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Breast

MR-guided laser-induced thermotherapy with a cooled power laser system: a case report of a patient with a recurrent carcinoid metastasis in the breast

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Abstract. We report a case of a 52-year-old woman with a palpable recurrent metastasis of a neuroendocrine carcinoma to the upper outer quadrant of the right breast. For the treatment of this lesion, MR-guided laser-induced thermotherapy was performed with a cooled power laser system (Nd:YAG-Laser). An open 0.2-T MR unit was used for the monitoring of the laser energy delivery to the breast; thus, a thermosensitive fast low-angle shot 2D sequence for MR thermometry was used, so the ablation of the tumor and the increase of laser-induced necrosis could be interactively visualized with the repetitive use of this sequence. The postinterventional MR control exams 1 day and 4 months after laser-induced thermotherapy at the 1.5-T MR unit (Magnetom Symphony Quantum, Siemens, Erlangen, Germany) verified the complete ablation of the tumor without any signs of residual or relapsing tumor.

Keywords. Minimal invasive therapy - Laser-induced thermotherapy - Breast - Metastasis - Open MRI

Introduction

Minimally invasive ablative procedures have gained interest for the treatment of malignant tumors in different organ systems [*1*, *2*, *3*, *4*, *5*, *6*]. Due to increasing experience with MR-guided laser-induced thermotherapy (LITT) of primary and metastatic liver tumors and lymph node metastases, the question arises as to whether this procedure may also be suitable for the treatment of metastases in other organ systems such as the breast. While surgical resection and radical or modified mastectomy still is the standard method for the treatment of primary breast cancer, controversy exists for the appropriate treatment of metastases to the breast. In the presented case we show the technical feasibility of LITT of the breast and document the size and configuration of a lesion induced by LITT.

Case report

A 52-year-old woman presented with a palpable nodule of 12 mm in size in her left breast which had developed within 8 weeks. The patient had underwent extensive abdominal operations because of a malignant neuroendocrine tumor (carcinoid). During the previous 2 years the patient underwent repetitive MR-guided LITT for treatment of unresectable liver metastases. Two years ago, the patient underwent an extensive surgical resection of a histologically verified carcinoid metastasis in the breast. The newly developed lesion was located exactly inside the scar tissue of the breast, where the prior resection was done. The diagnostic MRI was performed on a 1.5-T (Magnetom Symphony Quantum, Siemens, Erlangen, Germany), which showed the characteristic highly enhancing mass in the upper outer quadrant of the breast. Because of the MR characteristics and the identical location of the lesion to the prior surgically resected and histologically proven metastasis, the relapse of this lesion was assumed.

The patient refused another surgical resection as well as further systemic therapies and agreed to an individual study procedure, which was performance of LITT in order to achieve local tumor control. After informing the patient about potential complications, benefits, and disadvantages of LITT, consent was obtained. The MR-guided LITT was performed under local anesthesia with a single treatment session.

Laser coagulation was achieved with a neodymium-YAG laser light with a wavelength of 1064 nm (Dornier MediLas 5100, Dornier, Germering, Germany), delivered through optic fibers terminated by a specially developed diffuser. The diffuser was mounted at the end of a 400-mm-long silica fiber core and tipped with a glass dome of 1.1 mm in diameter.

The laser application kit (Somatex, Berlin, Germany) consisted of a cannulation needle, a sheath system, and a protective catheter which prevented direct contact of the laser applicator with the treated tissues enabling complete removal of the applicator even in the unlikely event of damage to the fiber during treatment. The cooling of the surface of the laser applicator and the radial temperature distribution were optimized and the maximum temperature was shifted into deeper tissue layers [*7*, *8*]. This simplified the procedure and increased the security of the intervention.

The laser system was placed outside the MR examination room and the laser light was transmitted through an optical fiber with a length of 10 m. The patient was examined with a standardized MR imaging protocol, which included thermosensitive plain 2D fast low-angle shot (FLASH) sequence. Due to the hypointense signal of the lesion on the plain T1-weighted sequence, which was caused by the surrounding fat tissue, the tumor could easily be identified during the intervention in the open 0.2-T MR environment (Magnetom Open Viva, Siemens, Erlangen, Germany). During the intervention, the thermosensitive 2D FLASH sequence was repeated for MR thermometry. The maximal diameter of the circular hypointense area during laser application was approximately 5 cm (see Fig. 3). In order to exclude residual metastatic tissue, contrast-enhanced T1-weighted spin-echo sequences after application of Gd-DTPA with a dosage of 0.2 mmol/kg body weight were applied before the laser catheter was taken off.

The patient was positioned in a prone position with the right breast fixed and medio-laterally compressed with a dedicated biopsy coil (Noras Medizintechnik, Würzburg, Deutschland). The tumorous lesion was localized on pre-interventional MR scans and the injection site was infiltrated with 20 ml of 1% lidocaine. After the imaging was finished, pethidine was administered intravenously. The laser application system was inserted under MR guidance by making use of the Seldinger technique using a left lateral access. In a first step the lateral skin wall was penetrated with a cannula needle measuring 1.3 mm in diameter (Somatex, Berlin, Germany) being advanced into the tumorous mass (Figs. 1, 2, 3, 4, 5). The plastic sheath was introduced followed by the protective catheter; thereafter, the laser catheter was inserted into the protective catheter. The 2D FLASH sequences were repeated every 20 s to assess the progress of heating the lesion and the surrounding tissue. Heating was revealed as a characteristic signal loss on the T1-weighted gradient-echo images as a result of the heat-induced decrease of the T1-relaxation time. Depending on the geometry and intensity of the signal loss and the speed of heat distribution, the position of the laser fibers, the laser power, and the cooling rate were readjusted. The laser application was stopped after the total coagulation of the lesion with a safety margin of approximately 5 mm was documented on the MR images. The applied energy was 39 W in a time period of 7 min. The overall intervention time was 40 min.

Fig. 1. Preinterventional plain transverse T1-weighted MR image of the right breast: visualization of the metastasis as a hypointense nodule with unsharp margins (*arrows*)

Fig. 2. Preinterventional plain transverse T1-weighted MR image of the right breast. Before the cannula needle is introduced, a cutaneous marker is placed to optimize the insertion point of the needle (*arrows*)

Fig. 3. Postinterventional transverse T1-weighted MR image 5 min after onset of laser energy application: demarcation of the diffusely spreading zone of low signal intensity corresponding to the area of increased temperature distribution (*arrows*). The region of the former tumor localization is characterized with the *circle*

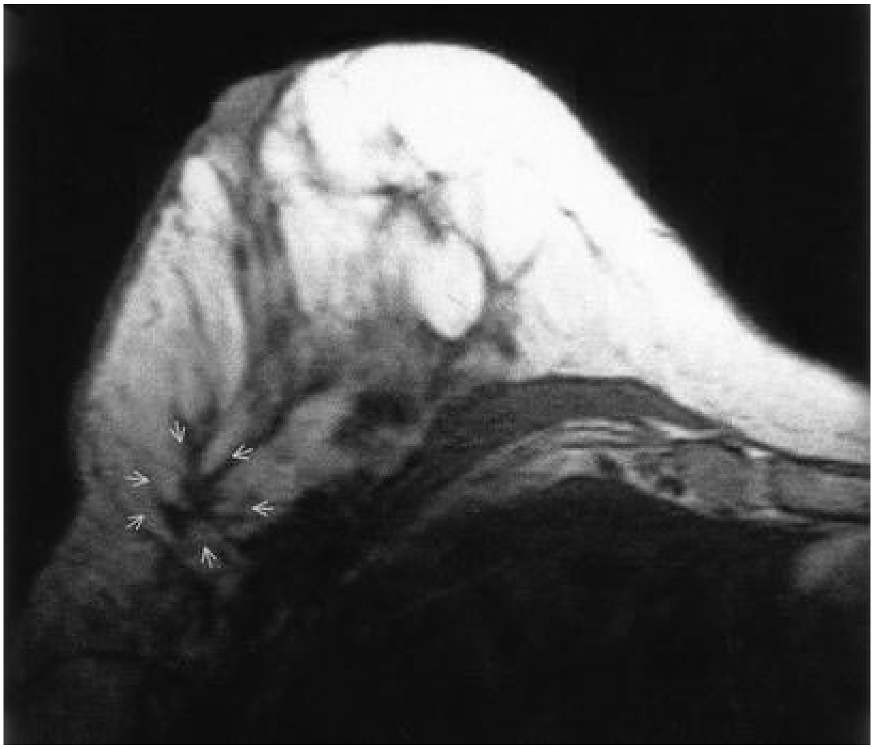

Fig. 4. Contrast-enhanced transverse T1-weighted MR image 1 day after laser-induced thermotherapy (LITT). There is no residual contrast-enhancing tumor visible (*arrows*). In the former localization of the tumor a necrosis with a rim of enhancement is shown

Fig. 5. Contrast-enhanced T1-weighted MR image 4 months after LITT: no evidence of recurrent tumor. There is also no evidence for a tumor relapse. In the former localization of the tumor a scar tissue with a low enhancement is demonstrated (*arrows*)

After switching off the laser, T1-weighted contrast-enhanced 2D FLASH images were obtained for verifying the induced necrosis. After the procedure, the puncture channel was sealed with fibrin glue (Tissuecol duo S, Baxter, Unterschleissheim, Germany). Follow-up examinations at the 1.5-T unit using plain and contrast-enhanced sequences were performed 24 h and every 4 months following the LITT procedure. Quantitative and qualitative parameters, including size, morphology, signal behavior, and contrast enhancement, were evaluated for deciding whether treatment could be considered successful or whether possible subsequent treatment sessions were required. The further evaluation included the clinical follow-up as well as the control of serum serotonin, which soon after the treatment dropped from 1236 ng/ml to normal values.

Discussion

Since the development of LITT a minimally invasive method has been placed at our disposal which is effective for treatment of liver tumors and soft tissue metastases as well as for the region of the brain, the skull base, face, and neck [*1*, *2*, *3*, *4*, *5*, *6*]. Especially MRI-guided LITT with its excellent soft tissue resolution and the temperature sensitivity of the MR sequences provides an exact supervision of the intervention. Complications, such as bleeding or the development of necrotic areas within vital structures, can thus be discovered in an early phase [*4*].

In our case MRI-guided LITT was used to localize and delete a relapsing breast metastasis due to a primary neuroendocrine carcinoma. Clinically a recurrent cancerous metastasis after previous resection was verified. After the treatment, a zonal structure of the lesion was observed, as also reported by Bremer et al. [*7*]. Around the central necrosis a contrast-medium-enhancing rim was found after Gd-DTPA application. The periphery of the lesion was finally surrounded by an edema as has been described by other authors [*7*].

Conventional breast-conserving operation techniques produce a considerable rate of complication, especially in recurrent tumors of the breast with complex scar tissues, and are often extremely difficult to perform. Considering these facts, MR-guided LITT as a combination of a well-evaluated minimally invasive ablation technique with a thermosensitive imaging modality with a high soft tissue contrast may become an interesting alternative at least for secondary breast malignancies and recurrent tumors.

Other groups have proven that radiofrequency (RF) ablation of mammary tissue is feasible but limited by numerous potential problems [*8*, *9*]. The major disadvantage of RF ablations is that a completely precise imaging modality for the peri-interventional monitoring of the ablation success is lacking due to the non-existent use of MRI for this treatment technique.

Limitations for all local ablation methods are possible cutaneous burns, which limit the treatment of superficial lesions. Furthermore, possible infections of the breast after minimally invasive treated breast cancer or metastasis must be assessed. Last, but not least, the degree of scarring after local ablations must be studied to ensure the assumed better cosmetic results in comparison with operative therapies. In our reported case, the degree of scarring was significantly lower as compared with surgery.

To our knowledge, this is the first published report on the use of cooled MRI-guided LITT (power LITT) for malignancy in the breast tissue. Previous reports of MRI-guided LITT of the breast with conventional laser systems [*10*, *11*, *12*] have already shown that MR imaging reliably demonstrates the position of the needle and the application system, and that MR thermometry precisely shows the energy uptake and change of temperature within the metastasis and surrounding normal glandular tissue. Wohlgemuth et al. [*13*] and Bremer et al. [*14*] showed in their study that there is a favorable correlation of the extent of necrosis in MRI and histology. The clear correlation of the induced size of necrosis and the applied energy was evaluated by Akimov et al. [*15*] and Atsumi [*16*]. The maximum extent of necrosis in their study was 2.5 cm with 6 W, so the security of ablation with the conventional laser systems was limited by the maximum reachable extent of necrosis. These limitations are overcome with the new cooled power laser systems, because the maximum amount of energy which can be applied is 35 W or more. With this power reserve, the extent of necrosis can be easily adapted to the size of the tumor. It has to be assessed in further studies whether the higher amount of applied energy increases the risk of liquification of fat because of fat necrosis. In our case, there was no evidence of clinically relevant amount of fat necrosis.

In conclusion, the introduction of power LITT into the local therapy strategies of the breast seems to be an essential step forward for the secure ablation of breast malignancies.

References

1.Vogl TJ, Straub R, Eichler K, Woitaschek D, Mack MG (2001) Modern alternatives to resection of metastases: MR-guided laser-induced thermotherapy (LITT) and other local ablative techniques. Ther Umsch 58:718-725

2.Schober R, Bettag M, Sabel M, Ulrich F, Hessel S (1993) Fine structure of zonal changes in experimental Nd: YAG laser-induced interstitial hyperthermia. Lasers Surg Med 13:234-241

3.Kahn T, Bettag M, Harth T (1996) Laserinduzierte interstitielle Thermotherapie von zerebralen Tumoren unter kernspintomographischer Kontrolle. Radiologe 36:713-721

4.Vogl TJ, Mack MG, Müller PK, Philipp C, Knöbber D, Roggan A, Wust P, Janke V, Felix R (1995) MR-gesteuerte laserinduzierte Thermotherapie bei Tumoren in der Kopf-Hals-Region: erste klinische Ergebnisse. Rofo Fortschr Geb Rontgenstr Neuen Bildgeb Verfahr 163:505-514

5.Vogl TJ, Müller PK, Hammerstingl R, Weinhold N, Mack MG, Philipp C, Deimling M, Beuthan F, Pegios W, Riess H, Lemmens HP, Felix R (1996) Malignant liver tumors treated with MR imaging-guided laser-induced thermotherapy: technique and prospective results. Radiology [redacted] :257-265

6.Vogl TJ, Eichler K, Straub R, Engelmann K, Zangos S, Woitaschek D, Bottger M, Mack MG (2001) Laser-induced thermotherapy of malignant liver tumors: general principals, equipment(s), procedure(s) - side effects, complications and results. Eur J Ultrasound 13:117-127

7.Bremer C, Kreft G, Filler T, Reimer P (2002) Accuracy of non-enhanced MRI to monitor histological lesion size during laser-induced interstitial thermotherapy. Eur Radiol 12:5-6

8.McGahan JP, Griffey SM, Schneider PD, Brock JM, Jones CD, Zhan S (2000) Radio-frequency electrocautery ablation of mammary tissue in swine. Radiology 217:471-476

9.Hilger I, Andrä W, Hergt R, Hiergeist R, Schubert H, Kaiser WA (2001) Electromagnetic heating of breast tumors in interventional radiology: in vitro and in vivo studies in human cadavers and mice. Radiology 218:570-575

10.Hall-Craggs MA (2000) Interventional MRI of the breast: minimally invasive therapy. Eur Radiol 10:59-62

11.Mumtaz H, Hall-Craggs MA, Wotherspoon A, Paley M, Buonaccorsi G, Amin Z, Wilkinson I, Kissin MW, Davidson TI, Taylor I, Bown SG (1996) Laser therapy for breast cancer: MR imaging and histopathologic correlation. Radiology 200:651-658

12.Lanzafame R (1995) Applications of laser technology in breast cancer therapy. Semin Surg Oncol 11:328-332

13.Wohlgemuth WA, Wamser G, Reiss T, Wagner T, Bohndorf K (2001) In vivo laser-induced interstitial thermotherapy of pig liver with a temperature-controlled diode laser and MRI correlation. Lasers Surg Med 29:374-378

14.Bremer C, Kreft G, Filler T, Reimer P (2002) Accuracy of non-enhanced MRI to monitor histological lesion size during laser-induced interstitial thermotherapy. Eur Radiol 12:237-244

15.Akimov AB, Seregin VE, Rusanov KV, Tyurina EG, Glushko TA, Nevzorov VP, Nevzorova OF, Akimova EV (1998) Nd: YAG interstitial laser thermotherapy in the treatment of breast cancer. Lasers Surg Med 22:257-267

16.Atsumi H, Matsumae M, Kaneda M, Muro I, Mamata Y, Komiya T, Tsugu A, Tsugane R (2001) Novel laser system and laser irradiation method reduced the risk of carbonization during laser thermotherapy: assessed by MR temperature measurement. Lasers Surg Med 29:108-117