Laser-induced Thermotherapy of Hepatic Metastases: Effect of Blood Flow Reduction on Lesion Diameter

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**Introduction:** Surgical resection is considered the only potentially curative option for primary and secondary malignant hepatic tumors. Few patients, however, are surgical candidates. Thus a minimally invasive form of palliative or curative therapy for primary and secondary hepatic tumors would be ideal. Image-guided thermal ablation techniques may fulfill these requirements. They use energy sources such as radiofrequency (RF), microwave, high-intensity focused ultrasound, and laser. There is practically no difference between RF and laser ablation regarding lesion size, but the laser technique has the advantage of being fully compatible with MR imaging. The ability to observe the thermal lesion ensures accurate energy application. The duration of heat and the applied power can be altered individually.

The results of previous studies suggest that the development of effective techniques for reducing hepatic blood flow may ultimately enable the destruction of greater liver tumor volumes during laser application (1,2). Total occlusion of portal inflow (Pringle maneuver) has been used but requires open laparotomy. Balloon occlusion of the hepatic artery may also be used in minimally invasive applicators but may not be sufficient due to collateral perfusion of the liver. Embolotherapy is another promising approach. Experiments combining transarterial starch microspheres and LITT achieved greater thermal lesions than LITT alone (2). The objective of this study was to combine temporary occlusion of the hepatic arteries with LITT in a clinical setting and to compare the results to those of intraoperative LITT during the Pringle maneuver and to LITT alone.

**Methods:** Fifty-six patients with a total of 104 metastases were treated by LITT. Inclusion criteria were (a) not more than 5 hepatic lesions, (b) a lesion diameter of less than 5 cm, (c) no evidence of extrahaepatic metastases, and (d) inoperability or refusal of surgery. The patients gave their written informed consent one day before laser therapy. Fourteen patients were treated percutaneously without embolisation (group 1), and 19 patients underwent percutaneous LITT with temporary occlusion of the hepatic arteries by injecting degradable starch microspheres (DSM) (group 2). In groups 1 and 2, the intervention was performed in an open MRI system at 0.2 T (Magneton OPEN, Siemens, Erlangen, Germany). A T1-weighted breath-hold gradient-echo sequence (FLASH 2D; TR 220ms; TE 9ms; FA 80°; SL 8mm). 1-2 sections with 10 slices each measuring time 23 s was performed to localize the liver metastases. After puncturing the liver, the appropriate applicator — a thermally stable, flushable puncture catheter (Somatex, Berlin, Germany) — was inserted via a sheath. A laser applicator with a 25mm active diffusing tip was used. The cooling pump and Nd:YAG laser (5100 Fibertome, Dornier Medizinlaser, Munich, Germany) were located outside the examination room beside the operating console of the MRI. The patients in group 2 then received 450 mg DSM (diameter: 45 μm; Spherez®, Pharmacia AB, Sweden) through a catheter selectively advanced into the proper hepatic artery in the angiography laboratory before MRI. LITT was then started. Laser output power was 24-30 W. Thermometry was performed by a T1-weighted gradient-echo sequence every 120 seconds (FLASH 2D; TR 110ms; TE 9ms; FA 80°; SL 8mm).

LITT was performed after laparotomy in 23 patients (group 3). The metastases were localized for puncturing by intraoperative ultrasound (IOUS) at 7.5 MHz. During the laser application, the blood flow was reduced by temporarily occluding the hepato-duodenal ligament (Pringle maneuver). The procedure was monitored by IOUS.

In groups 1 and 2, the first follow-up examination was performed 24 to 48 hours after laser treatment by a contrast-enhanced (0.1 mmol/kg bodyweight Gd-DTPA, Macnevis®) MRI at 1.5T (Magneton VISION, Siemens, Erlangen, Germany). Group 3 was followed up within the first week after LITT using contrast-enhanced MR or CT. Liver lesions were measured and volumes calculated according to the formula for spheroids. We determined the metastasis size before the intervention and the thermal necrosis size after LITT (non enhancing tissue in the portal venous phase). We also calculated the ratio between postinterventional lesion volume and applied energy (Table 1).

**Results:** Laser-induced thermotherapy was technically feasible in all 56 patients. Due to the free selection of slice orientation, MRI and IOUS were equally suited for metastasis puncture. Both methods showed a distinct laser effect in the lesion in the first 10 min. of energy application, and this additional verification of applicator position and ensured that the entire laser system was working well. After 15 min., however, the IOUS images were no longer diagnostic due to the total reflection caused by tissue vaporsisation, whereas the heating effect could be delineated throughout the whole procedure on the MR images. Temporarily interrupting perfusion did not increase morbidity. Five patients developed pleural effusion after therapy, one a subcapsular hematoma, and one a bile fistula. No major therapy-related complications or death appeared during the intervention or hospitalization. The mean liver lesion volumes are listed in Table 1.

**Discussion:** In thermal ablation, it is difficult to predict a precise lesion size at a certain power output and duration because absorption and scattering coefficients vary according to the type of tissue. This is why image guidance is important for the effective clinical use of LITT and for preventing undesired damage to normal adjacent structures. Sonographic findings observed during thermal ablation procedures are not sufficiently accurate in predicting the extent of coagulation (3). The increasing hyperechogenic area regularly seen at the applicator tip during energy application often obscures the applicator and tumor while increasing the difficulty of repositioning for further treatment. In contrast, heat-sensitive MR sequences permit adjustment of energy application.

The laser effect can be significantly enhanced by temporarily interrupting blood flow during laser application (1,4-6). After laparotomy, this can be done by the Pringle maneuver. However, an alternate occlusion method is needed, if LITT is performed percutaneously. Since blood is supplied to liver metastases primarily via the hepatic artery (7), a suitable approach would be the temporary occlusion of these arteries by injecting particles (8,9). Administering 450 mg of DSM via the proper hepatic artery substantially increased the coagulation diameter as compared to the control group without flow reduction.

In conclusion, percutaneous LITT in combination with DSM-induced hepatic inflow reduction produces lesion volumes similar to those achieved intraoperatively with the Pringle maneuver but are significantly larger than lesions created by LITT alone.

**References**


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