PREFACE

This issue of *Critical Reviews in Biomedical Engineering* is devoted to image-guided thermal ablation. Thermal ablation as applied for medical therapies aims to destroy unwanted biological tissue locally via heating or freezing, typically by using an applicator that is inserted and guided by medical imaging toward the target region. Ablative therapies have seen rapid development and growing clinical application for several diseases in the last three decades. What began primarily as a treatment for cardiac arrhythmias in the 1980s soon found utility in cancer care in the 1990s. The past 15 years have been characterized by growing clinical adoption of thermal ablation in parallel with substantial developments in technologies for energy delivery. Increasing interest in minimally invasive alternatives to surgery, coupled with a need to reduce the monetary costs associated with health care, have fueled much of the interest in ablative therapies. In 2010, the number of thermal ablations that will be performed around the world is estimated at several hundreds of thousands.

From a clinical perspective, thermal ablation often aims to achieve the same goals as surgical procedures. However, because ablation is less invasive, spares more normal tissue than surgery, and can be performed with lighter anesthesia, it can be used in patients for whom surgery is not an option. This is particularly true in oncology applications, in which the majority of new patients may not be surgical candidates, and other forms of treatment such as radiation or chemotherapy may not be effective or applicable. Drugs are also often not effective in the treatment of abnormally beating hearts (cardiac arrhythmia), and this is another field in which thermal ablation has found wide clinical use. During cardiac ablation, the abnormal electrical signal conduction in the heart that is responsible for the irregular beats is normalized by destroying the aberrant electrical pathways or foci. Other clinical problems that are now being treated by ablation include excessive uterine bleeding, varicose veins, and Barrett's esophagus.

The reviews in this issue discuss the individual constituents of a thermal ablation procedure, including the goals of thermal ablation, treatment planning strategies, biophysics of ablation systems, treatment monitoring, and assessment of treatment response. The article by John Pearce addresses the roles of temperature and time in cellular necrosis, apoptosis, and other tissue damage processes, highlighting research results in the temperature range relevant to thermal ablation (i.e., above 50^{o}C) and presenting mathematical models that allow for the prediction of cell damage based on time-temperature history. Building on this work, Stephen Payne et al. review the current state of mathematical modeling in thermal therapies by presenting techniques commonly used to calculate tissue temperature by solving the heat-transfer equation under special consideration of tissue perfusion. These two reviews provide the basic understanding of the biological and biophysical processes relevant to thermal ablation. The next article, by Christian Schumann et al., describes how these mathematical models can be integrated in a treatment planning system for a tumor ablation procedure. Currently, the treating physician plans an ablation procedure based primarily on expertise. A treatment planning platform that allows for patient-specific prediction of the zone of tissue death may yield more reliable and reproducible outcomes, particularly in complex cases, and may facilitate adoption of thermal ablation by less-experienced users.

The next three articles cover the most widely used methods of thermal ablation: radiofrequency electrical currents, microwaves, and lasers. All three methods employ interstitial applicators inserted into the target tissue, which subsequently heat the tissue surrounding the applicator. The review by Dieter Haemmerich outlines the technology behind radiofrequency ablation for both cardiac and oncology applications, whereas the article by Christopher Brace provides similar details of microwave ablation. The review by R. Jason Stafford et al. gives a technological overview of laser ablation, along with clinical examples of how lasers can facilitate treatment monitoring based on noninvasive magnetic resonance imaging thermometry. The article by Rao et al. gives a glimpse into the future, as thermal therapies are combined with drug- and radiation-based approaches to improve treatment success via biological synergy of these combinations.

Each article in this issue is based on many years of expertise by the respective authors and their research laboratories. This experience includes both technology development and clinical translation of technologies, as represented by the clinical experiences discussed in many of the articles. We hope that this issue will serve as a source of information for researchers aiming to get an introduction and overview of the field of thermal ablation.

—Dieter Haemmerich, PhD, DSc & Chris Brace, PhD