Irreversible Electroporation (IRE): A Novel Non-Thermal Modality for Central Pancreatic Tumors

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Introduction

- Pancreatic ductal adenocarcinoma (PDAC) remains one of the most challenging malignancies, with a 5-year survival rate of less than 12%. Approximately 30-40% of patients present with locally advanced pancreatic cancer (LAPC), where tumors enccase critical vascular structures, precluding surgical resection. Traditional thermal ablation techniques are contraindicated in central pancreatic locations due to the risk of thermal injury to adjacent vessels and organs.
- IRE represents a paradigm shift as a non-thermal ablative technique that uses short, high-voltage electrical pulses to create irreversible nanopores in cell membranes, leading to cell death while preserving the structural integrity of blood vessels, bile ducts, and other critical structures. This unique mechanism makes IRE particularly suited for treating centrally located pancreatic tumors that are otherwise deemed unresectable.

- **Purpose:** IRE is an emerging non-thermal ablative technique uniquely suited for treating pancreatic tumors located adjacent to critical vasculature. This educational exhibit aims to provide an overview of IRE in the management of central and peripheral pancreatic tumors, with emphasis on its safety, efficacy, and future directions.

Methods

A comprehensive literature review was performed using PubMed to identify clinical and preclinical studies on IRE for pancreatic cancer published since 2010. Key outcomes analyzed include treatment efficacy, procedural safety, and integration with systemic therapies. Relevant review articles and ongoing clinical trials were also included to highlight future research trends.

Results

Yun et al. (2023) - Technical Review	Rai et al. (2021) - Clinical Outcomes
Device Performance • Technical success: 95-100% • NanoKnife: 1500-3000V delivery • Optimal distance: 0.7-2.9 cm between probes	**Clinical Efficacy** • Median OS: 10-30 months • Local control: 65-85% at 12 months • Bridge-to-surgery: 5-15%
Safety Profile • Preserves vessels up to wall • No heat-sink effect • Best results: tumors <3 cm	**Complications** • Major complications: 8-42% • Mortality: 2% (open), 0% (percutaneous) • Hospital stay: 3-4 days
New Technologies • H-FIRE: eliminates muscle contractions • Robotic guidance: 2.2 vs 3.1 mm accuracy • Single-probe systems available	**Combination Benefits** • 3x gemcitabine concentration • Enhanced apoptosis: 34.2% vs 5.2% • Increased CD8+ T cells
Mechanism • Nanopore formation in cell membranes • Non-thermal ablation • Cardiac synchronization required	**Tissue Effects** • Apoptosis/necrosis: 24-72 hours • Fibrosis development: 14-28 days • Immune activation via DAMP release

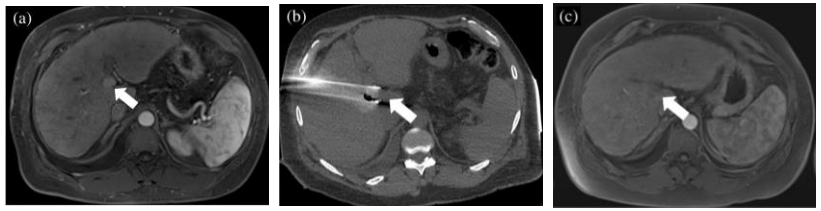

Figure 1 (Yun et al.): The patient underwent liver-directed IRE after a multidisciplinary tumor board discussion (a) pre-procedural MRI imaging demonstrates an enhancing mass (arrow) near the hepatic hilum. (b) intraprocedural CT imaging demonstrates two parallel probes with an enhancing zone of ablation in between the probes. Gas within the lesion (arrow) is an expected finding due to the dissociation of gases from the blood. (c) post-ablation 3-month follow-up MRI reveals hypoattenuation and lack of enhancement of the ablation target (arrow).

Discussion

- Non-thermal mechanism allows ablation near vessels without vascular compromise, a key advantage over thermal methods.
- Transient post-IRE swelling reflects treatment-related edema/inflammation, not tumor progression.
- Marked shrinkage by 2–6 weeks demonstrates durable local control consistent with prior IRE outcomes.
- Favorable safety profile is supported by minimal collateral damage despite initial volume fluctuation.
- Future directions include combining IRE with systemic or immunotherapies to enhance long-term efficacy

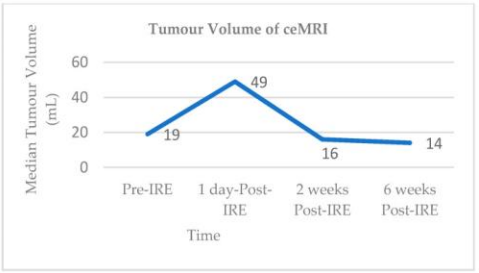

Figure 2 (Rai et al.)
Median tumor volumes on contrast enhanced MRI

References

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- Rai ZL, Feakins R, Pallett LJ, Manas D, Davidson BR. Irreversible Electroporation (IRE) in Locally Advanced Pancreatic Cancer: A Review of Current Clinical Outcomes, Mechanism of Action and Opportunities for Synergistic Therapy. J Clin Med. 2021;10(8):1609. Published 2021 Apr 10. doi:10.3390/jcm10081609