Radio-guided occult lesion localisation for breast lesions under computer-aided MRI guidance: the first experience and initial results

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Objective: The purpose of this study was to present an alternative technique for the pre-operative localisation of solely MRI-detected suspicious breast lesions using a computer-assisted MRI-guided radio-guided occult lesion localisation (ROLL) technique.

Methods: Between January 2009 and June 2010, 25 females with a total of 25 suspicious breast lesions that could be detected only by MRI, and for whom breast surgery was planned, underwent the computer-assisted MRI-guided ROLL technique. A seven-channel biopsy breast array coil and computerised diagnostic workstation were used for the localisation procedure. Three-phase dynamic contrast-enhanced axial images were taken. After investigating the localisation co-ordinates with the help of intervention software on a workstation, an 18 G coaxial cannula was placed in the exact position determined. Following verification of the cannula position by additional axial scans, ^{99m}Tc-labelled macroalbumin aggregate and MRI contrast material were injected. Post-procedure MRI scans were used to confirm the correct localisation.

Results: All the procedures were technically successful. The mean lesion size was 10.8 mm (range: 4–25 mm). The mean total magnet and the mean localisation times were 28.6 min (range: 18–46 min) and 13.1 min (range: 8–20 min), respectively. Grid and pillar methods were used for localisation in 24 procedures and 1 procedure, respectively. On histopathological examination, 6 malignant, 10 high-risk and 9 benign lesions were identified. All patients tolerated the procedure well. There were no major complications.

Conclusion: This is the first report documenting the application of MRI-guided ROLL. Based on our preliminary results, this technique is very efficient and seems to be a good alternative to wire localisation.

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MRI of the breast has now become an integral and necessary component of breast imaging practice [1]. It is a valuable tool with high sensitivity for the identification of breast cancer in high-risk patients, follow-up of patients with known breast cancer and in patients at a pre-operative stage in order to rule out any ipsilateral or contralateral disease [2–5]. It can detect suspicious breast lesions that are occult to clinical examination, mammography and ultrasonography [4, 6, 7]. It was reported that, although the addition of MRI to current evaluation (clinical, radiological and pathological) has no benefit on a reduction of operation rates, cost-effectiveness and quality of life, it has the potential to aid tumour localisation [8].

An MRI-guided intervention is necessary to make a definitive histological diagnosis of such “solely” MRI-detected suspicious breast lesions. Histopathological assessment

can be performed by MRI-guided wire localisation followed by surgical excision [6, 9, 10], or by alternative techniques to surgery such as MRI-guided percutaneous biopsy using fine needles [11], core needles [12, 13] or vacuum-assisted biopsy devices [7, 14]. For such a breast intervention to be clinically useful, factors such as safety, accuracy, availability, cost, patient preference for surgical biopsy and surgeon’s request should be considered. With fine or core needle, lesions measuring <1 cm may not always be accurately sampled, and vacuum biopsy would bring an extra cost burden if surgical biopsy is already planned.

MRI-guided wire localisation is a well-known (and currently the most commonly utilised) technique. Several authors have reported success with this technique for surgical biopsy [6–10]. According to them, it can be performed quickly and safely with relatively simple methods and commercially available equipment. However, this technique harbours several limitations and poses potential challenges during and/or after its application, such as the necessity to perform surgery on the same day owing to

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the risk of wire migration and/or accordion effect [6], breast pain, and poor cosmetic outcome after surgery [15].

Radio-guided occult lesion localisation (ROLL) has been documented as a more reliable and effective method than wire for the identification of non-palpable breast lesions [16, 17]. Routine ROLL involves the injection of ^{99m}Tc -labelled human serum albumin into the suspicious lesion under ultrasonography or mammography control within 24 h prior to surgery. Subsequently, surgical excision is performed with the help of a hand-held gamma probe [18].

To the best of our knowledge, ROLL has never been reported as an adjunct for the pre-operative localisation of solely MRI-detected suspicious breast lesions. Thus, the purpose of this study was to introduce a new technique—computer-aided and MRI-guided ROLL—to present its technical aspects and document our initial results.

Methods and patients

Patients and clinical indications

This study was conducted with the approval of the local ethics committee. Patients were informed about the procedure and informed consent was obtained from all of the patients.

From January 2009 to June 2010, 25 females with a total number of 25 suspicious breast lesions that could be detected only by MRI, and for whom breast surgery was planned, underwent the computer-assisted and MRI-guided ROLL technique, with subsequent surgery and histopathological analysis. The mean age of the patients was 48 years (range: 33–66 years). The clinical indications for MRI were screening in seven high-risk patients, follow-up examination in four patients with a history of breast cancer after ipsilateral or contralateral breast surgery, breast cancer staging in seven patients, and it was used as a diagnostic method in two patients with left axillary nodal metastasis. The remaining five patients underwent MRI owing to indeterminate findings on mammography and/or ultrasonography (Table 1). Also during this study period, two patients with MRI-detected suspicious breast lesions in a different hospital were referred to our clinic for pre-operative localisation. However, the procedure was cancelled for these patients since there were no breast lesions visualised on our dynamic MRI scans during the localisation procedure. In all 25 cases, the lesions were of the contrast-enhanced Breast Imaging Reporting and Data System (BI-RADS) 4 or 5 category and they were visible neither at mammography (Mammotom; Siemens, Erlangen, Germany) nor at high-frequency transducer-directed ultrasonography (12 MHz) (Sonoline G60S®; Siemens), including second-look ultrasonography.

Diagnostic breast MRI technique and interpretation

Diagnostic MRI was performed with the patient in a prone position in a 1.5 T MRI system (Symphony; Siemens) using a dedicated seven-channel biopsy breast array coil with compression plates (Invivo, Orlando, FL).

Our MRI protocol included a localising sequence followed by sagittal, coronal and axial sequences [repetition time (TR)/echo time (TE)/inversion time (TI), 6980/61/150; gap, 20; field of view (FOV), 330; matrix, 320 × 320; flip angle, 180°, frequency direction, right (R) > left (L)]. A T_1 weighted fast low-angle shot (FLASH) three-dimensional (3D) sequence (TR/TE, 11/5.16, gap, 20, FOV, 330, matrix, 200 × 256, flip angle, 25°, frequency direction, R > L, bandwidth, 150 Hz/Px) was then performed before and five times after a rapid bolus injection of 0.1 mmol l⁻¹ of MRI contrast agent per kilogram of body weight. Contrast material was administered through an indwelling intravenous catheter. Image acquisition started immediately after contrast injection. Each volumetric acquisition was performed in less than 2 min. Total imaging time was approximately 20 min. Section thickness was 2 mm without gap using a matrix of 200 × 256 and a FOV of 16–18 cm. Frequency encoding was in the R to L direction. After examination, the unenhanced images were subtracted from all enhanced images on a pixel-by-pixel basis simultaneously by diagnostic workstation.

MRI was interpreted on a computerised diagnosis workstation, a commercially available computer-aided detection (CAD) system (Dynacad®; Invivo), by one of three breast-imaging specialists (AA, GEI and MHY, who have had 15, 14, and 7 years of experience in breast MRI, respectively). MRI interpretation was carried out in conjunction with mammography and breast ultrasonography. The interpretation of the lesions was carried out according to the established standard BI-RADS, which is based on the morphological and enhancement characteristics [19]. For the lesions that were interpreted as suspicious or highly suggestive of a malignancy on MRI, correlative ultrasonography was performed to determine whether the lesion was also sonographically evident and thereby amenable to tissue sampling under ultrasonography guidance. If the lesion was reliably visualised on either ultrasonography or mammography, localisation or biopsy was performed with the guidance of these imaging modalities. MRI-guided localisation was performed only for those patients who had an MRI-detected BI-RADS 4 or 5 lesion with no mammographic or sonographic correlate.

MRI-guided ROLL technique

Lesion localisation was performed by two radiologists (MHY and FK) who have had 3 years of experience in MRI-guided breast interventions. Interventional procedures were performed with the 1.5 T MR system 7–32 days after the diagnostic MRI examination. The localisation was performed with the patient positioned prone with both breasts in a seven-channel biopsy breast array coil [SMS eLBS-IBC (7 CH) Breast Array Coil-Verio, Trio TIM 3.0 T; Invivo]. The breast undergoing localisation was placed in a dedicated biopsy compression device using a commercially available grid/pillar localising system (Grid and Pillar Immobilization Plates BB; Invivo). There were two different access methods for the interventional approach. In the first method, a sterile disposable square 18 gauge (18 G) cannulation needle block was used with the grid localisation system. A 2 cm-sided square block fitted into the desired grid opening served to stabilise and accurately guide the coaxial

Table 1. Indications of MRI, MRI characteristics of the lesions, pathological diagnoses and procedure times

Patient number	Age (years)	Indications	MRI appearance	Lesion size on MRI/histopathological lesion size (mm)	Pathological diagnosis	Intervention time (min)	Total time (min)
1	51	History of contralateral breast cancer	Left, retroareolar, irregularly contoured distorted mass	12/10	Invasive ductal cancer grade 2	10	23
2	52	Family history of breast cancer	Right, deep-located, uniformly contoured enhancing mass	10/10	Intraductal papilloma	14	26
3	35	Problem-solving	Right, retroareolar, irregularly contoured non-mass	13/9	Fibrocystic changes	14	27
4	41	Contralateral breast cancer	Right, deep-located, uniformly contoured enhancing mass	12/14	Sclerosing adenosis	13	32
5	64	History of ipsilateral breast cancer	Left, enhancing uniform nodular mass	9/10	Atypical ductal hyperplasia	17	34
6	45	History of ipsilateral breast cancer	Right, millimetric, enhancing nodular mass	6/6	Fibroadenoma	16	35
7	32	Contralateral breast cancer	Left, asymmetrical contrast-enhancing, irregularly contoured non-mass	11/10	Radial scar	20	37
8	49	Family history of breast cancer	Left, irregularly contoured mass, enhancing suspicious areas, multicentricity?	13/8	Invasive lobular cancer grade 2	18	37
9	33	Axillary metastasis	Left, irregularly contoured enhancing mass	13/15	Invasive ductal cancer grade 3	12	30
10	47	Contralateral breast cancer	Left, hazy contoured asymmetrical enhancing lesion	13/10	Sclerosing adenosis	13	24
11	46	Problem-solving	Left, enhancing mass adjacent to the pectoralis muscle	7/9	Atypical ductal hyperplasia	10	39
12	56	Family history of breast cancer	Right, enhancing focus	5/9	Fibrocystic changes	10	22
13	43	Problem-solving	Right, enhancing mass	6/6	Intraductal papilloma	17	37
14	45	Family history of breast cancer	Left, irregularly contoured enhancing non-mass lesion	14/10	Radial scar	20	46
15	50	Problem-solving	Right, irregularly contoured enhancing non-mass lesion	6/9	Sclerosing adenosis	10	23
16	39	Family history of breast cancer	Right, enhancing millimetric focus	4/5	Sclerosing adenosis	15	23
17	54	Contralateral breast cancer	Right, irregularly contoured enhancing lesion	12/14	Invasive ductal cancer grade 3	9	25
18	57	Contralateral breast cancer	Right, uniform contoured enhancing nodular mass	7/7	Atypical ductal hyperplasia	8	19
19	52	Problem-solving	Left, lobulated contoured enhancing nodular mass	9/10	Fibroadenoma	8	18
20	57	Axillary metastasis	Left, irregularly contoured enhancing mass	8/8	Invasive ductal cancer grade 2	13	25
21	66	History of contralateral breast cancer	Left, irregularly contoured enhancing non-mass lesion	25/21	Atypical ductal hyperplasia	14	28
22	45	Family history of breast cancer	Right, lobulated contoured enhancing nodular mass	7/7	Fibroadenoma	15	26
23	46	Contralateral breast cancer	Right, asymmetrical contrast-enhancing non-mass	15/13	Invasive lobular cancer grade 3	12	23
24	48	Family history of breast cancer	Left, irregularly contoured enhancing non-mass lesion	15/12	Atypical ductal hyperplasia	8	20
25	46	Contralateral breast cancer	Left, deep-located, asymmetrical contrast-enhancing, irregularly contoured non-mass	15/15	Sclerosing adenosis	12	25

needle to its intended tissue target. In this localisation system, intervention was implemented perpendicular to the compressed breast skin in a mediolateral/lateromedial approach. In the second system, there was a plate with transverse rails for the craniocaudal movement of the pillar system, which had an anteroposterior movable head with a sterile disposable sleeve. The sleeve, 4 cm in length, provided a guide path for coaxial cannula placement. The pillar head provided angle shot movement for reaching deep-seated lesions in the lateromedial direction. The pillar localisation method was used for only one patient who had a deep lesion adjacent to the pectoralis muscle. The method of choice was determined and a device system was set up accordingly prior to intervention.

MRI scan was performed after the patient had been immobilised with the coil's compression plaques. In T_1 FLASH 3D sagittal sequence images (TR/TE, 11/5.16, gap, 20, FOV, 350, matrix, 218×256 , flip angle, 25° , bandwidth, 150 Hz/Px, frequency encoding direction, A>P), the applicability of intervention and visibility of two indicator fiducial markers on the compression plate were controlled. If appropriate, 3-phased dynamic axial images (T_1 FLASH 3D, TR/TE, 12/5.45, gap, 20, FOV, 200, matrix, 192×256 , bandwidth, 150 Hz/Px, flip angle, 25° , frequency direction, A>P) with $0.1 \text{ mmol l}^{-1} \text{ kg}^{-1}$ MRI contrast agent (MagnevistTM; Bayer, Schering Pharma, Leverkusen, Germany) were obtained, and these images were delivered to the workstation. Contrast agent was administered by bolus injection. The pre-contrast images were subtracted from the received images simultaneously and suspected lesions were visualised. Three points (two indicator points on compression plates and an established lesion centre) were marked to locate three dimensions with the help of intervention software. Software provided the exact lesion depth, appropriate grid and needle-block hole selection, or the pillar position and access angle.

Next, the MRI table was removed from the gantry and the interventional procedure was performed while the patient remained stationary. Before the procedure, the skin was disinfected and local skin anaesthesia with 2–3 ml prilocaine HCl (Citanest[®]; AstraZeneca, London, UK) was applied subcutaneously within the lesion alignment. An MRI-compatible 18G titanium cannula (Coax Needle 150/16; Invivo) was inserted via the exact grid position and cannula block hole to the derived lesion depth (Figure 1). Afterwards, the correct positioning of the cannula was confirmed with axial slices in the FLASH 3D sequence. The cannula tract was seen as a thin hypointense metallic artefact line. In one patient localised with the pillar method, an artefact of the sleeve was observed in the direction of the lesion in the same axial slice. In both methods, we passed to the next localisation stage when the needle positioning was accurate. Accuracy was determined on the basis of the cannula positioning being at 1 cm or less from the lesion. Contrast-enhancing lesion and anatomical landmarks in the previous and current MRI were compared for verification. Localisation was achieved by either the medial or lateral approach. We selected the most convenient access site depending on the localisation of the lesion. Midline lesions were localised from the lateral approach because of the ease of the procedure.

Figure 1. Patient is positioned in a prone position and the left breast is immobilised with compression plates. Insertion of an 18 G cannula from the lateral approach is shown.

Next, the patient was moved out from the magnet in order to perform ROLL. The cannula within the breast was manually advanced 0.5 cm beyond the lesion, and then 1 mCi (37 MBq) of $^{99\text{m}}\text{Tc}$ -labelled macroalbumin aggregate in 0.2 ml saline and 1 ml of saline-diluted (1:200) MRI contrast agent were injected consecutively. The injections were given without any delay in order to avoid contrast washout. After injecting the contrast agent, the patient was taken back into the magnet and post-localisation control scans were performed. The localisation was considered satisfactory when the injected contrast material covered the target lesion or was within 1 cm of the target lesion (Figures 2 and 3). A quick sketch was made in order to provide the surgeon with the localisation of the suspicious lesion.

In the operating room, before the induction of general anaesthesia, the surgeon used a hand-held gamma probe (EuroProbe, EuroMedical Instruments, Strasbourg, France) to identify and mark the site of the lesion by locating the area of maximal radioactivity, thus allowing the incision to be made exactly over the lesion. Then, a skin incision was made and the probe was used to define the margins of resection. The primary lesion was excised with the surrounding tissue. After the excision, the probe was then used to examine the resection bed to verify that there were no residual areas of high radioactivity.

Data collection and image analysis

The morphological and enhancement characteristics of each lesion were recorded on the basis of the American College of Radiology breast MRI lexicon [19], and the following data were provided: lesion type (focus, mass or region), size, shape, margin, location, distribution, enhancement patterns (homogeneous, heterogeneous or rim enhancement) and enhancement kinetics (persistent, plateau or washout). The depths of the breast lesions from the closest medial or lateral skin surface were also documented.

One imaging researcher (FK) prospectively collected and recorded the data, including the use of medial versus lateral approach, the visibility of the lesion with the radionuclide material injection and the injection

Figure 2. Pre-operative MRI-guided radio-guided occult lesion localisation in a 41-year-old patient with known contralateral invasive breast carcinoma. Axial localising images [repetition time (TR)/echo time (TE), 11/5.16; flip angle, 25°] show that the right breast is being compressed slightly. (a,b) The indentations of the grid lines are seen as small notches over the lateral aspect of the breast skin. (a) A 3 phase dynamic axial T_1 fast low-angle shot (FLASH) three-dimensional (3D) (TR/TE, 12/5.45, flip angle 25°) and (b) subtraction images show a 12 mm enhancing mass with fine contours (arrow). (c) Axial FLASH 3D images (TR/TE, 11/5.16, flip angle 25°) show an inserted cannula artefact as a hypointense line next to the lesion (arrowhead). (d) The T_1 FLASH 3D axial scan is taken after injection of the radio-nuclide and the contrast agent. The contrast agent accurately dyes the breast parenchyma in proximity to the lesion (arrow).

co-ordinates in every procedure. The duration of each step of the procedure, total magnet time (from the start of MRI scanning until the patient exited the MR suite) and total localisation time (from the moment the lesion was visualised at the console until the final injection) were prospectively recorded.

The histopathological results were reviewed with the pathologist to verify that the specific lesion had been excised and examined. The results were categorised as benign (fibrocystic changes, fibroadenoma, sclerosing adenosis, atypical lobular hyperplasia), malignant (invasive or *in situ* ductal disease) or a high-risk lesion (atypical ductal hyperplasia, radial scar, intraductal papilloma). In malignant cases, a clearance margin of ≥ 2 mm was accepted on histopathological evaluation.

Results

Procedures

All of the patients tolerated the procedure well. One patient experienced breast pain during the procedure. In one case, the injected contrast material was seen extravasated in a 2 cm-sized area covering the lesion on control MRI. There were no complications. The mean total magnet time was 28.6 min (range: 18–46 min). The mean localisation time was 13.1 min (range: 8–20 minutes) (Table 1). 5 lesions were localised by a medial approach and 20 were localised by a lateral approach. The grid method and pillar method were used for localisation in 24 procedures and 1 procedure, respectively.

The cannula's metallic artefact was not found to obscure any lesion.

Lesions and histopathology

Out of the 25 lesions, 15 (60%) had a mass morphology, 8 (32%) were non-mass lesions and the remaining 2 (8%) were foci. Of the mass lesions, six had spiculated and four had lobulated contours. The mean lesion size was 10.8 mm (range: 4–25 mm) and the mean lesion depth within the breast was 25.4 mm (range: 10–55 mm). Of the 25 cases, multicentricity was suspected in 1 patient in whom MRI and mammography also demonstrated a second suspicious lesion, and this second lesion was localised under mammography guidance. This patient underwent mastectomy since malignancy was detected in both of these lesions on frozen examination. 9 (36%) lesions showed moderate and 16 (64%) lesions showed marked early enhancement patterns. Delayed enhancement patterns were plateau in 11 lesions (44%), and washout in 14 (56%) (Table 1).

On histopathological examination, 6 (24%) malignant lesions (invasive ductal and lobular carcinoma), 10 (40%) high-risk lesions (atypical ductal hyperplasia, intraductal papilloma, radial scar) and 9 (36%) benign lesions (fibrocystic changes, sclerosing adenosis, fibroadenoma) were identified (Table 1). The mean pathological lesion size was 10.3 mm (range: 5–21 mm). None of the pathology results documented invasive cancer at the surgical margins of the malignant specimens.

Except for the one patient who underwent mastectomy, all patients later underwent follow-up MRI

Figure 3. Pre-operative MRI-guided radio-guided occult lesion localisation (ROLL) in a 49-year-old patient with a suspicious lesion exhibiting spiculated contours and a washout enhancement pattern. There were also suspicious contrast enhancements, which indicated multicentricity. The most suspicious lesion with a spiculated contour was localised with ROLL. Histopathological examination revealed an invasive lobular carcinoma. (a) T_1 fast low-angle shot (FLASH) three-dimensional (3D) sagittal image shows two fiducial markers and grid compression marks on the lateral breast skin (arrows). (b) A contrast-enhanced axial subtraction image [T_1 FLASH 3D, repetition time (TR)/echo time (TE), 12/5.45; flip angle, 25°] indicates a spiculate-contoured enhanced 13 mm parenchymal mass lesion (arrow) together with other suspicious contrast enhancements (arrowheads). A thin hypointense cannula artefact appears 5 mm from the lesion (arrowhead). After advancing the cannula 5 mm, the ^{99m}Tc -labelled macroalbumin aggregate in 0.2 ml saline and 1.5 ml of saline-diluted (1:200) MRI contrast agent is injected. (c) The derived axial T_1 FLASH 3D scan and (d) the subtraction image show (e) 2 cm of contrast-dyed parenchyma covering the spiculated lesion (arrowheads).

investigation 3–6 months after surgery in order to verify the complete removal of the lesions. No residual lesions were detected in any of them.

Discussion

The ROLL technique is a relatively new method to localise and orientate non-palpable breast lesions for surgical excision. Since its first description in 1996 at the European Institute of Oncology in Milan [20], this technique has allowed easier, more accurate and more rapid removal of such breast lesions than wire localisation [15, 18, 21–25]. We adopted ROLL in our centre in December 2004, and since then we have employed this technique under mammography or ultrasonography guidance in approximately 360 patients [18].

Our MRI-guided ROLL technique overcomes the important challenges associated with MRI-guided wire localisation. The most important challenge with the wire procedure is the necessity for surgical excision on the same day as wire insertion owing to the potential risks of

wire migration. Wire migration, if it occurs, mandates a second MRI-guided intervention, which increases workload and leads to frustration in busy medical centres. In our previous ROLL study, which included only breast cancer patients [18], same-day injection of the radiotracer was not found to be superior to day-before injection. We concluded that a day-before protocol could be scheduled at the convenience of both patients and hospital staff without compromising the success of the ROLL procedure. Consequently, all the patients in the present study underwent MRI-guided ROLL 1 day before surgery. Eventually, this provided the major advantage of eliminating any difficulties in co-ordinating the schedules of the nuclear medicine and radiology departments, and the operating room.

Another potential problem with wire localisation is inaccuracy due to the accordion effect. Briefly, the wire is deployed in a breast under compression in a direction parallel to the direction of cannula placement. When compression is released, any error in the depth of direction can be exaggerated, thus resulting in this accordion effect [6]. The MRI-guided ROLL technique overcomes this problem

because the radiotracer, which is directly injected into the lesion, remains within the lesion.

With this technique, we have not encountered any serious complications or noteworthy drawbacks so far during either lesion localisations or surgical excisions. The extravasation of the injected contrast material observed in one case did not cause any problem regarding breast pain, nor were there any surgical complications such as wrong tissue targeting or wider excision. All the surgical excisions were performed successfully. Specimen radiography was not performed because only the lesions that were occult on other imaging modalities were localised. Of the 25 cases, multicentricity was suspected in only one patient, in whom we performed MRI-guided ROLL for the lesion detected only by MRI. The second suspicious lesion that was also mammographically demonstrable was localised under mammography control. Since the frozen examination revealed malignancy in both of these excised lesions, mastectomy was performed in this case.

Margin clearance itself is a very important factor in determining the success rate of this technique [18]. None of the pathology results documented invasive cancer at the surgical margins of the malignant specimens. Except for the patient with multicentric malignancy, follow-up MRI performed in all the 24 cases revealed no lesions. Our early favourable results cannot prove the high success rate of MRI-guided ROLL since this study has been conducted on a limited number of patients so far. Taking into consideration the results of the previously published papers comparing ROLL with wire localisation [15, 22, 24], our technique seems to result in a better concentricity of the lesion and an improved rate of clear margins.

The localisation of deep lesions is generally difficult because the lesion may remain posterior, and would therefore not be included in the grid compression plate. Instead, the pillar localisation method can be used for those deep lesions adjacent to the pectoralis muscle, as was the case in one of our patients. Localisation of the medial lesions used to pose technical challenges. Our dedicated seven-channel biopsy breast array coil enabled both medial and lateral access with the patient in a prone position.

The commercially available CAD system provides an opportunity for examining automatically generated subtraction images, multiplanar reformatted images and dynamic maximum intensity projections simultaneously. Areas of enhancement are automatically identified by colour overlays on all axial MRI slices, and the enhancement kinetics can easily be generated from regions of enhancement. A recent study confirms that automated analysis at 50% and 100% thresholds shows high sensitivity and specificity for readers with varying levels of experience [26]. Most importantly, the CAD system improves the accuracy and speed of MRI-guided intervention procedures by automatically identifying the exact cannula insertion site and the depth of the lesion within the breast. The needle was correctly positioned in all our interventions. The short intervention time of this technique also provided confirmation of accurate needle localisation before the lesion became invisible because of contrast washout.

With this procedure, the mean localisation time was 13.1 min and the mean total magnet time was 28.6 min. Considering the differences in the technical aspects of the previously published studies that used MRI-guided wire localisation techniques, our mean total magnet time was longer than the 21 min reported by Gossman et al [9], similar to the 31 min reported by Morris et al [6], and shorter than the 62 min reported by Causer et al [10] and the 64 min reported by Daniel et al [27].

Several studies showed that ROLL is safe for both patients and medical staff in terms of radiation exposure, because of the low levels of the injected activity and the optimal characteristics of ^{99m}Tc . The dose absorbed from the inoculated area is negligible and concentrated within the removed tissue. The lack of contamination from radioactive waste indicates that no additional radiation protection measures are required [18, 28, 29].

As seen from the results of the present study, the malignancy ratio is low, with only 6 malignant cases out of 25, which seems to contradict the accuracy rate of MRI. However, in addition to these 6 malignant cases, there were also 10 suspicious lesions that were proved to be high-risk lesions on histopathological examination. Nevertheless, the low malignancy rate can be explained by the lesion characteristics on MRI, as well as our rather broader clinical indications for a surgical biopsy, since all the patients included had a history of previous breast cancer, high-risk factors or indeterminate findings on mammography and/or ultrasonography. Furthermore, the patients were not biopsied pre-operatively by other diagnostic means (such as fine-needle, core-needle or vacuum-assisted biopsy). The main reason why we did not consider pre-operative biopsy is that, taking into consideration the patients' preference for surgery and the surgeons' request, surgical excision was already planned for all the cases; thus, the addition of biopsy would have resulted in an extra cost. In addition to this, if performed, negative biopsy results would not have completely ruled out malignancy in this high-risk patient population.

The major limitations of this study are the limited number of cases and the short follow-up period of up to 6 months. We consider this study as preliminary and we plan to increase the number of patients undergoing this procedure in the near future, and we hope to achieve similarly favourable results. The applicability, accuracy and efficacy of MRI-guided ROLL require such further research.

In conclusion, the ultrasonography- and mammography-guided ROLL technique is a well-documented method. This is the first report to present the application of ROLL under MRI guidance for the pre-operative localisation of solely MRI-detected breast lesions. Based on our initial results, the MRI-guided ROLL technique seems to be a good alternative to wire localisation in the indicated subset of patients.

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