to the characteristic morphology of the fibroglandular tissues, which comprises a mixture of patchy and linear hypointensities as compared to the surrounding hyperintense fatty tissues. The presence and location of RBT were recorded. Whole-breast MRI readings were obtained by an experienced board-certified breast radiologist.

Statistical Analyses

Data were expressed as means ± standard deviations for continuous variables. Categorical variables were compared using the Fisher's exact test. Statistical analyses were performed using Statistical Product and Service Solutions (SPSS) for Windows (Version 19.0; IBM Corp.).

RESULTS

In total, 54 R-NSM procedures were performed in 43 patients (11 with bilateral mastectomies) who underwent postoperative MRI to evaluate the risk of RBT (Fig. 1). The mean age of patients at surgery was 47.8 ± 8.5 years (range, 34–67 years). Of the 54 R-NSM cases, 48 (88.9%) underwent therapeutic mastectomies for breast cancer

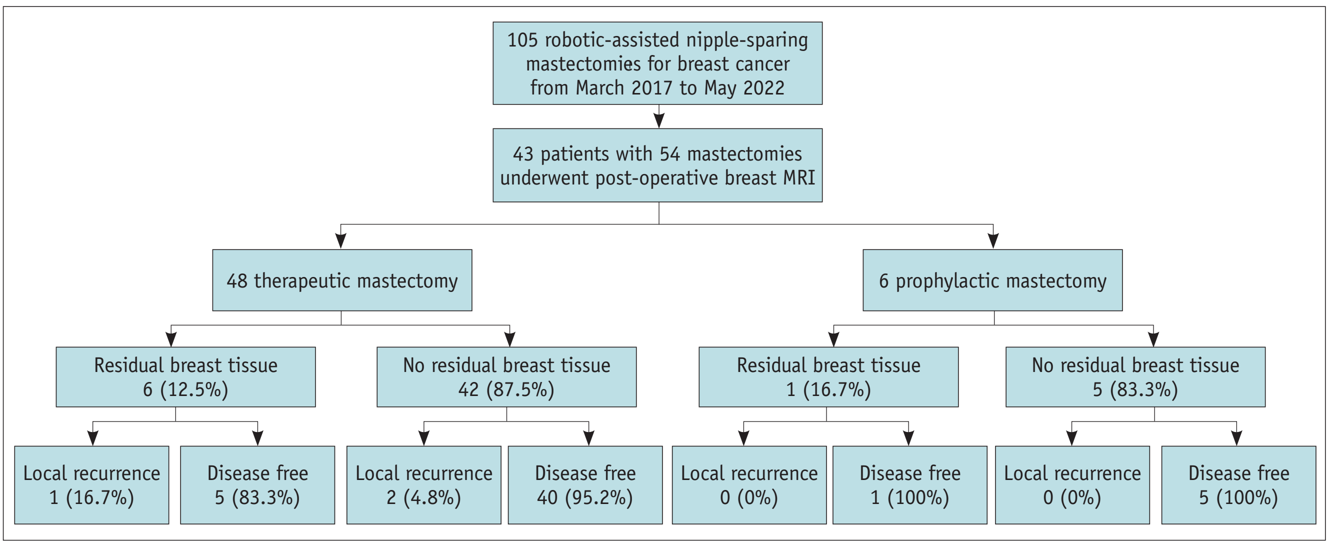

Fig. 1. Flow chart of study population selection. Forty-three patients with 54 robotic-assisted nipple-sparing mastectomies (R-NSM) were enrolled in this study, including 48 therapeutic R-NSM and 6 prophylactic R-NSM. MRI = magnetic resonance imaging

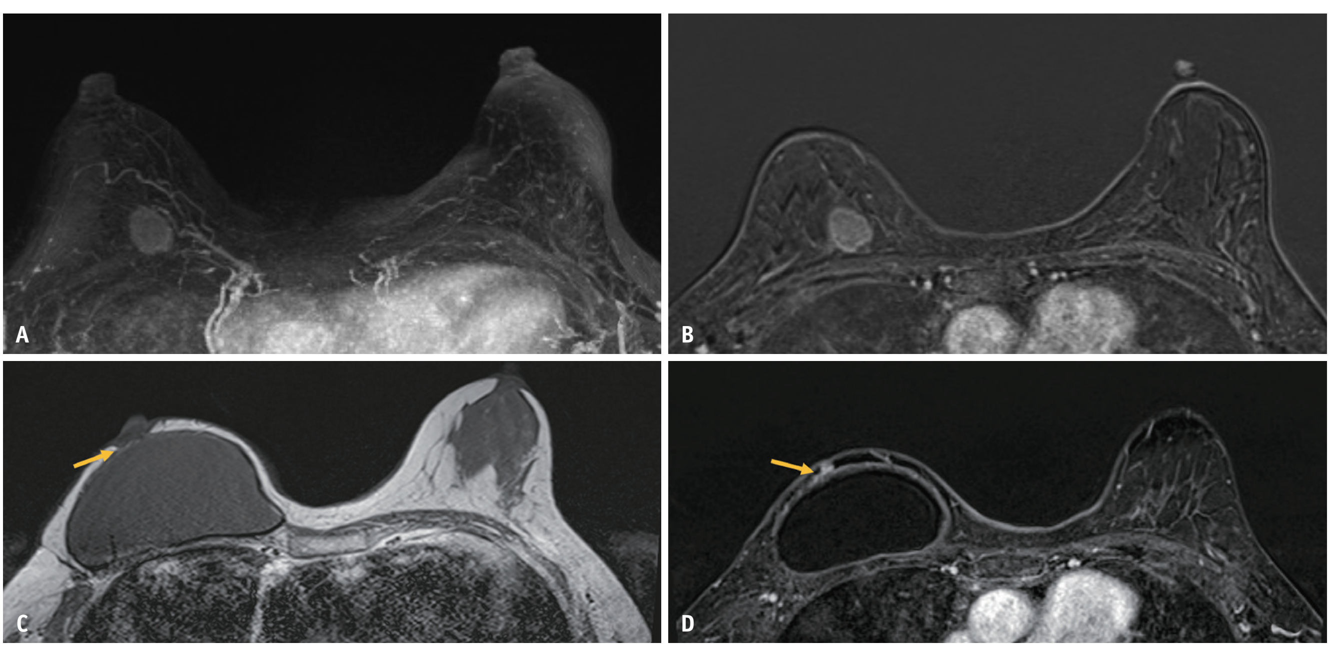

Fig. 2. Pre- and postoperative magnetic resonance imaging (MRI) of a right-sided robotic-assisted nipple-sparing mastectomy and immediate gel implant breast reconstruction with local recurrence at skin flap and residual breast tissue (RBT) at nipple areolar complex. **A, B:** Preoperative breast MRI shows a round invasive carcinoma in the upper inner quadrant of the right breast. **C:** Postoperative breast MRI after mastectomy and implant reconstruction. RBT is identified at the areolar site (arrow). **D:** Postoperative breast MRI shows a small, enhancing tumor recurrence (arrow) anterior to the implant. The local recurrence is at the skin flap site, which did not develop from the RBT.

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and 6 (11.1%) underwent risk-reducing contralateral prophylactic mastectomies. Immediate breast reconstruction was performed in 52 patients with R-NSM (96.3%) (Fig. 2 and Supplementary Fig. 1). The clinical and demographic characteristics of the patients are presented in Table 1.

Table 1. Patient Characteristics (54 R-NSM in 43 Patients) Enrolled in This Study

Characteristics	Values
Age, yr	47.8 ± 8.5
BMI, kg/m^2	22.8 ± 3.8
Mastectomy indication	
Therapeutic	48 (88.9)
Prophylactic	6 (11.1)
Location	
Left	27 (50)
Right	27 (50)
Breast cup size* (NA = 5)	
A	11 (22.4)
B	18 (36.7)
C	13 (26.5)
D	7 (14.3)
Pathologic tumor size, cm	2.5 ± 2.5
Pathologic stage† (NA = 6)	
0	11 (22.9)
I	13 (27.1)
IIa	13 (27.1)
IIb	5 (10.4)
IIIa	6 (12.5)
Lymph node metastasis† (NA = 6)	
Yes	16 (33.3)
No	32 (66.7)
Lymph node stage† (NA = 6)	
N0	32 (66.7)
N1	12 (25.0)
N2	4 (8.3)
Reconstruction	
Yes	52 (96.3)
Gel implant	50 (92.6)
TRAM flap	1 (1.9)
LD flap	1 (1.9)
No	2 (3.7)
Perioperative parameters	
Total operation time, min	204 ± 81.7
Blood loss, mL	41 ± 23
Mean mastectomy weight, g	279 ± 133
Implant volume, mL	338 ± 81
Follow-up length, month	49.3 ± 22

Data are mean ± standard deviation or number (%). *The breast cup size of five cases is not recorded, †Forty-eight therapeutic R-NSM were enrolled in this study. R-NSM = robotic-assisted nipple-sparing mastectomy, BMI = body mass index, NA = not available, TRAM flap = transverse rectus abdominis myocutaneous flap, LD flap = latissimus dorsi flap

Of the 54 mastectomies analyzed, RBT was detected in 7 cases (13.0%): 6 of 48 therapeutic mastectomies (12.5%) and 1 of 6 prophylactic mastectomies (16.7%) (Fig. 1). The RBT was located in the areolar region (5/7 [71.4%]) and upper inner quadrant (2/7 [28.6%]). A literature review of RBT for patients receiving R-NSM or conventional NSM was performed (Table 2), and 37.9%–100% RBT incidence was reported in different study groups.

In our study, three patients developed local recurrence. One of seven (14.3%) R-NSMs treated with RBT developed local recurrence in the skin flap. In this case, although RBT was detected in the areolar region, a small tumor recurrence was found anterior to the implant and therefore was not considered to originate from the RBT (Fig. 2). In the remaining 47 R-NSMs that did not undergo RBT, 2 (4.3%) developed local recurrence, without a significant difference from those who underwent RBT (P = 0.346). These three patients received wide excision of the recurrent tumors and had post-mastectomy radiotherapy. Subsequently, none of the patients had disease recurrence or distant metastases and were regularly followed up.

DISCUSSION

As a surgical innovation in modern NSM techniques, the presence of RBT after R-NSM is possible but has not been widely studied. Park et al. [4] evaluated the presence of RBT after robotic mastectomy by performing R-NSM in five cadaveric breasts to detect RBT in 15.7% of all biopsies (11/70), all detected behind the nipple-areolar complex (NAC) tissues, although no histologically detectable RBT was found in the skin flap. To our knowledge, this is the first study to evaluate the risk of RBT in patients with breast cancer receiving R-NSM. Among the evaluated 54 breasts, 7 (13%) that underwent R-NSM were associated with RBT.

In our study, of the seven patients who underwent RBT, five (71.4%) underwent RBT in the areolar region, which is consistent with previous reports [2,19,20]. The subareolar region can be a challenging area for dissection during NSM because of the lack of Cooper's ligaments under the NAC [21]. The potential benefit of completely retrieving breast tissue from the areolar region during NSM is that it can help ensure the complete removal of the breast tissue and reduce the risk of cancer recurrence. Conversely, completely retrieving breast tissue in the areolar region during NSM may increase

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Table 2. Literature Reviews about RBT after NSM or R-NSM

Author	Year	Number of Breasts Evaluated	Indications	Surgical Procedure	Diagnostic Method	Measures of RBT	Number of RBT Positive Procedures	RBT Identification Rate
Giannotti et al. [20]	2018	248	Therapeutic/prophylactic	NSM	MRI (T1WI)	Qualitative	183	71.8%
Woitek et al. [2]	2018	16	Therapeutic	NSM	MRI (T1WI and T2WI)	Quantitative	8	50%
Papassotiropoulos et al. [27]	2019	61	Therapeutic/prophylactic	NSM	Biopsy	Qualitative	42	68.9%
Grinstein et al. [28]	2019	338	Therapeutic/prophylactic	NSM	MRI (T2WI)	Quantitative	128	37.9%
Park et al. [4]	2021	5	Therapeutic	R-NSM	Full-thickness Biopsy	Qualitative	11 of the 70 biopsies taken from 5 breasts	15.7% (11/70) per biopsy 100% (5/5) per breast
Wu et al. (present study)	2023	54	Therapeutic/prophylactic	R-NSM	MRI (T1WI)	Qualitative	7	13.0%

RBT = residual breast tissue, NSM = nipple-sparing mastectomy, R-NSM = robotic-assisted nipple-sparing mastectomy, MRI = magnetic resonance imaging, T1WI = T1-weighted images, T2WI = T2-weighted images

the risk of complications, such as nipple necrosis, infection, and scarring, which can have negative cosmetic effects. Novel NSM techniques such as endoscopic or robotic-assisted NSM aim to leave as little residual glandular tissue as possible while preventing total nipple necrosis.

Preoperative staging breast MRI has proven valuable and is endorsed by official guidelines [22-24]. Breast MRI provides substantial information about the size, location, and extent of the tumor as well as the involvement of nearby lymph nodes. Preoperative breast MRI is performed in certain patients with breast cancer, such as those with a high risk of recurrence, those with a known or suspected multifocal or multicentric disease, and those with dense breast tissue. Postoperative breast MRI is not generally recommended as a routine tool for the follow-up of this population. However, because the treated breast undergoes significant anatomical and histological changes after surgery, breast MRI has emerged as a valuable adjunct tool for breast evaluation in patients post-surgery. Additionally, postoperative breast MRI could be a reliable non-invasive imaging modality for evaluating the potential presence of RBT in postoperative breasts. Breast MRI can detect RBT in 50%–100% of all NSM cases, especially behind the NAC region or those with thicker skin flaps (> 5 mm) [2,19,20]. When radiologists study the postoperative breast MRI of patients after NSM, RBT evaluation can also be performed simultaneously.

In the present study, RBT detected by postoperative MRI was 12.5% (6/48) for therapeutic mastectomies and 16.7% (1/6) for prophylactic mastectomies, which was not as high as the reported 37.9%–100% of RBT in cases of conventional NSM evaluated by MRI [2,20] (Table 2). During R-NSM, we applied the tunneling technique followed by superficial dissection. As the dissection progressed across the breast, the procedure became easier because of the enlarged optical space. However, this is different from conventional NSM, where dissection becomes increasingly challenging as we move further from the access incision [25], which may contribute to the relatively higher frequency of RBT as detected in conventional open NSM. Considering the prevalence through our literature review, our data suggest acceptable results for RBT after R-NSM. However, owing to the small sample size included in this study, this result and any further risk of breast cancer should be justified by future studies.

Among the three patients who developed local recurrence in our study, one was found in the group with RBT, which constituted 14.3% (1/7) of patients, whereas two were observed in the group without RBT, representing 4.3% (2/47) of patients. The difference in the local recurrence rates between the two groups was not statistically significant ($P = 0.346$). In cases where the RBT was present and local recurrence occurred, the recurrent tumor did not develop from the RBT and was located far away from it (Fig. 2). These findings suggest that local recurrence is not related to RBT, as many other factors contribute to local recurrences, such as metastasis caused by inoculation, tumor biology, lymphogenic spread, and incomplete removal of carcinoma [26-28].

Our current study had a limitation. We examined few patients, giving rise to possible selection bias, considering that not all R-NSM cases were evaluated. However, our study enrolled 43 breast cancer patients with preoperative and postoperative breast MRIs, which enabled us to objectively evaluate the risk of RBT in 54 breasts, post-R-NSM. A larger, corroborating study is currently ongoing to further examine the utility of breast MRI for RBT detection in breast cancer patients who underwent R-NSM and conventional NSM for local disease recurrence.

In conclusion, R-NSM could safely excise most of the breast tissue, leaving a minimal risk of RBT. Thus, R-NSM, which is a surgical innovation, did not increase the prevalence of RBT, and breast MRI showed feasibility as a noninvasive imaging tool for evaluating the presence and location of RBT.

Supplement

The Supplement is available with this article at https://doi.org/10.3348/kjr.2022.0708.

Availability of Data and Material

The datasets generated or analyzed during the study are available from the corresponding author on reasonable request.

Conflicts of Interest

The authors have no potential conflicts of interest to disclose.

Author Contributions

Conceptualization: Joseph Lin, Hung-Wen Lai. Data curation: Chiung-Ying Liao, Joseph Lin, Hung-Wen Lai, Chen-Te Chou. Formal analysis: Joseph Lin. Funding acquisition: Hung-Wen Lai. Investigation: Wen-Pei Wu, Chiung-Ying Liao, Chen-Te Chou. Methodology: Wen-Pei Wu, Joseph Lin, Hung-Wen Lai, Shou-Tung Chen, Chen-Te Chou, Dar-Ren Chen. Project administration: Wen-Pei Wu. Resources: Hung-Wen Lai, Shou-Tung Chen, Dar-Ren Chen. Software: Wen-Pei Wu, Chiung-Ying Liao, Hsin-I Huang. Supervision: Hung-Wen Lai, Shou-Tung Chen, Chen-Te Chou, Dar-Ren Chen. Validation: Wen-Pei Wu, Chiung-Ying Liao. Visualization: Shou-Tung Chen, Dar-Ren Chen, Hsin-I Huang. Writing—original draft: Wen-Pei Wu. Writing—review & editing: Wen-Pei Wu, Joseph Lin, Hung-Wen Lai.

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