Effect of modification of irreversible electroporation parameters and the presence of a metal stent on the electric field distribution visualized in a static electric field

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Abstract
Background Irreversible electroporation (IRE) is an ablation method that, due to its non-thermal technique, seems particularly suitable for ablation of tumors in proximity of vital structures. However, thermal effects are observed near the needle electrodes in clinical practice and the optimal parameter settings necessary for a precise and controlled tissue ablation are not well understood. In addition, the effects of IRE near a metal stent are currently unknown, both in terms of ablation efficacy and safety, due to disturbance of the electric field and potential thermal effects. Visual insight in the electric field line pattern could offer a more profound understanding of the thermal effects, influence of parameter settings and the influence of a metal stent on the ablation zone. The aim of this study was to visualize the influence of IRE ablation parameters on the electric field distribution and to compare these observations with mathematical models.

Methods Experiments were performed in a static electric field using a high-voltage generator connected to two electrodes in a transparent tube filled with castor oil and semolina. Semolina was used to visualize the electric field lines. The effect of variations in inter-electrode distance, active needle length, voltage and presence of a metal stent on the field distribution were studied. Experimental findings were compared with a 2D model of the electric field distribution and a finite difference model (FDM).

Results A 3D visualization of the electric field line distribution was demonstrated (*figure 1*). The highest electric field line density was observed adjacent to the active needle length and increased with decreasing inter-needle distance. Furthermore, the area in which field lines were visualized increased with increased active needle length. Experimental findings were in line with observations from the mathematical models. Lastly, redistribution of the electric field towards a metal stent was observed, whereby regular electric field lines were not present in a triangular shaped area between the needles and stent.

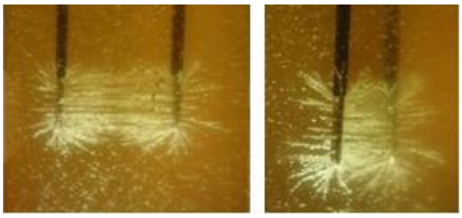

Figure 1 Aggregation of semolina in castor oil according to the electric field line pattern, from a front (left) and side (right) point of view.

Conclusion A 3D visualization technique of the electric field distribution in a static electric field was developed. This technique provides insight in the effects of IRE ablation parameters on the electric field distribution and could be helpful by identifying the locations where thermal effects are most likely to occur. Redistribution of the electric field towards a metal stent was observed, indicating an effective irreversible electroporation near a metal stent cannot be guaranteed. Further research on effective and safe IRE tumour ablation near a metal stent is required before the contraindication to perform IRE in patients with a metal stent can be discarded.