A Software Prototype for Real-time Ablation Zone Planning Using Distance Transformation Calculated Isosurfaces

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Purpose

Thermal or electrical ablative techniques are used in a variety of pathologies, such as local tumor control or local pain treatment. Additionally to cryoablation, microwave ablation and radiofrequency ablation, irreversible electroporation (IRE) was recently added to the toolbox of image guided therapy (IGT). For all aforementioned techniques planning and monitoring of the ablation areal is central to the procedure's success [1]. Many published methods include CPU-intensive simulations of ablation techniques [2,3]. We present a method to plan and monitor estimated ablation volumes in real-time.

Methods

A research software prototype was developed using MeVisLab (http://www.mevislab.de). In a showcase application the electrical field of irreversible electroporation was estimated using Euclidian distance transformations (DTF): a distinct inverse DTF around every manually determined (Figure 1) needle tip was calculated after manually segmenting the needle tips in an intraprocedural CT scan. Subsequently, summation of the distance fields was performed, isosurfaces at three distinct isovalues were calculated (Figure 2) and compared to postprocedural imaging (Figure 3).

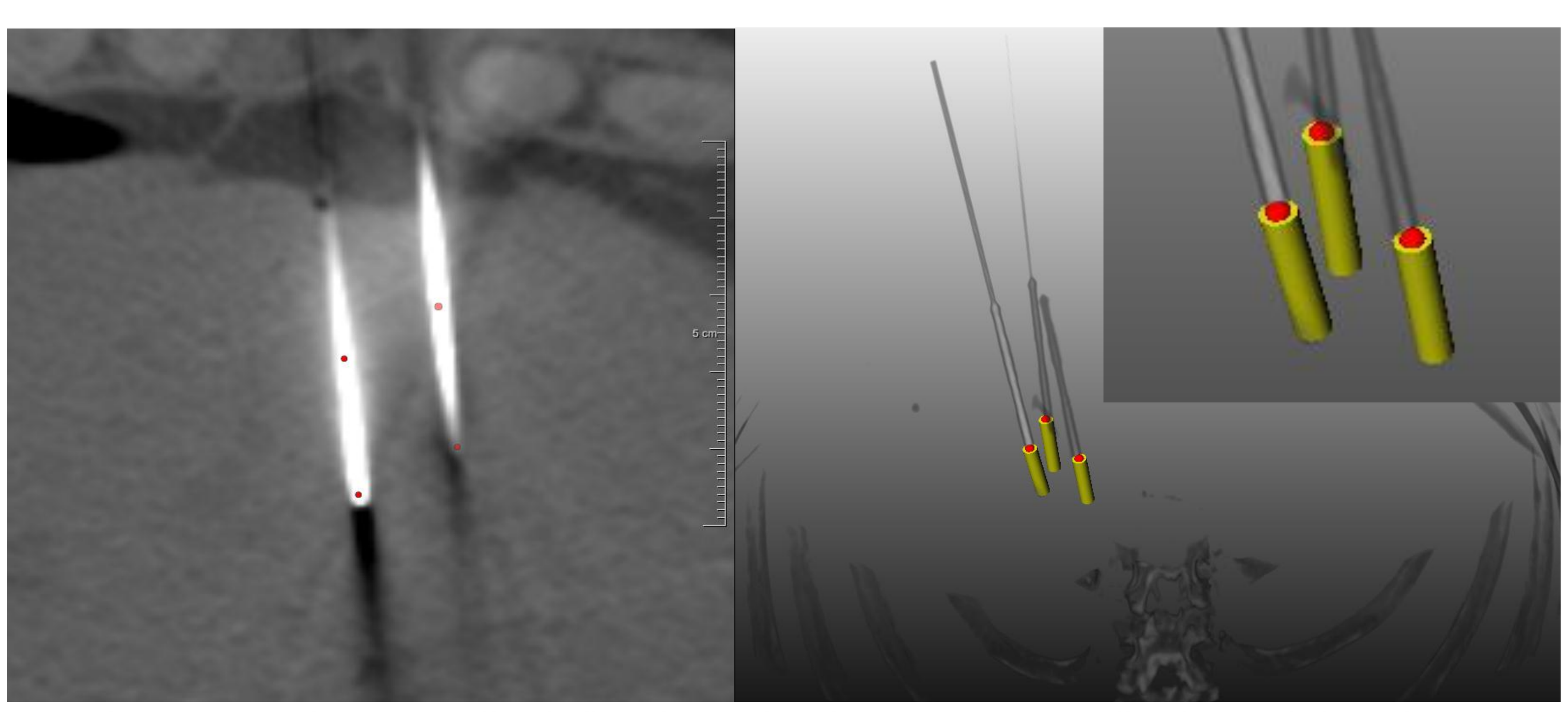

Figure 1. Left: Manually defined seed points at two needle tips. Right: Three cylinders (yellow) generated via six seed points.

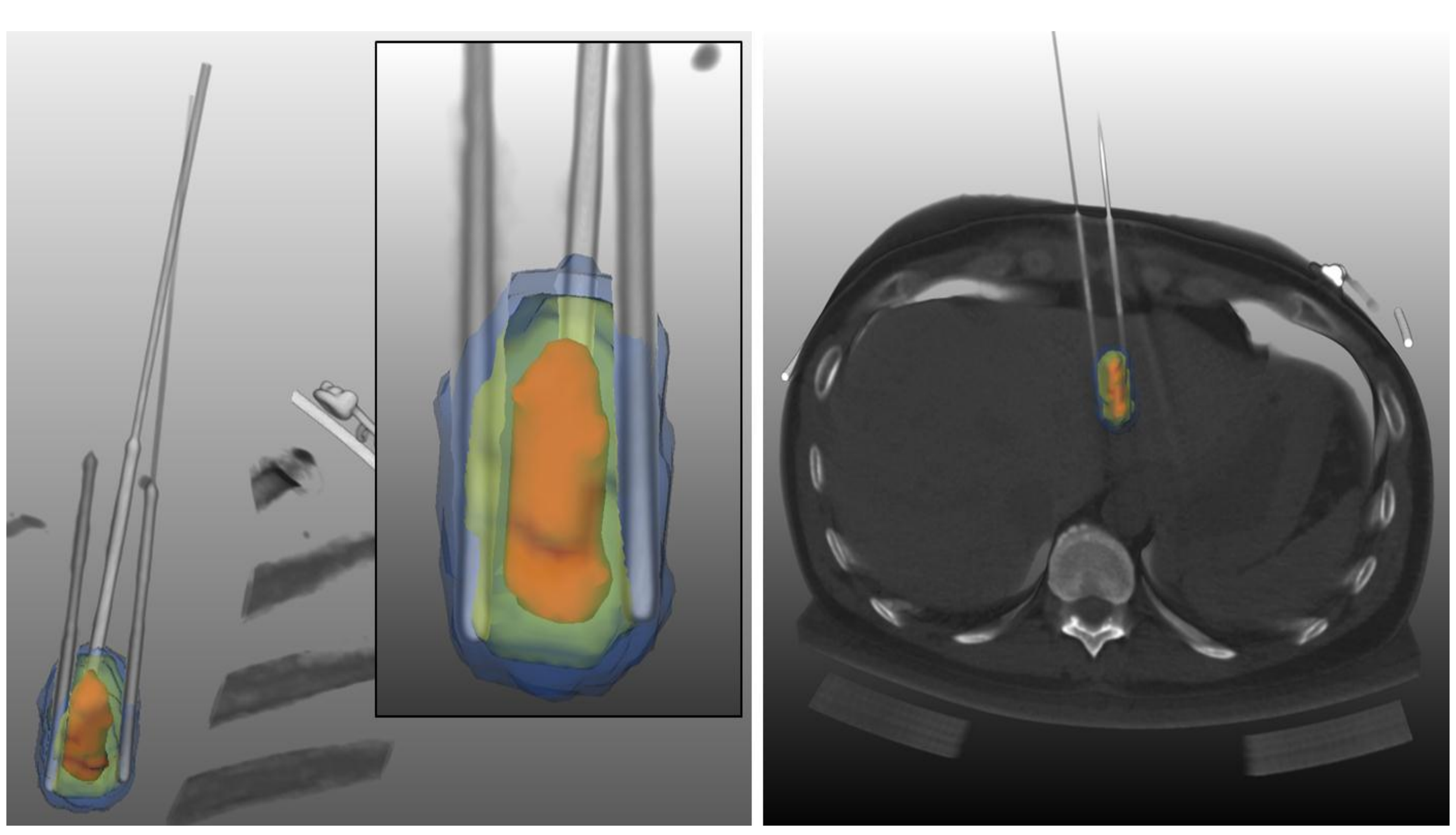

Figure 2. Several isosurfaces around three IRE needles: low energy level (orange), medium energy level (green) and high energy level (blue).

Results

The segmentation and isosurface calculation could be performed swiftly with minimal user interaction. A qualitative comparison of the generated isosurfaces with postprocedurally acquired MRI imaging showed reasonable concordance of the predicted and achieved ablation volume in the presented use case of irreversible electroporation (Figure 3).

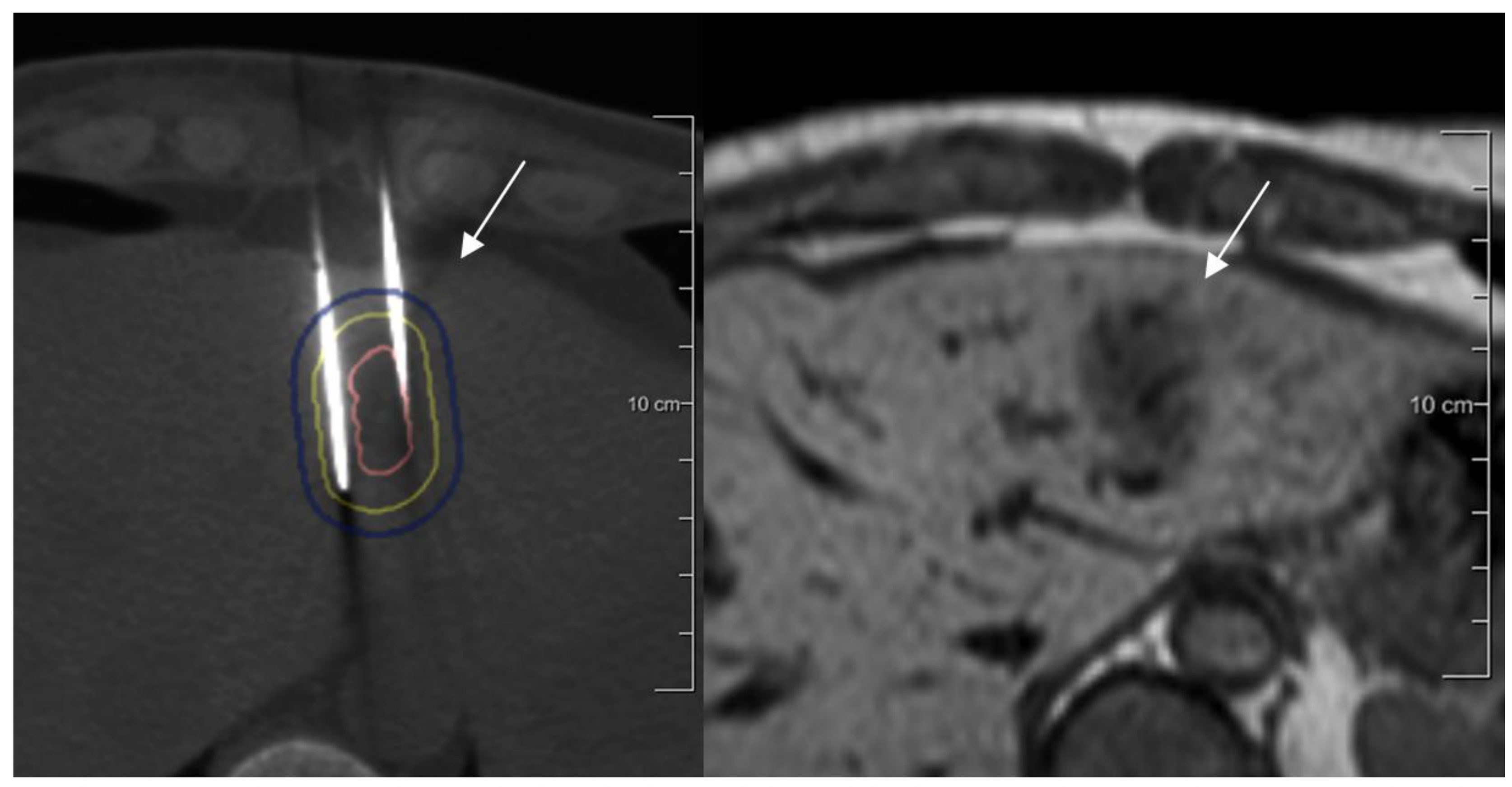

Figure 3. Distance based simulation of the ablation areal on an intraprocedural CT (left) and ablation areal in postprocedure MRI (right).

Conclusion

A software prototype was developed for preprocedural planning and intraoperative monitoring of ablative procedures such as IRE. The method needs to be validated against known ablative technologies and parameter sets for different ablation scenarios need to be determined [3,4]. Potential applications of the technique are real-time navigation based ablation volume calculation, real-time monitoring and adjustment of ablation volumes, especially in IRE, cryotherapy and microwave ablation. The value of the more tissue dependent and heat sink prone radiofrequency ablation is however questionable. The easy extensibility towards modified ablation volume calculations could be of further value.

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