The role of breast MRI in pre-operative planning of surgery

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Purpose

To estimate the abilities of breast MRI in 3D pre-surgical planning in women with breast carcinoma.

Surgery for breast cancer has changed markedly during the past 20 years. Radical mastectomy in small cancers is not commonly performed at present, while breast-conserving surgery (BCS) has become the standard therapy for early breast cancer. In BCS, preoperative evaluation of the tumor extension is extremely important [4, 14]. It is essential to achieve a complete resection of the tumor while preserving the cosmetic outcome. On the one hand an incomplete resection of the primary tumor results in the higher incidence of recurrence [5, 7, 9, 13]. On the other hand, superfluous excision of healthy parenchyma impairs the cosmetic outcome [12]. Consequently, an accurate determination of breast cancer extent is of great importance.

Magnetic resonance imaging (MRI) is a useful modality for the detection, diagnostic and size assessment of breast cancer [3, 6, 8], and it is the most accurate tool for identifying cancer extent compared with conventional mammography and ultrasonography (US) [2].

The size of lesions on MRI is usually concordant with the size at pathology. Therefore MRI can be used for planning the most appropriate treatment and may prevent unnecessary mastectomies or assign patients with large tumors to neoadjuvant protocols [2].
Methods and Materials

Written informed consent was obtained from each patient after a full explanation of the purpose, nature, and risks of all procedures. The institutional review board of Federal Center of Treatment and Rehabilitation approved all study procedures.

Patients:

Pre-operative MRI was performed prospectively in 162 women with histologically proven breast carcinomas diagnosed between October 2011 and December 2012. MR-mammography was also performed in 7 patients without unequivical verification (because of the lack of histologic material after needle biopsy). This group of patients had highly suspicious data of malignancy according to conventional X-rays and ultrasonography.

Among the whole group of patients 67 women (mean age, 48±12 years; range, 26-74 years) with breast carcinoma of stage I - IIb were chosen. The size of the tumor was measured in three perpendicular directions and varied from 0,7 cm up to 2,5 cm. The patients with stage IIb and the size of the tumor larger than 2,5 cm were excluded from breast-conserving surgery. According to the results of the needle biopsy 63 patients of this group had ductal carcinomas and 4 - lobular carcinomas.

Methods:

- Mammography in standard craniocaudal and mediolateral projections - in patients older than 35 years (GE Senographe Essential, USA).
- Targeted X-rays images with magnification in 1,8-3,6 times - in patients with visible tumors and microcalcifications.
- Ultrasonography (2D, color Doppler mapping sonography with using transducers 10L4s 8/10/12 MHz, Mindrey M5, Korea).
- Stereotactic core-needle biopsy or fine-needle biopsy.
- MR-mammography.
All patients underwent standard MRI in the prone position using a 1.5-T system (Avanto; Siemens Medical Solutions, Erlangen, Germany) with a double breast coil (four-channel breast array coil). Before the administration of contrast material, bilateral sagittal fat suppressed T2-weighted images and axial T1- and T2-weighted images were obtained. In addition, axial diffusion weighted images were acquired. Turbo inversion recovery magnitude (TIRM) was used for fat suppression. Dynamic MRI using a three-dimensional fat-suppressed sequence with parallel acquisition was obtained before and five times after the bolus injection of 0.1 mmol Gd-DTPA/kg at a rate of 2 ml/s. Both breasts were examined in the axial plane before and after contrast injection.

Table 1. Acquisition parameters for 3D T1-weighted dynamic contrast-enhanced MRI

<table>
<thead>
<tr>
<th>T1-weighted 3D gradient-echo sequence (FLASH)</th>
<th>Siemens Avanto 1.5T</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR/TE</td>
<td>5.2/2.4</td>
</tr>
<tr>
<td>Flip angle</td>
<td>10°</td>
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<tr>
<td>Field of view (mm)</td>
<td>340 x 340</td>
</tr>
<tr>
<td>Slice thickness (mm)</td>
<td>0.9</td>
</tr>
<tr>
<td>Matrix</td>
<td>448x340</td>
</tr>
<tr>
<td>Time (s)</td>
<td>60</td>
</tr>
<tr>
<td>In-plane resolution (mm)</td>
<td>0.9x0.9</td>
</tr>
</tbody>
</table>

MR-planning was performed using 3D-reconstructions (MIP, MPR) in orientation corresponding to the patient's position during the surgery. The lesions were measured by surface area and volume including perifocal nodules and the areas of the architectural distortion. Vasculature of the surrounding tissues was also taken into account. The safety margin of 1.0-1.5 cm between the lesion and healthy tissues was defined with additional 0.5-1.2 cm (in average 0.9 cm) for possible inaccuracy caused by breast tissue dislocation. 3D images with all measurement were saved as a JPEG image and downloaded into Viewsonic Picoprojector. The images contained three obligatory reference points: the distance from the lesion to the nipple, the distance from the lesion to the skin and the distance from the lesion to the pectoral muscle (musculus pectoralis major) or adjacent chest wall.

Before the surgery the US-guided or mammography-guided marking with methylene blue was performed. The tumor was outlined on the overlying skin with the marker. Then the surgeons used Viewsonic Picoprojector with superimposing image on the patient's breast using following reference points: the nipple, skin marker of the lesion and margin of the pectoral muscle (major). According to this image and preoperational US final resection lines were modified and drawn on the skin. The surgical treatment was
performed according to the topographometric layouts. The removed sectors of the tissues at first underwent X-rays examination (sectorography) and then they were urgently histologically examined on cleanliness of the resected margins. In case of incomplete resection immediate lump re-excision was performed.
Fig. 1: Screenshot of postcontrast images of the right breast in axial, sagittal, frontal planes and MIP. Patient 57 years old with enhancing tumor located on the border of upper quadrants of the right breast.

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Fig. 2: Sagittal image of the same patient with all required measurements: the distance from the lesion to the nipple, the distance from the lesion to the skin, the distance from the lesion to the pectoral muscle and the volume of the lesion.

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Fig. 3: Measurements of the size and the volume of the lesion including surrounding architectural distortion. Safety margins between the lesion and healthy tissues are marked.

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**Fig. 4:** Measurements of the size and the volume of the lesion including surrounding architectural distortion.

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Fig. 5: The technique of superimposing image from Picoprojector on the breast skin using following reference points: the nipple, the lesion and margin of the musculus pectoralis major.

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Fig. 6: Stages of the tumor excision during the breast-conserving surgery.

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Fig. 7: The same patient. Intraoperative control X-ray image of resected tissues.

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Results

3-D MR-mammography was performed for all 169 patients including women with non-palpable breast cancer showing microcalcification detected by conventional mammography. Twelve patients with non-palpable tumor were examined, and all tumors were clearly displayed by MRI.

After MR-mammography the type of surgery was modified in 29 of 169 patients (17,2%):

- In 15 women (8,9%) therapeutic approach was altered (patients underwent breast-conserving surgery instead of radical mastectomy);

- 14 patients (8,3%) underwent a wider surgical excision than it was planned initially (radical mastectomy was performed instead of radical resection);

- in 140 cases (82,8%) the treatment approach did not changed.

- in 7 patient (4,1%) who had no definite treatment approach (due to the absence of conclusive verification because of the lack of histologic material) ductal carcinoma was confirmed initially by means of MR-mammography and subsequently by intraoperative and postoperative histologic examinations. Five of those patients underwent breast-conserving surgery and two - radical mastectomy.

In the group of 67 patients with MR-planning, cleanliness of the edges of the resection was histologically confirmed in 64 cases (95,5%). In 3 cases (4,4%) cancer cells were found along one margin of the resection. In one patient cancer cells were found along lateral margin, while the others had cancer foci at the surface of the only distal (inferior) margins.

In patients with negative margins the distant between the surfaces of the tumor and resection margins ranged from 1,5 cm up to 3,0 cm. In 2 cases (2,9 %) an excision of the resection edge appeared superfluous in the range up to 0,9 cm.

The tumor size determined by standard MRI in prone position ranged from 0.7 to 2.5 cm (average, 1.6±0,4 cm), and the histopathological tumor size ranged from 0.4 to 2.5 cm (average, 1.4±0,4 cm). The maximal discrepancy in the size was 0,3-0,4 cm.

According to the results of routine histologic examination and immunohistochemistry patients were treated subsequently in compliance with primary standards.
Conclusion

3D MR-planning combined with marking technique and navigation is one of the most promising future technologies. It is a reliable diagnostic method to confirm tumor extension compared with other conventional methods (mammography and ultrasound).

3D MR-planning allows determining the volume of resected breast tissues avoiding unnecessary removal of healthy breast parenchyma.

Navigation with use of Picoprojectors is a cost-effective and relatively reliable method.

However, the localization of the lesion on breast MRI in the prone position (standard MRI) differs from that in the operative position due to soft tissue shifts and deformation of the breast under the effect of gravity. Therefore it is necessary to modify and improve this method to increase the accuracy of the surgery.

Also it is essential to evaluate long-term results in patients, who underwent BCS with the help of marking and navigation technique, especially in those who had positive resection margins.
References


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