AbstractID: 14545 Title: SonoKnife -- Feasibility of Line-Focused Ultrasound for Thermal Ablation

The SonoKnife is a new line-focused ultrasound device concept for non-invasive thermal ablation. The concept was motivated by the poor outcome in the treatment of advanced HNSCC recurrences and positive lymph nodes comprising a high-risk patient population. It is hypothesized that by incorporating thermal ablation, the need for further surgery may be reduced or circumvented while enhancing the therapeutic benefits of additional conventional therapies (i.e., radiotherapy and/or chemotherapy), when indicated.

The basic SonoKnife applicator is a cylindrical section ultrasonic transducer (single element or array). Line-focusing may have advantages over the more common point-focusing HIFU approach. In particular, a line-focused radiator will produce lower peak acoustic intensities in tissues when compared to an equivalent area spherically focused radiator, thereby minimizing nonlinear propagation and cavitation effects. Another advantage may be the faster ablation of large tumors by scanning a line-focus rather than a “point”-focus. Moreover, an array can be used to vary the length of the acoustic edge in real time.

Numerical simulations were performed to characterize the acoustic edge and optimize basic design parameters: size, f-number, frequency, depth of line-focus, and thickness of coupling bolus. Pressure fields were computed using FOCUS (Fast Object-oriented C++ Ultrasound Simulator), an open–source software package for numerical modeling of ultrasonics for therapy and imaging. The angular spectrum method was also incorporated to speed up the calculations of 3D pressure fields. These acoustic propagation models are to be integrated with thermal models into an image-based treatment planning system.

The shape, volume (dimensions) and depth of the acoustic edge as a function of basic design parameters were obtained. The minimum radiating area to guarantee sufficient energy for thermal ablation was determined for several transducers for a clinical range of tumor sizes and depths. Spatial peak intensities were compared to spherically focused transducers of equivalent radiating area. Based on preliminary simulations the first prototype is being developed for laboratory measurements.

In conclusion, the FOCUS simulation package was found to be an effective and efficient tool for the characterization of the SonoKnife. Simulations showed feasibility for thermal ablation with the SonoKnife in terms of energy requirements. Peak intensities were lower for the SonoKnife than for equivalent radiating area spherically curved radiators, as expected. For a more comprehensive characterization, tissue heterogeneities and nonlinear effects must be taken into account and thermal simulation studies need to be performed. Finally, the design of a clinical-grade system must incorporate precise image-guidance, which represents a formidable challenge.

Learning Objectives:

1. Learn about the new SonoKnife concept and its potential advantages relative to spherically focused HIFU radiators for advanced recurrent cancer in the head and neck.
2. Understand the main design parameters and their effect on the acoustic edge from numerical simulation results.
3. Learn about the main components necessary for a clinical practicable treatment planning system.
4. Gain practical understanding from the first SonoKnife applicator prototype and initial laboratory measurement results.
5. Appreciate the need for real-time image-guidance necessary for clinical deployment of a SonoKnife system and its potential combination with IG-IMRT/STRS.

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