ELSEVIER

Techniques in
Vascular and
Interventional
Radiology

Introduction to Irreversible Electroporation—Principles and Techniques

Kenneth R. Thomson, MD, FRANZCR, EBIR, Helen Kavnoudias, PhD, and Robert E. Neal II, PhD

Irreversible electroporation (IRE) is a novel nonthermal focal ablation technique that uses a series of brief but intense electric pulses delivered by paired electrodes into a targeted region of tissue, killing the cells by irreversibly disrupting cellular membrane integrity. Unlike other ablation methods, IRE has relatively little effect on connective tissues and nerves and has a low patient effect. The ability of IRE to achieve cell death immediately adjacent to large vessels without effect on the vessels themselves has raised the possibility of better treatment of advanced pancreatic cancer. Because of the low effect on the patient, IRE is well suited for use in conjunction with chemotherapeutic agents. The IRE effect is not uniform and is dependent on the intrinsic conductivity of the tissue, the number of pulses delivered, the current flow achieved, and the total time for the treatment. It is currently under investigation for a wide range of solid tumors and prostate cancer in humans and in animals in the breast, brain, and spinal cord. In clinical practice, IRE can be administered either percutaneously under imaging guidance or at open operation under direct vision. In animals there is some evidence of an immune response presumably due to exposure of the intracellular target material, resulting in a greater therapeutic effect. Unlike many other cancer treatments, IRE has been introduced for human clinical use at a very early stage of development of the technique and much of the basic understanding of how and when to use IRE is still under investigation.
Tech Vasc Interventional Rad 18:128-134

KEYWORDS electroporation, ablation, tumor

Preparation of the Patient

Our early work indicated that for procedures near the heart, heart-gated delivery of the pulses was essential to remove the possibility of cardiac arrhythmia.[1] As cardiac gating increases the time to complete each cycle of pulses, there is a reluctance to continue cardiac gating when treating tissue far removed from the heart such as prostate.

A major restriction of irreversible electroporation (IRE) is the need for a general anesthetic with complete muscular paralysis. In this regard, using IRE under direct vision during a surgical operation has the advantage of wide acceptance of the need for general anesthetic for surgery.

For best results it is essential to produce a change in conductivity of the target tissue to cause an increase in current flow of between 10 and 20 A. Aerated lung has a poor conductivity and as a result satisfactory IRE of lung lesions has proved difficult to achieve (Fig. 1).

Patients who have metallic stents in the biliary tree have a risk of short circuit if 2 activated electrodes are in contact with the metal of the stent. In actual practice, however, it is a simple matter to avoid this type of electrode positioning (Fig. 2). We have investigated the effects of prostate seeds on IRE electrode placement on a bench top model and it appears that an adverse event because of the seeds interacting with the electrodes is unlikely.[2] We have also performed IRE adjacent to a fiducial marker coil without incident.

The Alfred Human Research and Ethics Committee approved the use of IRE on an experimental basis as a palliative measure. However, our results indicate that IRE is as effective as any other ablation technique and it deserves to be used much more widely. Like any other

Department of Radiology, Alfred Hospital, Melbourne, Australia.
Address reprint requests to Kenneth R. Thomson, Department of Radiology, Alfred Hospital, PO Box 315, Prahran VIC 3181, Australia. E-mail: k.thomson@alfred.org.au

 1089-2516/13/$ - see front matter
http://dx.doi.org/10.1053/j.tvir.2015.06.002

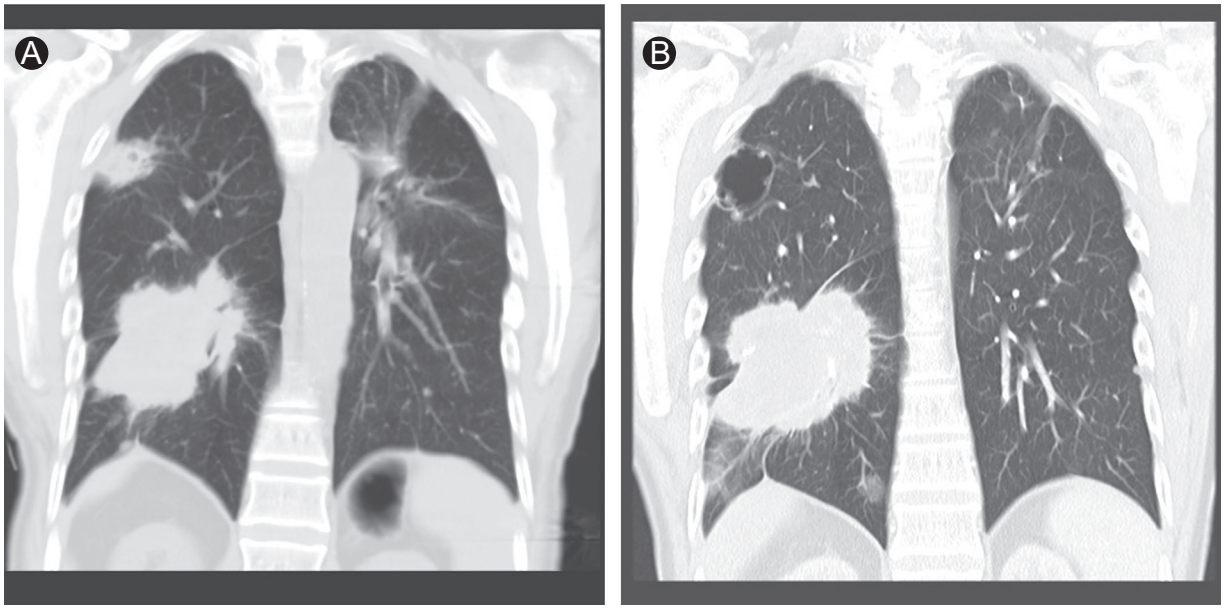

Figure 1 Aerated lung has a poor conductivity and as a result satisfactory IRE of lung lesions has proved difficult to achieve. Edema and hemorrhage obscured the lesions and it was difficult to determine ablation margins. A pneumothorax was also very common. These images show the results from IRE of 2 lesions in the right lung. A month after treatment there was no effect on the larger lesion in the lower zone and a pneumatoccoele with margins of active tumor in the upper lobe lesion. (A) Pretreatment colorectal metastases right lung. (B) Results of IRE at 1 month.

ablation technique, the best results are achieved with lesions under 3 cm in diameter. However, if care is taken in positioning, there is no theoretical limit to the size of ablation that can be achieved. In the liver and kidney very large areas of ablation with IRE are possible with little effect on the patient (Fig. 3).

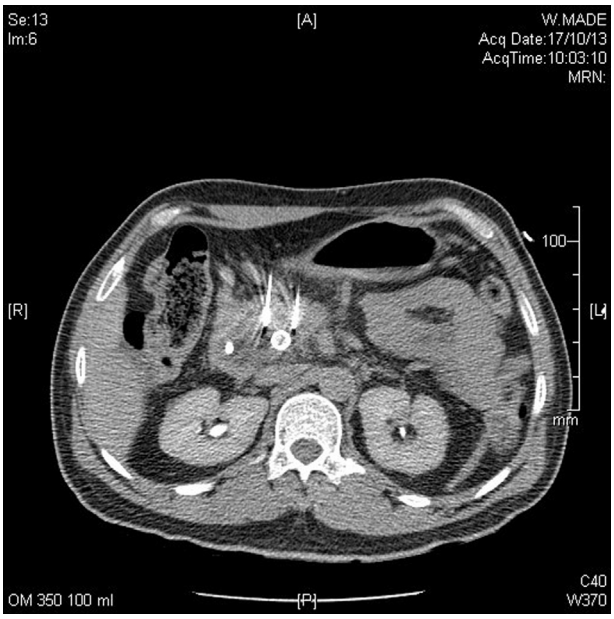

Figure 2 Patients who have metallic stents in the biliary tree have a risk of short circuit if 2 activated electrodes are in contact with the metal. It is a simple matter to avoid this type of electrode positioning as the metallic stent is visible on any imaging modality, in this example CT.

Complications from IRE itself are very unusual. However, complications from the general anesthetic and paralysis arise if the patient is poorly positioned and great care should be taken when positioning the arms of the patient to prevent brachial plexus injury. In most cases an indwelling urinary catheter is required until the patient has fully recovered from the anesthetic.[3]

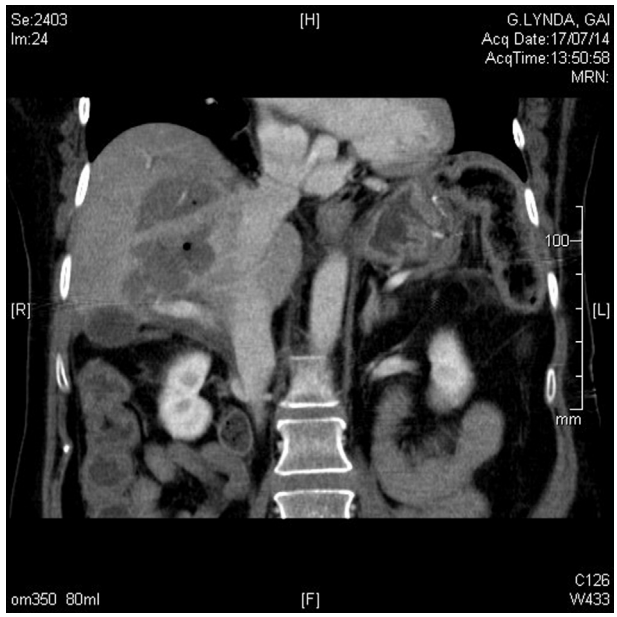

Figure 3 In the liver and kidney very large areas of ablation with IRE are possible with little effect on the patient. In this case a large IRE ablation zone crosses a major hepatic vein without causing venous occlusion.