Minimally invasive image guided therapy

The recent clinical emergence of minimally invasive image guided therapy has demonstrated promise in the management of brain metastasis, although control over the spatial pattern of heating currently remains limited. Based on experience in other organs, the delivery of high-intensity contact ultrasound energy from minimally invasive applicators can enable accurate spatial control of energy deposition, large treatment volumes, and high treatment rate.

A four-element linear ultrasound transducer (f = 8.2 MHz) originally developed for transurethral ultrasound therapy was used in a porcine model for generating thermal ablations in brain interstitially. First, the feasibility of treating and retreating preciselyin vivo brain tissues using stationary (non-rotating device) ultrasound exposures was studied in two pigs. Experimental results were compared to numerical simulations for maximum surface acoustic intensities ranging from 5 to 20 W cm(-2). Second, active MRT feedback-controlled ultrasound treatments were performed in three pigs with a rotating device to coagulate target volumes of various shapes. The acoustic power and rotation rate of the device were adjusted in real-time based on MR-thermometry feedback control to optimize heat deposition at the target boundary. Modeling of in vivo treatments were performed and compared to observed experimental results.

Overall, the time-space evolution of the temperature profiles observedin vivo could be well estimated from numerical simulations for both stationary and dynamic interstitial ultrasound exposures. Dynamic exposures performed under closed-loop temperature control enabled accurate elevation of the brain tissues within the targeted region above the 55 °C threshold necessary for the creation of irreversible thermal damage. Treatment volumes ranging from 1 to 9 cm(3) were completed within 8 ± 3 min with a radial targeting error <2 mm on average (treatment rate: 0.7 ± 0.5 cm(3)/min). Tissue changes were visible on T1-weighted contrast-enhanced (T1w-CE) images immediately after treatment. These changes were also evident on T2-weighted (T2w) images acquired 2 h after the 1st treatment and correlated well with the MR-thermometry measurements.

These results support the feasibility of active MRT feedback control of dynamic interstitial ultrasound therapy ofin vivo brain tissues and confirm the feasibility of using simulations to predict spatial heating patterns in the brain [1].

1)
N'Djin WA, Burtnyk M, Lipsman N, Bronskill M, Kucharczyk W, Schwartz ML, Chopra R. Active MR-temperature feedback control of dynamic interstitial ultrasound therapy in brain: In vivo experiments and modeling in native and coagulated tissues. Med Phys. 2014 Sep;41(9):093301. doi: 10.1118/1.4892923. PubMed PMID: 25186419.