Computational Evaluation of Esophageal Damage after Pulsed Field Ablation for Treatment of Atrial Fibrillation

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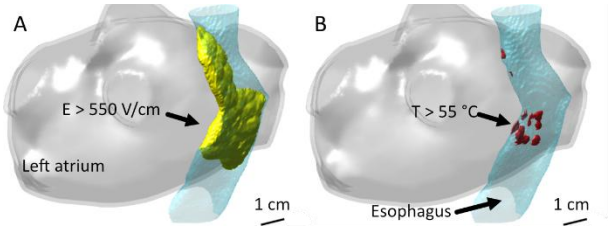
Pulsed field ablation (PFA) is a novel, non-thermal modality for cardiac ablation based on electroporation. However, reports of esophageal injury – a complication typically associated with thermal methods – are emerging, and the underlying cause remains unclear. This study uses computational modeling, based on clinical data, to investigate the biophysical mechanisms of esophageal damage following extensive posterior wall PFA.

Clinical and imaging data were obtained from a 59-year-old patient who underwent point-by-point PFA using the Intellanav Stablepoint catheter (Boston Scientific) and the Centauri pulse generator (Cardiofocus). Wide antral pulmonary vein isolation and left atrial posterior wall isolation were achieved. Endoscopy after 24 hours demonstrated erythematous and edematous mucosa with partial desquamation of the distal anterior esophagus. A patient-specific numerical model was developed from a three-dimensional reconstruction of the atrial and esophageal anatomy. The model was used to simulate 80 PFA lesions on the posterior wall, using positions and timings from the clinical electro-anatomical mapping system.

The computational results showed a significant biophysical impact on the esophagus. A volume of 3.3 mL of esophageal tissue was exposed to an electric field exceeding the putative electroporation threshold of 550 V/cm (Fig A). Additionally, the simulation predicted a temperature increase to over 55 °C in a 0.03 mL volume, indicating a small thermal footprint (Fig B). These modeling results are consistent with the transient esophageal injury observed clinically.



In conclusion, this study provides evidence that esophageal damage following PFA is likely caused by a combination of direct electroporation and a possible minor thermal component. It highlights that close inter-lesion spacing during posterior wall ablation can cause a non-negligible temperature rise and significant electroporation in the esophagus. These findings underscore the importance of computational modeling to understand and improve the safety of PFA procedures.