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TISSUE THERMAL DAMAGE IS REDUCED WHEN USING INSULATED ELECTRODES IN COMPARISION TO STANDARD ELECTRODES DURING ELECTROSURGERY: A COMPUTATIONAL INVESTIGATION

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Summary: Electrosurgery is characterised by the passage of radiofrequency electrical current through the patient's tissue, causing resistive heating also known as Joule heating. This results in the elevation of temperatures, thermal damage, and can impair tissue healing. Temperatures can exceed 200°C and depends on electrode design, operating conditions (current density, waveform, and usage time), and tissue electrical and thermal conductivity properties [1, 2]. Electrodes with a side-layer of insulating material may reduce thermal spread in comparison with an uncoated electrode [3]. This reduced thermal spread occurs principally because of current density focusing in the intended direction during application. Empirically quantifying tissue temperature, and damage during electrosurgery has its difficulties: thermographic imaging only captures surface temperatures, thermocouples are inaccurate in RF environments (optical probes are an alternative), and tissue damage assessment requires histological expertise and ex-vivo models will never recapitulate the in-vivo environment. Therefore, in this study, finite element analysis (FEA) is employed to interrogate how the electrode, operating conditions, and tissue properties influence thermal damage in the surrounding tissue, which to date is not yet fully understood. The objective of this study is to develop a computational model which represents electrosurgical cutting with insulated and uncoated electrodes to enhance our understanding of how these primarily geometrical parameters influence electrosurgery. Geometries of an uncoated and insulated electrode were imported into Comsol Multiphysics and 3D models were generated of the electrodes inserted into tissue, reflecting experimental work being carried out in tandem with this work. The electrical potential distribution is described by the quasistatic approximation of the Maxwell equations, $\nabla\bullet(\sigma\bullet\nabla\varphi)=0$, where σ is electrical conductivity, and φ is electrical potential. The time-dependent temperature within the tissue is described using the Pennes bioheat transfer equation without accounting blood perfusion effects (ex-vivo conditions), $\rho c(dT/dt)=\nabla\bullet(k\bullet\nabla T)+q_{em}$, where ρ, c, k, T, and q_{em} are the density, specific heat, thermal conductivity of tissue, temperature and joule heating source term ($q_{em}= \sigma|\nabla\varphi|^2$), respectively. The parameters σ and k are implemented as temperature dependent properties. Electrosurgery in 'cut mode' applies current to tissue at a frequency of 391 kHz and appropriate tissue properties are obtained from the IT'IS database to reflect this [4]. Electrical potential is applied to electrode at physiologically relevant magnitudes obtained experimentally by differential probing at different electrosurgical generator power settings. A zero electrical potential (φ=0 V) is applied where the grounded pad is located. This study provides unique information regarding the thermal spread surrounding electrosurgical electrodes, which is otherwise difficult to obtain directly through experiments. The results demonstrate the effectiveness of insulated electrode designs for thermal damage reduction. This is comparable to experimental work comparing insulated and uncoated electrodes subjected to robotically controlled electrosurgery [3]. The model developed in this work can inform device design in a time-efficient and cost-effective manner, and help design electrodes for areas of the human body where the reduction of thermal damage is of utmost importance.

References

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