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A NEW VERSATILE MR-GUIDED HIGH-INTENSITY FOCUSED ULTRASOUND (MRgHIFU) DEVICE: SYSTEM PERFORMANCE ASSESSMENT AND CLINICAL FEASIBILITY

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Purpose: Originally developed for the treatment of uterine fibroids, whole-body MRgHIFU systems are not optimal for treating musculoskeletal tumors because of the difficulty in patient positioning¹, as well as the need for a dedicated, expensive water-filled MR-table. We have developed a new portable MRgHIFU device in which the transducer can be directly positioned on the patient.

Methods: The proposed device relies on: (1) An MR-safe flexible supporting device that allows free manipulation of the transducer. Up to 4 supporting legs with adaptable length can support the transducer holder. Once the transducer is in the desired position, the supporting device is rigidified using the granular jamming principle². (2) A navigation software that guides the physician during the transducer positioning process outside the MRI bore, through a virtual environment, displaying the target, the planned configuration, and the actual position of the transducer in real time. Once the transducer has been positioned, the HIFU ablation is monitored in real time using Proton Resonance Frequency Shift (PRFS) Thermometry. Positioning accuracy was first evaluated in a phantom. First clinical results on a patient suffering from a bone metastasis in the forearm are also presented.

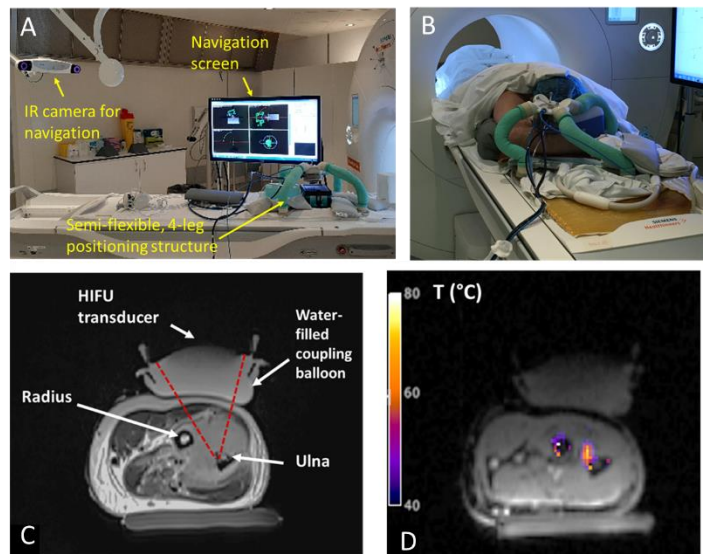


Fig. 1 : (A) General setup; (B) Experimental setup for the presented clinical case: the transducer is positioned over the forearm; (C) Transverse MR image showing the HIFU transducer, and the target on the ulna; (D) Real-time MR Thermometry during the ablation

Results: The average targeting error of the complete process was found to be equal to 5 ± 2 mm in terms of focus position, and 4 ± 2 degrees in terms of transducer orientation. In the clinical trial, the lesion to be treated in the first patient was an ellipsoid of $81 \times 47 \times 34$ mm³. Five different transducer positions were necessary to cover the whole volume, in addition to using electronic steering (using a 128-element, 1MHz transducer) for each transducer pose. The patient was successfully treated: Pain score decreased from 8/10 to 3/10 four days after treatment, and 85% of the lesion was treated. Pain palliation was durable, and no adverse effects were reported.

Conclusion: The proposed MRgHIFU device allows easy and accurate positioning of the HIFU transducer directly on the patient. This system is intended to be modular and flexible: It can be easily adapted to a variety of clinical applications that may require different HIFU transducers in terms of central frequency, aperture, number of elements and geometry. We expect this device to increase the accessibility to MRgHIFU therapies thanks to its versatility and its intrinsic low-cost nature.

References: 1. Joo, B. *et al.* Pain Palliation in Patients with Bone Metastases Using Magnetic Resonance-Guided Focused Ultrasound with Conformal Bone System: A Preliminary Report. *Yonsei Med J* **56**, 503–509 (2015).
2. Behringer, R. P. & Chakraborty, B. The physics of jamming for granular materials: a review. *Rep Prog Phys* **82**, 012601 (2019).