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Ablation enlargement by combining short high-voltage pulses with long low-voltage pulses

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Irreversible electroporation (IRE) uses $\sim 100 \mu\text{s}$ pulsed electric fields to permanently disrupt cell membranes for tumor treatment. Combining short high-voltage (SHV) pulses with long low-voltage (LLV) pulses, a new modality of the pulsed electric fields exhibits the synergistic effect which could enhance the cell cytotoxic effect. Here, the ablation by 2D monolayers mimic in vitro model and rabbit liver in vivo model was investigated. For 2D monolayers mimic in vitro model, combining SHV pulses with LLV pulses produced larger ablation area than that by either SHV pulses or LLV pulses applied respectively. Even when applying the same pulse number with either SHV pulses or LLV pulses, combining SHV pulses with LLV pulses also produce larger ablation region. For rabbit liver in vivo model, Combining SHV pulses with LLV pulses yielded an ablation area of 50.70 mm^2 , which was increased by 112.58% relative to that after SHV pulses applied alone and 134.18% relative to that after LLV pulses applied alone. With the same pulse number, the ablation area by SHV+LLV pulses was still 75.92% larger than that after LLV pulses. Particularly, when the lag time between the SHV pulses and LLV pulses protocols was adjusted to 100 s, the ablation region would be further decreased (32.21%). However, SHV pulses and LLV pulses sequence mattered, LLV + SHV pulses could not decrease cell viability. The combining SHV pulses with LLV pulses exhibited the synergistic effect, which is that the SHV pulses has a stronger electric field that creates a larger electroporated area in liver tissue and make it more susceptible to the subsequent LLV pulses, then resulting in highly efficient tissue ablation.

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