Diagnostic and Interventional Imaging (2014) 95, 339—343

TECHNICAL NOTE / *Oncology*

Magnetic resonance guided focalised ultrasound thermo-ablation: A promising oncologic local therapy

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KEYWORDS
High-intensity focused ultrasound;
Functional MRI;
Thermo-ablation;
Bone pain;
Non-invasive

Pain management of bone metastases is usually made using systemic and local therapy. Even though radiations are nowadays the gold standard for painful metastases, innovations regarding minimally invasive treatment approaches have been developed because of the existing non-responder patients [1]. Indeed, cementoplasty and thermo-ablations like radiofrequency or cryotherapy have shown to be efficient on pain [2—4]. Among thermotherapy, magnetic resonance guided focalised ultrasound is now a new non-invasive weapon for bone pain palliation.

Discussion

Magnetic resonance image-guided focused ultrasound surgery (MRgFUS, ExAblate, InSightec, Tirat Carmel, Israel) is an innovative technology combining two distinct approaches: high-intensity focused ultrasound (HIFU) and a magnetic resonance imaging system (MRI) [5].

HIFU is a well-known technique, which has been first introduced for biological ablation in 1942 [6]. It allows destroying targeted tissue not invasively by increasing the temperature locally. What is new about it is the MRI guidance and monitoring. Indeed, functional and morphologic sequences provide both accurate localisation targeted tumours and temperature monitoring [7—9].

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http://dx.doi.org/10.1016/j.diii.2013.09.003

The device is made of a modified table compatible with the existing MRI platform and a workstation to control the system (Fig. 1).

Focused ultrasound waves are generated from a phased array transducer with 256 elements. The waves are focused for 15 to 25 seconds to yield heat on an ellipsoid-shaped spot measuring up to 7 cm. Each ultrasound energy deposition is called ''sonication''.

The energy delivered by a single shoot is sufficient to increase tissue temperature above the denaturing proteins thermal dose threshold. It results in a coagulative necrosis [10].

The operator desktop station allows both the MRI and the HIFU system control. After calibration, the first step is the definition of the treatment zone. T2-weighted images are used by the physician to define the tumor target. Moreover, the fusion with CT scan can be helpful. Then, to ensure that the entire volume receives adequate thermal dose, the software proposes a three dimension treatment plan composed of multiple sonications [10,11]. However, the operator can change the shape, size, intensity of the acoustic beams to tailor the treatment ''in real time'' and protect surrounding organs at risk [12,13]. On the screen, feedback to predict efficiency of the sonication is available through ultrasound propagation monitoring and in vivo magnetic resonance thermal map (Fig. 2) [14]. In addition, after the procedure, a post-contrast sequence offers an estimation of the ablated tissue which turns out to be non-perfused. Also, functional MRI sequences could improve residual tumour estimation after treatment using perfusion MR or diffusion weighted imaging.

For bones, the targeted ablation aims at denervating the periostium invaded by the tumour and yielding pain relief. In this case, the focus point is placed behind the targeted bone to allow a larger field of heating (Fig. 2). This is made possible because bone absorbs about 50 times as much ultrasound energy as soft tissues [15].

Typical bone procedure lasts 2 hours, including approximately 1 h of sonication time. As the periosteal ablation is painful, the anaesthesia management is a key factor to maintain the patient's comfort, avoids movements during the procedure, and allows the physician to reach adequate levels of energy. Two options are possible: first, a locoregional anaesthesia like nerve block or spinal; second, the combination of a deep sedation and a local anaesthesia (usually performed under x-ray guidance).

MRgFUS device is approved by Food and Drug Administration (FDA) and the European Community (CE) for the treatment of uterine fibroma and painful bone metastases and is currently under evaluation for the treatment of solid tumours in the brain, breast, prostate, liver and pancreas [16—19]. Others devices are available but only two are guided by MRI. Each system needs to be marked for a specific indication; we have summarised the existing devices in Table 1.

Among different studies, all patients have reported fast (< 48 h) and significant pain reduction (Visual score drop > 2 points) in treated bones and a drop in the use of painkillers [19,20]. No adverse events have been recorded. These results are very promising and a larger multicenter study for bone palliation using the MRgFUS approach is being conducted to compare it with radiation. The real challenge

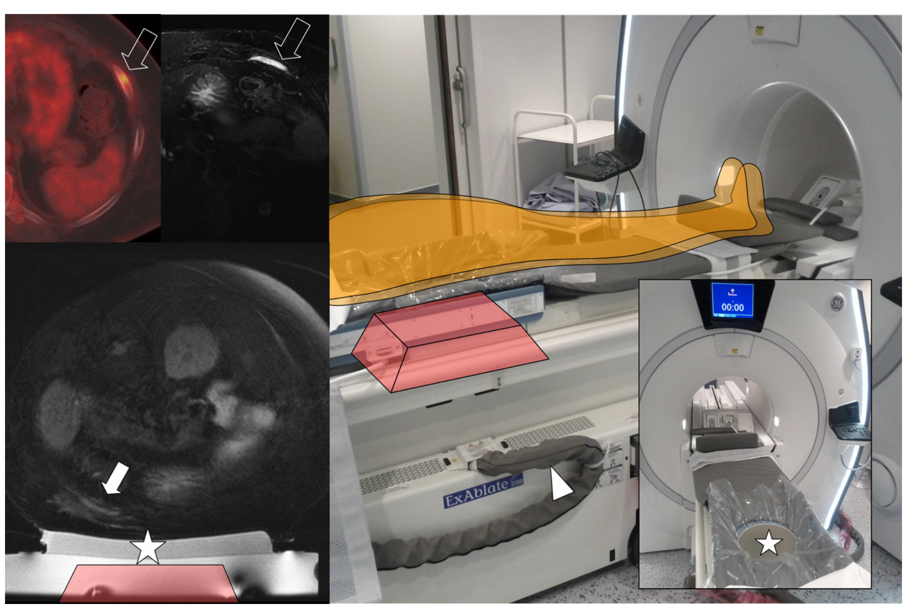

Figure 1. Painful rib metastasis treated by MRgFUS, hardware device and patient positioning. A 54-year-old patient with lung cancer has left thoracic pain (numerical scale = 6/10). A whole body PET-CT has been performed and showed a left rib lesion. Before treatment, an axial T2-weighted MR is performed to be sure that the targeted rib lesion is visible (empty arrow). During the treatment, a local anaesthesia performed on the periosteum (hypersignal T2) allows pain control (plain arrow). As the transducer (red prism) is inside the MRI table, the patient has to be installed in ventral decubitus position to expose the target toward the ultrasound beam. The skin must be directly in contact with the gel pad and the water bath (star) to avoid air interface (risk of skin burn). The system needs a cooler system connected to a water source (plain arrowhead).