Simulation estimates thermotherapy damage in prostate cancer
By Cheryl Guttman Krader

Grapevine, TX—French researchers aiming to develop image-guided laser interstitial thermotherapy (LITT) for prostate cancer have successfully created a 3-D numerical simulation method for accurately estimating the thermal effects and tissue damage caused by the procedure.

The data were presented by first author Mohamad-Feras Marqa, at the American Society for Laser Medicine and Surgery annual meeting in Grapevine, TX. Marqa, a physicist and doctoral student at INSERM U703, University of Lille 2, France, reported the findings from a study in which the predictions from the numerical simulation of LITT were validated against in vivo data collected in animals with experimentally induced prostate adenocarcinoma tumors treated with LITT. The simulation estimates for both the temperature increase produced in the tissue and the volume of thermal damage were ≤1% of the values measured in the preclinical model.

Based on data from 10 treated animals, the mean intratumoral temperature increased from a baseline value of 37°C to a maximum of 155°C; the mean volume of necrosis determined histologically was 0.98 cm³. According to the numerical simulation, the maximum achieved temperature was 156.6°C, and the volume of thermal damage was 0.99 cm³.

"Accurate modeling of the laser-tissue interaction is necessary to optimize treatment planning and outcomes of LITT," Marqa explained. "In contrast to other modeling attempts, our methods considered the Bioheat equation together with changes in the tissue properties during temperature elevation."

LITT shows promise

Senior author Nacim Bertrouni, PhD, told Urology Times, "As researchers aim to develop minimally invasive focal therapies for low-risk, low-volume prostate cancer, LITT appears to be a promising method. However, the clinical utility of this modality will depend on designing techniques for accurate conformation of the treated area and precise dosimetry planning.

"Our group, directed by Professor Serge Mordon, PhD, and including urologists Pierre Colin, MD, and Arnauld Villers, MD, PhD, is dedicated to meeting this challenge by developing image-guidance and other tools to assist focused therapies. Our research program represents a multipronged approach comprised of preclinical testing programs, development of numerical simulation techniques, and creation of physical phantoms that together will enable treatment planning, urologist training, and optimal patient outcomes," added Dr. Betrouni, a research scientist at INSERM U703.

To create the 3-D numerical simulation, Marqa first constructed a geometric model using proprietary software (COMSOL Multiphysics v4.0), and then employed a finite element method to simulate the heat distribution. The temperature increase was determined by solving the Bioheat equation, and the volume of thermal damage was estimated using the Arrhenius integral application, taking into account that irreversible cellular injury occurs at a temperature of 50°C.
For validation testing, the researchers employed a preclinical model used before for investigating high-intensity focused ultrasound treatment of prostate cancer. Tumors were established by Dr. Colin in Copenhagen rats by subcutaneous injection of prostate adenocarcinoma cells into the flank region. LITT was performed using a commercially available 980-nm diode laser with a cylindrical diffusing fiber (10-mm long, 500-micron core diameter) inserted into the tumor. The tumors were irradiated for 75 seconds using a power of 5 watts and fluence of 1,145 J/cm$^2$.

The location for insertion of the fiber was determined by pretreatment magnetic resonance imaging, intratumoral temperature was measured using a thermocouple located at the tip of the laser fiber, and animals were euthanized 48 hours after the procedure for histologic analysis to determine the volume of prostate tissue necrosis.