LABORATOIRE THÉRAPIE
ET APPLICATIONS ULTRASONORES

Master/Engineering student project – 6 months

3D Ultrasound Navigation platform for image-guided interstitial Focused Ultrasound treatment of Hepatocellular Carcinoma

Context:

Hepatocellular carcinoma (HCC) is the sixth most common cancer worldwide, and the fourth deadliest in 2018. Liver transplantation is the most effective way of treating HCC. However, due to the shortage of grafts, it is performed in only 3% to 4% of patients. Interstitial thermal ablation treatments offer a less invasive alternative for the patient and have the advantage of preserving a greater proportion of non-tumoral tissue[1]. However, these interstitial treatment techniques are unable to treat HCCs larger than 25 mm in radius, or require the insertion of multiple treatment needles, increasing the complexity of the procedure. In addition, the treatment is not conformal; the thermal ablation volume is not directional and does not adapt to the shape of the tumor[2,3].

High-intensity ultrasound therapy techniques are promising in the case of HCC, as they could enable treatment radii more than 3 cm to be achieved with a single needle and conformal treatment[4-7]. The use of conformal thermal therapy with focused ultrasound (FUS) alone may make it possible to treat currently untreatable HCC while preserving structures at risk, thereby expanding their use for this medical indication.

A new prototype (V2) of a miniature high-intensity focused ultrasound (HIFU) catheter has been recently developed by our group. This V2 catheter has been optimized (from a V1 prototype) to be used in dual-mode for both 2D ultrasound (US) imaging and ultrasound (HIFU) therapy. Recent work has demonstrated the possibility of inducing directional HIFU ablations under US imaging guidance (USgHIFU) in *in-vitro* liver tissues, along target radii extending over > 25 mm.

However to date, the HIFU ablations could only be performed following a 2D treatment planning, while full conformal treatments of HCC volumes need to be validated in 3D. We therefore need to couple these USgHIFU techniques with virtual navigation strategies and medical robotics to achieve 3D treatments. Initial work prior to the project led to the creation of a virtual 3D ultrasound navigation platform assisted by medical robotics[8]. First, this platform enabled the ultrasound reconstruction of a tumor volume in 3D (2D US imaging + catheter mechanical rotations/translations) using the V1 USgHIFU catheter controlled by a robotic arm. Second, these tumor volume reconstructions were used to validate 3D planning of conformal HIFU treatments in numerical modeling only. To date indeed, no proof of concept of full 3D conformal HIFU treatment could be demonstrated experimentally with the V1. In this internship project, we propose to address this point by combining for the first time a 3D Ultrasound Navigation Platform to a promising USgHIFU V2 catheter.

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3. Yu, H., & Burke, C. T. (2014, June). Comparison of percutaneous ablation technologies in the treatment of malignant liver tumors. In Seminars in interventional radiology (Vol. 31, No. 2, p. 129). Thieme Medical Publishers.

Unité de recherche U1032
Cyril LAFON, Directeur
151 Cours Albert Thomas
69424 LYON Cedex 03
Tél. +33 (0)4 72 68 19 30
Fax. +33 (0)4 72 68 19 31
u1032@inserm.fr
http://labtau.univ-lyon1.fr

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5. Delabrousse E, et al. Automatic Temperature Control for MR-Guided Interstitial Ultrasound Ablation in Liver Using a Percutaneous Applicator: Ex Vivo and In Vivo Initial Studies. Magn Res Med 63:667-679(2010)
6. Chopra, R et al. (2012). MR imaging–controlled transurethral ultrasound therapy for conformal treatment of prostate tissue: Initial feasibility in humans. Radiology, 265(1), 303-313.
7. N'Djin, W. A. et al. (2012). Coagulation of human prostate volumes with MRI-controlled transurethral ultrasound therapy: Results in gel phantoms. Medical physics, 39(7Part1), 4524-4536.
8. Daunizeau, L. et al. Robot-assisted ultrasound navigation platform for 3D HIFU treatment planning: Initial evaluation for conformal interstitial ablation. Computers Biol Med, 124, 103941 (2020)

Project objectives:

The Master's/Engineering student will be responsible for getting the 3D ultrasound navigation platform up and running again and helping to improve it. The student will also investigate new HIFU treatment planning for achieving full conformal ablations of HCC volumes. First, the student will investigate the theoretical feasiblity, by carrying out numerical HIFU modeling (Rayleigh integral, heat transfer equation in biological tissues for thermal therapy) using CIVA software. Finally, the student will assist the team to investigate experimentally the feasibility of conformal HIFU therapies in an *in-vitro* liver model. In case of success, the student could participate to *in vivo* investigations at the end of his/her project. The Master's/Engineering student will be working with two PhD students, one being a biomedical engineer and the other an interventional radiologist. A Researcher Associate will supervise the work.

Skills:

The candidate must be an Engineering Student or a Master Student in one of the following fields: Biomedical Engineering, Computer programming, Medical Imaging or System and Image.

- Programming skills: C++, Matlab, CAD softwares (ideally 3DSlicer)
- Signal and image processing
- Medical imaging: Ultrasound, MRI

Contacts:

Send a CV and a motivation letter to:

- W. Apoutou N'DJIN (**apoutou.ndjin@inserm.fr**)
- Thomas BISCALDI (**thomas.biscaldi@inserm.fr**)