



Biomedical Paper

Computer Model for Cryosurgery of the Prostate

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ABSTRACT The objective of this study was to devise an interactive tool to assist in cryoablation therapy through computer modeling, simulation, and visualization. CryoSim, a software package, accepts a set of acquired and processed three-dimensional ultrasound images, then models heat diffusion (formation of the iceball) based on numerical approximation of the heat equation and knowledge of the thermal properties of the underlying tissues. Results of cryoexperiments were found to be significantly similar to those generated by CryoSim. Therefore, CryoSim provides a viable technique for predicting the outcome of cryosurgery, and establishes a platform for future automation of cryosurgery. *Comp Aid Surg* 4:193-199 (1999). ©1999 Wiley-Liss, Inc.

Key words: cryosurgery, prostate cancer, three-dimensional ultrasound, computer modeling

OBJECTIVE

Prostate cancer is the second leading cause of cancer death in American men. In 1997, approximately 209,900 new cases of prostate cancer were diagnosed, and the disease resulted in more than 41,800 deaths.^{7,18} Traditional treatments for prostate cancer include surgical removal or radiation therapy. Recently, however, cryosurgery has been accepted as a treatment option in localized carcinoma of the prostate, in part because of new technological advances and a refinement of the technique by Onik et al.^{9,19} Prostate cryosurgery has certain advantages over other procedures, including lower morbidity, short hospital stay, minimal blood loss, and the ability to retreat patients when necessary.^{1,5,8}

Cryoablation therapy is a method of minimally invasive cancer treatment that uses liquid nitrogen or supercooled argon to freeze and thus destroy tumors. Liquid nitrogen cools the tumor via a set of cryoprobes which have adjustable flow

rates, cooling temperatures, and activation times. Although cryoablation has been used for some time, the efficacy of the cryoprobe system has not been extensively studied. Cryosurgery of the prostate is performed under ultrasound monitoring. Unfortunately, the iceball of frozen tissue obstructs the propagation of sound waves, and only the front of this ball is visible. In addition, whereas the temperature of the leading front of the iceball in the prostate is -8°C , the temperature needed to kill the tissue has been reported to be between -40° and -50°C .¹⁶ At present, it is difficult to monitor the temperature of the prostate as it is being frozen. Two- and three-dimensional (2D and 3D) modeling of cryosurgery has been described in numerous papers, but there have been no studies of cryosimulation of the prostate in 3D models.^{2,11,13-15} We have therefore developed a computer program to model cryosurgery mathematically. This tool mon-

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