CLINICAL STUDY

Minimally Invasive Percutaneous Treatment of Small Renal Tumors with Irreversible Electroporation: A Single-Center Experience

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ABSTRACT

Purpose: To evaluate whether irreversible electroporation (IRE) can be used as an ablation technique for small renal tumors (T1a cancers or small benign tumors) and to describe features after ablation on computed tomography (CT) or magnetic resonance (MR) imaging.

Materials and Methods: In this retrospective study, 20 patients (mean age, 65 y ± 12.8 y) underwent CT-guided IRE of T1a renal carcinoma (n = 13) or small benign or indeterminate renal masses < 4 cm in size (n = 7). Mean tumor size was 2.2 cm ± 0.7. The ablation area was verified with contrast-enhanced imaging performed immediately after the procedure to determine technical success. Imaging was performed 6 weeks (20 of 20 patients), 6 months (15 of 20), and 12 months (6 of 20) after ablation. Medical records and CT/MR imaging features of all patients were reviewed for recurrence, symptoms, and complications after treatment.

Results: Technical success was achieved in all patients (100%); there were no major procedure-related complications. Minor complications occurred in 7 patients, including self-limiting perinephric hematomas, pain difficult to control, and urinary retention. Mean procedure time was 2.0 hours ± 0.7. At 6 weeks, 2 patients required salvage therapy because of incomplete ablation. At 6 months, all 15 patients with imaging studies available had no evidence of recurrence. At 1 year, 1 patient (1 of 6) was noted to have experienced recurrence. CT/MR imaging after IRE ablation demonstrated an area of nonenhancement in the treatment zone that involuted over ~6 months.

Conclusions: Renal IRE appears to be a safe treatment for small renal tumors. Tumors treated with IRE demonstrated nonenhancement in the treatment zone with involution on follow-up CT/MR imaging.

ABBREVIATIONS

IRE = irreversible electroporation, RCC = renal cell carcinoma

Renal cell carcinoma (RCC) is one of the most lethal cancers in the United States, with approximately 63,000 new cases and 13,000 deaths annually (1). Several minimally invasive techniques, such as radiofrequency (RF) ablation, cryoablation, microwave ablation, and other thermal ablation techniques, have been developed and implemented to treat small renal tumors (T1a renal malignancies and small benign renal tumors < 4 cm in size). Numerous studies have shown the efficacy of these techniques as equivalent to partial nephrectomy (2–7). However, thermal ablation techniques have limitations. For example, thermal ablation can damage normal, non–tumor-containing tissues surrounding the target lesion (5); of particular concern are possible injuries to critical structures such as arteries, veins, small intestine, colon, ureter, or the renal collecting system (8). Meta-analyses have shown that the most common complications from RF ablation, cryoablation, and microwave ablation are paresthesias at the probe site, vascular injury, urothelial injury (usually self-contained urinoma), and bowel injury, although together they total < 5% (9–11). Also, all

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thermal ablation technologies are less effective in treating lesions near larger blood vessels secondary to the well-documented heat sink effect (8,11,12).

Irreversible electroporation (IRE) is a newer ablation method that can be used to treat small renal masses tumors < 4 cm). Because IRE employs a nonthermal ablation, IRE could permit the treatment of tumors in close proximity to critical structures, while preserving normal renal parenchyma, with decreased complications. Clinically, IRE has been reported to be effective in the treatment of pancreatic, lung, hepatic, renal, and adrenal lesions (13–18). In terms of renal application, two studies have shown that IRE is effective and limits damage to the treatment area of the ablated lesion within porcine kidneys (12,19). The purpose of this study was to determine the clinical efficacy and safety of in situ renal tumor ablation by IRE and to describe imaging features after ablation.

MATERIALS AND METHODS

All patients were counseled by their treating physician regarding management options for small renal masses, including surgery, ablation, and active surveillance, and provided written and verbal informed consent for the IRE procedure. The patients were part of an institutional review board–approved retrospective institutional renal mass database. Records of all patients who underwent IRE for treatment of small renal masses at our institution were included in this retrospective study. The selection of ablation modality was determined by the provider based on size and location. Tumors particularly close to back and paraspinal muscles were selected for IRE with the intent to reduce pain after the procedure, which often occurs with thermal ablation. Patients with nodal or distant metastases and patients with multiple tumors ipsilaterally were excluded from the study.

Patients

The study comprised 20 patients (12 women and 8 men) with a mean age of 65 years ± 12.8. In 16 patients, tumors were incidentally discovered on abdominal computed tomography (CT) or magnetic resonance (MR) imaging scans. Two patients had prior partial nephrectomies and were found to have new tumors on follow-up scans. One patient with von Hippel-Lindau disease had a tumor detected on screening CT. The final patient had an immunoglobulin G deficiency, and the tumor was detected as part of routine screening CT. At the time of diagnosis, 10 of the patients had a history of hypertension. Three patients presented with a diagnosis of an additional malignancy (prostate, bladder, and colon). The remaining comorbidities are listed in the Table. All of the tumor locations were peripheral (clear of any critical structures or vessels), which allowed us to assess the possibility of IRE more safely in this early experience.

Table 1. Patient and Tumor Characteristics in Technically Successful IRE

Characteristic	Value
Average age (y)	65 ± 12.8
Average tumor size (cm)	2.2 ± 0.7
Comorbidities (no. patients)	
Coronary artery disease	4
Hypertension	10
Diabetes	7
Chronic obstructive pulmonary disease	5
Sleep apnea	1
von Hippel-Lindau disease	1
Other cancer diagnosis	3
Average operating room time (h)	2.0 ± 0.7
No. probes	3.7 ± 0.7
Histology (no. patients)	
Clear cell	10
Papillary	3
Oncocytoma	2
Not available	5
Location (no. patients)	
Upper pole	4
Interpolar	10
Lower pole	4
Creatinine before intervention (mg/dL)	0.99 ± 0.4
Creatinine 6 wk after intervention (mg/dL)	0.95 ± 0.2
GFR before procedure (mL/min/1.73 m^2)*	73.4 ± 22.2
GFR after procedure (mL/min/1.73 m^2)*	73.7 ± 22.8

Note–Values are given as mean ± SD or number.
GFR = glomerular filtration rate; IRE = irreversible electroporation.
*Our laboratory does not specify the exact GFR when values are ≥ 60 mL/min/1.73 m^2. The average GFR was > 60 mL/min/1.73 m^2 in all patients, per our laboratory, before and after the procedure. We recalculated the GFR using the Modification in Diet in Renal Disease equation to obtain an actual GFR when not stated by our laboratory (20).

Imaging and Pathologic Diagnosis

All patients underwent initial imaging, either contrast-enhanced MR imaging or CT, using established institutional renal mass protocols to confirm a renal tumor. Most patients (15 of 20; 75%) had biopsy confirmation of the renal tumor before or at the time of the procedure. The average tumor size was 2.2 cm ± 0.7. Tumor size was determined based on the largest diameter on CT or MR imaging performed before the procedure. A needle biopsy diagnosis was made in 15 of 20 (75%) patients; 10 were clear cell–type cancers, two were oncocytomas (detected on biopsy at the time of ablation), and three were papillary-type cancers. Two patients had bilateral renal tumors. In one case, IRE was performed on both tumors; the other patient had IRE on one tumor and partial nephrectomy on the other. Two patients had prior nephrectomies for treatment of RCC; tumors on the remaining solitary kidney were later detected on follow-up imaging and treated with IRE. Patients with