

Niche Applications of Irreversible Electroporation

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Irreversible electroporation (IRE) induces cell death by exposing it to high-voltage, low-energy DC current pulses. The mechanism of cell death and healing is a departure from the other existing technologies such as radiofrequency ablation, microwave ablation, and cryoablation. These thermal ablative technologies have several applications in oncology but have limitations that have also been established. IRE has shown promise to overcome some of these limitations and has enabled the use of an ablative technology in treating lesions close to the bile ducts and vasculature and in organs such as the pancreas. This review highlights some of the niche applications of IRE and the data so far. Tech Vasc Interventional Rad 18:170-175 © 2015 Elsevier Inc. All rights reserved.

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Irreversible Electroporation Outline

Electroporation is the permeabilization of the cell membrane due to an applied electric field. The permeabilization can be reversible or irreversible depending on the voltage of the applied electrical pulses. The use of electroporation to increase the permeability of the cell membrane in tissue was introduced by Okino and Mohri in 1987 and by Mir et al in 1991. Both studies independently discovered that combination of an anticancer drug with reversible permeabilization of cell membranes using electric pulses greatly enhanced the effectiveness of the treatment rather than either one alone.^{1,2} The application of reversible electroporation was extensively studied for the treatment of cancer in combination with cytotoxic drugs, such as bleomycin. This technique was termed as electrochemotherapy.² Davalos et al studied the cellular destruction via application of electrical currents; irreversible electroporation (IRE) using a mathematical model and in vitro models. This study also concluded that IRE could induce cell death without using thermal energy.

Subsequent studies followed to optimize the tissue ablation in vivo. Edd et al demonstrated clear demarcation between ablated and nonablated zones produced after

IRE.³ IRE was also shown to be safe when applied in close proximity to sensitive structures like the urethra, and it was also proposed that IRE may induce an immunological response aiding clearance of the dead tissues after treatment.^{4,5} Since then, multiple applications of IRE have been reported in various organ systems including the liver, kidneys, lungs, and pancreas.⁶⁻⁹ The safety and efficacy of IRE as a predominantly nonthermal minimally invasive ablative modality has been established.

This article reviews niche applications of IRE when other ablative modalities may be suboptimal secondary to their proximity to blood vessels, bile ducts, and other organs and extra visceral applications where other modalities may not be a viable option or require additional maneuvers to perform the treatment safely.

Proximity to Vascular Structures

The “heat-sink” effect is a well-recognized limitation of radiofrequency ablation where heat loss secondary to convection leads to suboptimal ablation of lesions that are in close proximity to vessels larger than 3 mm in size.¹⁰ Lesions located within 1 cm from a vessel of diameter 1 cm or more are not treated owing to high recurrence rates.¹¹ Also, the centrally located lesions are more difficult to ablate because of their proximity to blood vessels. Application of microwave or other ablative modalities in close proximity to the aorta has not been reported though use of cryoablation has been reported in large para-aortic lesions with reasonable success.¹²

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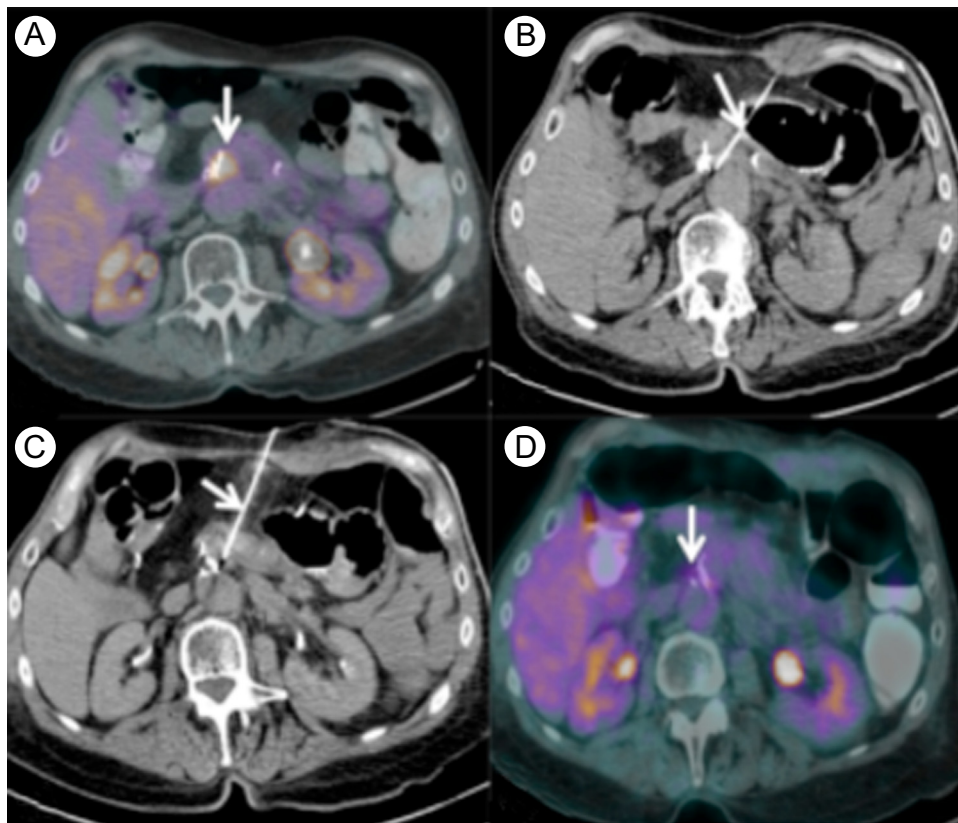


Figure 1 A 69-year old with pancreatic cancer following the Whipple procedure and chemotherapy. PET-CT scan shows hypermetabolic activity in the pre-aortic region (A). IRE procedure performed with placement of 2 unipolar probes via transgastric approach (B and C). Post-IRE treatment PET scan shows no evidence of hypermetabolic activity in the treatment zone (D). PET, positron emission tomography. (Color version of figure is available online.)

The effects of IRE on vasculature in close proximity to the ablation zone were reported on 101 patients who underwent percutaneous IRE procedures for primary and metastatic tumors in different organs.¹³ In total, 129 lesions were treated and 158 vessels were examined for patency on follow-up. Posttreatment contrast-enhanced computed tomography and magnetic resonance imaging scans were reviewed to evaluate caliber, patency, and flow

defects of vessels in close proximity to the ablation zone (defined as vessels within 0-1 cm from the treatment zone). Overall mean follow-up was 10.3 months. Abnormal vascular changes were noted in 7 of 158 (4.4%) vessels. There was no significant association between distances from the treatment zone and presence of narrowing or thrombosis at the follow-up imaging (Mann-Whitney U , $P = 0.772$; logistic regression, $P = 0.593$;

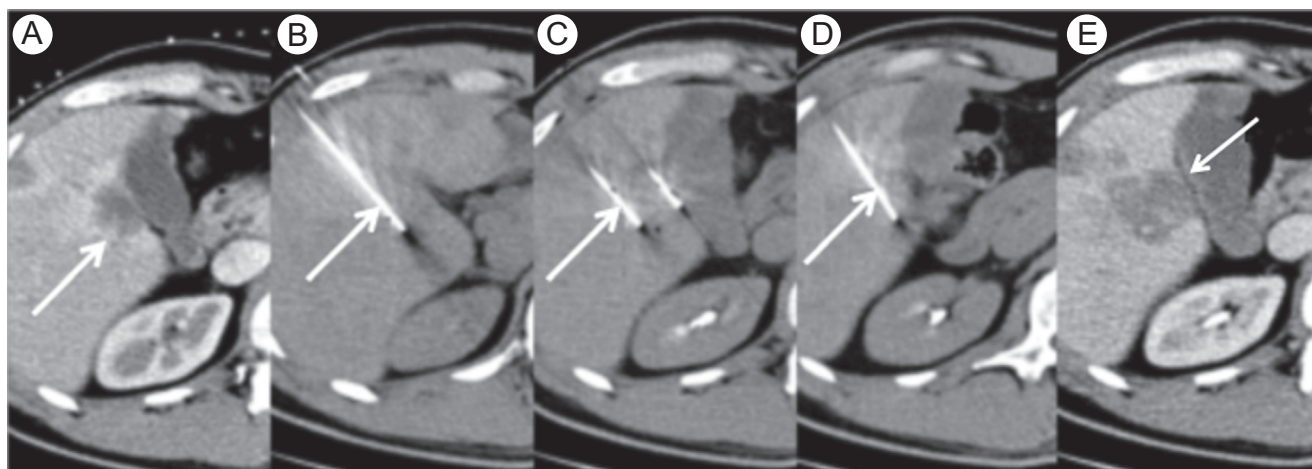


Figure 2 A case of hepatic epithelioid hemangioendothelioma that was treated with IRE. CECT scan shows a segment 4B lesion abutting the gallbladder (arrow, A), which was treated with 4 monopolar probes (arrows, B-D). Post-IRE CECT scan shows no evidence of gallbladder wall injury or thickening (arrow, E).

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