Modeling Study of a Pulsed Radiofrequency for Pain Relief

E. Ewertowska[1], M. Trujillo[2], E. Berjano[1]

[1]Department of Electronic Engineering, Universitat Politècnica de València, Valencia, Spain
[2]Instituto Universitario de Matemática Pura y Aplicada, Universitat Politècnica de València, Valencia, Spain

Abstract

Radiofrequency ablation is one of the common methods used to treat pain, movement or mood disorders. It bases on the electromagnetic energy provided to the selected tissue when an alternating current is applied. The resistive heating produced in this process provokes temperature rise in target tissue and generates lesion for intended therapeutic effects. However, in case when no tissue damage is expected, pulsed radiofrequency (PRF) technique is used. The energy is supplied by a train of pulses that reduces significantly temperature rise in tissue but takes advantage of high electric field effects [1, 2]. Habitually in a clinical procedure, temperature controller is additionally employed. There exist variety of protocols of PRF used clinically for pain relief; however, in this theoretical study we limited to compare two of them: A standard pulse protocol and a modified standard pulse, which was proposed as a less-damaging alternative [3, 4]. The modified standard pulse protocol states that by modifying pulse train characteristics within the same range of energy applied, less thermal variations we obtain what implies less damage but at the same time does not influences electrical effect.

The model was solved as a coupled thermo-electric problem by means of COMSOL Multiphysics® software. The governing equation for thermal model was expressed by the bioheat equation that coupled both current flow and resistive heating phenomena. Model included tissue electrical conductivity changing in a function of temperature, Arrhenius damage function and temperature controller. Sensitivity analysis was completed separately for geometry dimensions, mesh refinement and time step size. Voltage pulses for electrical heating shown in Fig. 1, were modelled as a periodic rectangular function applied at a given frequency. For the temperature control Events interface with the respective implicit events for power switch were added.

Results showed differences in temperature distributions for both pulse timings while the electric response was not significantly changed. After applying the temperature controller, noticeable difference in temperature distributions and damage level were observed, as shown in Fig. 2. The electric response was dependent on the number of pulses reduced due to the control of temperature.

This paper focuses on modeling the clinically approved protocols for pulsed radiofrequency in order to support the experimental results and enhance, if it is possible, the method for pain relief. Many factors need to be taken into account for thermal and

electric response analysis. COMSOL Multiphysics permits to model diverse physical phenomena and to predict and design a therapy to obtain the intended effects.

Reference

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[3] O. Rohof, Caudal Epidural of Pulsed Radiofrequency in Post Herpetic Neuralgia (PHN); Report of Three Cases, Vol. 4 (3), p. 10 (2014)
[4] R. Vallejo et al., Pulsed radiofrequency modulates pain regulatory gene expression along the nociceptive pathway., Pain Physician, Vol. 16 (5), p. 601 (2013)

Figures used in the abstract

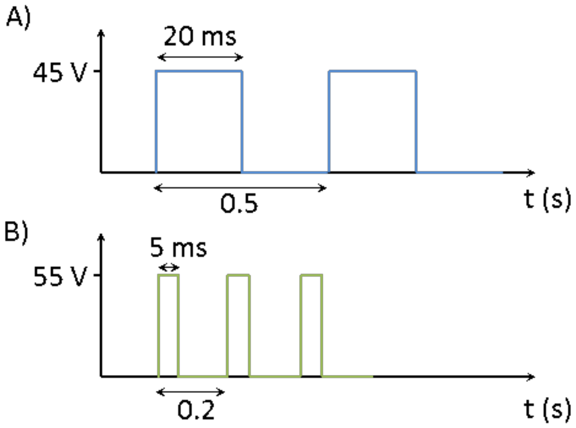

Figure 1: Periodic rectangular pulses applied in PRF: (A) standard pulse (SP), (B) alternative pulse (AP).

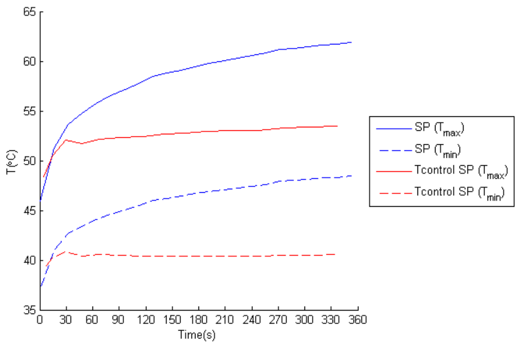

Figure 2: Temperature distributions at the electrode tip with and without temperature control for the same pulse SP.