# Thermal effects of irreversible electroporation

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## INTRODUCTION

Radiofrequent (RF) and Microwave (MW) ablation are techniques used to treat tumor lesions at challenging locations, e.g. liver and pancreas. Controlling the ablation effect to limit ablation to the tumor tissue is often difficult. This is an issue, for instance for patients with locally advanced pancreatic cancer (LAPC) where local thermal ablation is used with the risk of potentially damaging surrounding structures. Secondly, cooling by blood flow may prevent an effective temperature rise in tumor tissue in proximity of large blood vessels.

Irreversible electroporation (IRE) is a technique causing permeabilization of the cell membrane through electrical pulses, thereby destroying the tumor. This non-thermal ablation mechanism is expected to cause less morbidity than thermal ablative strategies. Another advantage would be that local bloodflow has no impact on this non-thermal ablation pattern. However, clinical application of IRE may be associated with a temperature rise at the tumor site. We investigated the presence of thermal effects for IRE in a realistic animal model.

## MATERIALS AND METHODS

Experiments were performed with a standard clinical IRE protocol for 2x2 IRE electrodes inserted with 15mm spacing in a tissue equivalent gel ($\sigma$=0.71 S $m^{-1}$,$\varepsilon$=102). For the four combinations of adjacent electrodes 25 pulses of 100 μs were applied with an interval of 1 sec between the pulses.Temperature measurements were performed with four fiber optic temperature probes along a line starting at the center of the ablation zone extending outward. Simulations of the temperature rise were performed using hyperthermia treatment planning software developed for interstitial hyperthermia treatment using a 27MHz local current field technique [1,2]. This quasi static model is suitable for simulating IRE.

Liver and pancreas tissue was electroporated *in vivo* in four healthy pigs with permission of the local ethical committee. Two, three or four IRE electrodes were placed in porcine liver or pancreas in a configuration as used in human clinical treatments. Temperature measurements were performed by placing up to four fiber optic temperature probes along a line starting at the center of the ablation zone extending outward. Standard clinical IRE protocols were performed.

## RESULTS

The IRE experiments in tissue equivalent gel showed a temperature rise within the implant closely resembling simulation results. The temperature rise depends on stage and location, which reflects the IRE protocol where different pairs of electrodes are consecutively active throughout the procedure

Electroporation was applied at various positions in the pancreas and liver of four pigs. The IRE applications resulted in a minimum temperature rise of 1-2°C and a maximum temperature rise of 30°C in both organs. However, the temperature rise does not always occur immediately and is not evenly distributed throughout the target zone.

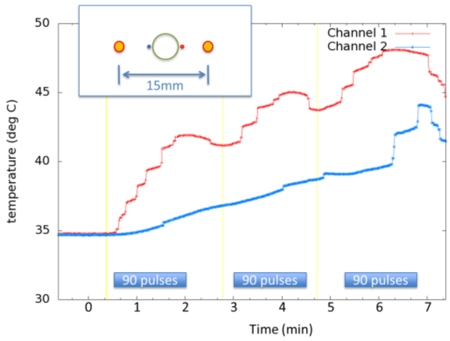


Figure 1: temperature recorded during IRE in two fiber optic thermometry probes positioned around a bile duct in between two IRE electrodes during three pulse trains in a two electrode implant in the pancreas.

Figure 1 shows an example measured in a pancreas. The temperature is recorded in thermometry probes positioned in between two IRE electrodes during an IRE procedure. Both measurement points are on a line between the two electrodes. The temperature rise at the first probe position closely follows the IRE pulses, whereas the temperature rise at the second probe lags behind, which suggests that at this location the temperature rise is caused by conduction from areas directly heated by IRE.

## CONCLUSIONS

Significant thermal effects capable of causing thermal ablation were frequently present during electroporation in this study. Its occurrence and magnitude depends on location and local anatomy. Accurate predictions require incorporation of the full anatomy in a dedicated treatment planning system. A research project has started to investigate these issues in more detail and to construct a planning system that incorporates both thermal and non-thermal effects of IRE. More research is needed to demonstrate what role thermal and non-thermal effects play in the clinical effectiveness of IRE.

## ACKNOWLEDGMENTS

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