Automatic Trajectory Planning for IRE treatment in Liver Tumours: A Numerical Study

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ABSTRACT

Background:
Irreversible electroporation (IRE) had shown promising results for treating tumors by avoiding heat/cold sink effect and preserving vital structure from thermal injury. Treatment of tumor demands maximization of ablation coverage by finding optimum electrode positioning. However, there has been little attention to the position feasibility during needle insertion.

Purpose:
This study attempts to combine IRE simulation with needle trajectory planning in order to estimate the actual volume of the ablation region during IRE therapy.

Material and Methods:
The trajectory of multiple needles is planned automatically using 3D segmentation of critical structures. Selection of possible insertion zone is considered as a multi-objective optimization problem which should optimize clinical requirements, such as distance to critical structure, needle length, and insertion angle. The final insertion points are chosen using Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) [1] and Faire Un Choix Adéquat (FUCA) [2]. Insertion points are evaluated by finite element modeling in 3D realistic models of target tissues (liver tumors and surrounding non-cancerous tissue considered as a 5 mm safety margin) to determine the maximum target volumes exposed to IRE (Electric Field ≥ 800 V/cm) based on the location of the needles and pulse amplitude tuning.

Results:
Seven tumors (n=3; diameter ≤ 1cm, n=3; 1cm<diameter≤2cm; n=1, 2cm<diameter≤3cm) were treated with 2, 3, and 4 needles, respectively. In small tumors, TOPSIS insertion points allowed better IRE coverage (95% - 100%) of the total volume and 67%-77% of their safety margin. At the same time, FUCA insertion points performed better in medium and large tumors with IRE coverage of target volumes (80%-98%) and their corresponding safety margin (51%- 65%). Pulse amplitude for the reported IRE coverage was tuned between 1300V-2600V, considering that electric current must not exceed 30A.

Conclusion:
This study showed that FUCA-based needle insertion planning provides better insertion trajectories for efficient IRE ablation in simulation environments rather than TOPSIS insertion points. Notice that a complete coverage of the safety margin volume was not reached, and hence further optimization of needle positioning is encouraged.

References:

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