CLINICAL STUDY

Percutaneous Renal Cryoablation: Short-Axis Ice-Ball Margin as a Predictor of Outcome

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ABSTRACT

Purpose: To determine if CT characteristics of intraprocedural ice balls correlate with outcomes after cryoablation.

Materials and Methods: A retrospective review was performed on 63 consecutive patients treated with renal cryoablation. Preprocedural and intraprocedural images were used to identify the size and location of renal tumors and ice balls as well as the tumor coverage and ice-ball margins. Review of follow-up imaging (1 mo and then 3–6-mo intervals) distinguished successful ablations from cases of residual tumor.

Results: Patients who underwent successful ablation (n = 50; 79%) had a mean tumor diameter of 2.5 cm (range, 0.9–4.3 cm) and mean ice-ball margin of 0.4 cm (range, 0.2–1.2 cm). Patients with residual tumor (n = 13; 21%) had a mean tumor diameter of 3.8 cm (range, 1.8–4.5 cm) and mean ice-ball margin of −0.4 cm (range, −0.9 to 0.4 cm). Residual and undertreated tumors were larger and had smaller ice-ball margins than successfully treated tumors ($P < .01$). Ice-ball diameters were significantly smaller after image reformatting ($P < .01$). Ice-ball margins of 0.15 cm had 90% sensitivity, 92% specificity, and 98% positive predictive value for successful ablation. Success was independent of tumor location or number of cryoprobes.

Conclusions: Ice-ball margin and real-time intraprocedural reformatting could be helpful in predicting renal cryoablation outcomes. Although a 0.5-cm margin is preferred, a well-centered ice ball with a short-axis margin greater than 0.15 cm strongly correlated with successful ablation.

ABBREVIATIONS

ROC = receiver operating characteristic, SRM = small renal mass, 3D = three dimensions

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Small renal masses (SRMs) are increasingly diagnosed at an earlier stage because of the increased use of cross-sectional imaging (1–3). The optimal treatment strategy for many patients with SRMs has shifted from radical nephrectomy to nephron-sparing options such as partial nephrectomy, radiofrequency ablation, microwave ablation, and cryoablation (4–6). Percutaneous renal cryoablation is a well-tolerated option for patients with SRMs who are poor surgical candidates (7). It is ideally suited for patients with peripherally and posteriorly located tumors smaller than 4 cm (7–9). However, studies have shown that cryoablation of larger and centrally located renal tumors can also be successful (10,11).

The ice-ball edge during cryoablation does not necessarily correlate with the kill zone. In vivo and in vitro animal studies have demonstrated that killing benign renal epithelial cells requires temperatures lower than −20°C, which correlates to 0.3 cm within the edge of the ice ball (12–15). Some renal tumors are more resistant to the effects of freezing and require temperatures lower than −40°C for complete necrosis, which correlates to 0.5–0.6 cm within the edge of the ice ball (16). The results of these animal studies have led some interventionalists to recommend that the ice ball exceed the tumor margin by 0.5 cm to minimize local recurrence (8). The purpose of the present study was to evaluate computed tomography (CT) characteristics of the intraprocedural ice ball and determine if there are characteristics that can predict treatment outcomes.

MATERIALS AND METHODS

Institutional review board approval and waiver of consent were obtained for this retrospective analysis of all renal cryoablation procedures performed at a single academic institution from January 1, 2005, through December 31, 2012, and pertinent medical records. A total of 81 patients were identified by searching the records of a dedicated interventional radiology database (HI-IQ; ConexSys, Lincoln, Rhode Island) for all cryoablation procedures between 2005 and 2012. All patients were referred for percutaneous cryoablation because of renal tumors suspicious for malignancy on the basis of radiologic features and clinical presentation (n = 73) or radiologic features and biopsy results (n = 8).

A total of 81 patients were identified; 16 were excluded because of inadequate preprocedural, intraprocedural, or follow-up cross-sectional imaging for analysis. Additionally, two patients were excluded because the tumor undergoing ablation had previously been treated surgically. A total of 63 consecutive patients (40 men and 23 women; mean age, 71.5 y; age range, 45–89 y) with renal tumors were included in the study. The pretreatment, intraprocedural, and postablation follow-up images were reviewed for tumor location and size, ice-ball size/geometry, and residual tumor following ablation. A summary of demographic characteristics is included in **Table 1**.

Table 1. Patient Demographic Data (N = 63)

Characteristic	Value
Age (y)	
Mean	71.5
Median	74
Range	45–89
Sex	
Male	40
Female	23
Lesion diameter (cm)	
Mean	2.7
Median	2.6
Range	0.9–4.5

Percutaneous Renal Cryoablation Technique

The preprocedural diagnostic CT or magnetic resonance (MR) images were used to localize the lesion before cryoablation. The patient was positioned to optimize cryoablation access, and the entry site was identified on an unenhanced axial CT scan. If indicated, hydrodissection was performed by injecting sterile water (100–500 mL) through a 22-gauge needle under CT guidance to separate the lesion from adjacent bowel loops, organs, or muscles at the discretion of the treating physician (17). Cryoablation probes with diameters of 1.7 mm and 2.4 mm (Endocare; HealthTronics, Austin, Texas) were inserted under CT guidance with the treatment zone centered on the target lesion. The number, position, and diameter of the probes were chosen at the discretion of the attending interventional radiologist.

In all cases, a 10-minute freeze, 8-minute thaw, and 10-minute refreeze cycle was performed. An unenhanced intraprocedural monitoring CT scan was performed at the end of the first 10-minute freeze cycle to assess the radiographic ice ball and to detect complications (18,19). At the end of the 10-minute refreeze cycle, a second unenhanced intraprocedural monitoring CT scan was performed to assess tumor coverage by the ice ball. Upon completion of cryoablation, the probes were thawed and removed.

Image Review of Tumor Size, Ice-Ball Characterization, and Treatment Response

All diagnostic preprocedural, intraprocedural, and follow-up images were retrospectively reviewed by a senior radiology resident and attending interventional radiologist with more than 10 years of experience. Any discrepancies between diagnostic imaging interpretations were settled by an attending abdominal imaging radiologist with more than 20 years of experience. Any differences in assessments regarding the intraprocedural images were settled by one of two interventional radiologists each with more than 15 years of experience (M.C.S. or T.W.I.C.).

All patients underwent preprocedural contrast-enhanced CT or MR imaging before percutaneous renal cryoablation (range, 0–14 wk; median, 7 wk). Tumor location was classified as exophytic, parenchymal, or endophytic depending on the circumference extending beyond the expected renal contour. Exophytic tumors had greater than 50% circumference beyond the renal margin, parenchymal tumors had 25%–50%, and endophytic tumors had less than 25%. Maximum lesion diameters were measured in the standard anteroposterior, transverse, and craniocaudal planes relative to the tumor's axis.

The unenhanced intraprocedural monitoring CT scan obtained at the end of the 10-minute refreeze step of the