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Original Article

Percutaneous computed tomography-guided cryoablation for renal tumor: Experience in 30 cases

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Abstract

Background: Percutaneous cryoablation is a minimally invasive alternative for surgical resection of a renal tumor. We report our experience with applying computed tomography-guided cryoablation in renal tumors, focusing on the technique, safety, and treatment response.
Methods: We retrospectively reviewed the medical records of patients who received cryoablation from October 2009 to August 2013 for renal tumor diagnosed by imaging studies performed at Taipei Veterans General Hospital, Taipei, Taiwan. Patient comorbidities and tumor morphology, technical success rate, tumor control rate, renal function change, and complications were recorded.
Results: A total of 30 patients (32 tumors) were treated, comprising 30 renal cell carcinomas and two angiomyolipomas. The mean age of the patients was 73.7 years (range, 34−89 years). The patients were referred for percutaneous cryoablation arising from old age, medical comorbidities, or preexisting malignancy. The mean follow-up period was 15.2 months (range, from 32 days to 47.4 months). According to the Clavien−Dindo classification, surgical complications included one Grade III, four Grade II, and two Grade I complications. The mean decrease in hemoglobin was 0.77 g/dL (range, from +1.1 g/dL to −3 g/dL). The mean hospital stay after cryoablation was 2.2 days (range, 1−10 days). Incomplete ablation was noted in two patients and local tumor recurrence in two patients. One of them received repeated cryoablation and achieved successful local control. Of the 22 renal cell carcinoma patients with follow-up period > 6 months, 19 patients achieved successful local tumor control (86.4%). The percentage change of glomerular filtration rate before and 3−6 months after the procedure was +1.9%, which was statistically nonsignificant ($p = 0.94$).
Conclusion: Computed tomography-guided percutaneous cryoablation is a safe and effective technique for treating renal tumors with excellent renal function preservation.
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Keywords: cryoablation; imaging-guided ablation; renal cell carcinoma

1. Introduction

Percutaneous cryoablation is a minimally invasive alternative for surgical resection of a renal tumor. The cryoprobe creates a low-temperature zone surrounding the needle tip. By applying the cryoprobe directly to the lesion, the fast cooling process can cause tumor necrosis and achieve tumor ablation. Cryoablation offers comparable efficacy and a low

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complication profile compared with partial nephrectomy. According to the American Urology Association guidelines, cryoablation and radiofrequency are alternative treatments to partial nephrectomy for renal tumors not larger than 3.5 cm when surgery is contraindicated. Certain reports have recommended 4.0 cm as the cutoff value for size.[1,2] Because of diverse patient factors (e.g., age and comorbidities) and tumor characteristics (e.g., size and location) of each patient, a thorough discussion of the advantages and disadvantages of cryoablation with patients is essential for selecting the most suitable treatment method.

Although percutaneous cryoablation is a relatively new ablation technique compared with radiofrequency ablation, it has rapidly gained prominence in the arena of renal tumor treatment because of its advantages, including reduced pain,[3] clear demonstration of the ablation area by applying computed tomography (CT) or magnetic resonance imaging (MRI), MRI-compatible device available, and a relatively low risk of damaging the collecting system.[4,5] The procedure can be performed under ultrasound (US) guidance, CT guidance, or MRI guidance.[6] Because of its popularity and ability to accurately present the ablation area, CT guidance is the most common method. In this paper, we report our experience of applying percutaneous CT-guided cryoablation in renal tumors.

2. Methods

We retrospectively reviewed the medical records of patients who received cryoablation for renal tumor from October 2009 to August 2013. The patients were referred for cryoablation from urologists because of contraindication or patient refusal of surgery. From a web-based electronic medical record system, clinical data including age, sex, previous medical history, and laboratory data were recorded. The final diagnosis of renal tumor was made according to the results of a percutaneous biopsy or clinical course. Only those who received cryoablation for curative purposes were recruited. The Institutional Review Board of Taipei Veterans General Hospital approved this study.

We reviewed patient preprocedure CT and MR images and recorded tumor characteristics, including size (maximal diameter) and location. Tumor location at the medial, anterior, lateral, or posterior aspects of the kidneys, and its relationship with the renal pelvis and ureter were also recorded.

2.1. Percutaneous cryoablation technique

All cryoablation procedures were performed by a single radiologist with 10 years of experience in interventional radiology. The number of probes and the needle trajectory were planned in the preprocedure imaging.

Patients were admitted to the ward the day before the procedure, wherein baseline renal function, hemoglobin, and coagulation profile were checked. The procedure was performed using an angio CT suite (Angio CT MIYABI, combining the Siemens SOMATOM 16-slice CT on rails with the AXIOM Multistar angiography unit, Siemens, Erlangen, Germany) with patients lying in an orthogonal or oblique decubitus position based on the tumor location. All procedures were performed under general anesthesia to ensure that the patients could keep the position during the entire procedure.

For those patients where tissue proof was required, a biopsy was performed immediately prior to cryoablation. We performed a coaxial biopsy using an 18-gauge semiautomatic needle. To avoid hemorrhage interfering with tumor targeting, we did not fire the biopsy gun until all cryoprobes were appropriately inserted. After the biopsy, cryoablation commenced. We used an argon-based cryoablation machine and cryoablation probes (PERC-24 and PERC-17; Endocare, Inc., Irvine, CA, USA; IceRod and IceSphere; Galil Medical, Arden Hills, MN, USA). The numbers and types of probes were selected to achieve an appropriate ice-ball shape and adequate coverage. The probes were placed at the periphery of the tumor with the distances between each probe no larger than 2 cm. A 10-minute freeze > 10-minute passive thaw > 10-minute freeze cycle was routinely applied. During the cycle, a CT scan was performed at 5-minute intervals (or shorter if necessary) to monitor the ice-ball expansion. The shape and size of the ice could be controlled by changing the power and freezing time of each probe. If inadequate coverage of tumor margin was noted, more probe(s) would be added. The duration of each cycle and the power of each probe could be adjusted accordingly, to prevent adjacent vulnerable organ injury or inadequate coverage.

Several techniques can be adopted to facilitate the procedure. If the tumor was completely embedded in renal parenchyma, administering an intravenous contrast medium facilitated targeting (Fig. 1). When vulnerable structures such as the bowel were too close to the tumor, we used a hydrodissection technique by injecting diluted iodine contrast medium into the space between the lesion and the protected structures. For a centrally located tumor, a preprocedure retrograde double J ureteral stent placement was routinely prescribed and performed by a urologist to ensure the adequate protection of renal pelvis. When the tumor was located at the lower pole of the kidney and close to the ureter, we used the balloon displacement technique to protect the ureter. Generally, preprocedure retrograde double J ureteral stent placement would be prescribed for better visualization and protection of the ureter. During the procedure, under either fluoroscopic or CT guidance, an angioplasty balloon catheter was inserted into the space between the tumor and the ureter (Fig. 1). The hydrodissection technique was typically less effective in the retroperitoneum. When cryoablation ended, active thawing with helium allowed the rapid removal of the cryoprobes. After cryoablation, patients were prescribed absolute bed rest for 4 hours under close vital-sign monitoring. Renal function and hemoglobin levels were typically checked the next morning. Discharge was approved if no significant change occurred in the laboratory findings. Most patients were discharged the day following the procedure. For those with double J ureteral stenting, it was typically removed at the first outpatient clinic follow-up, which was 7 days after the procedure.

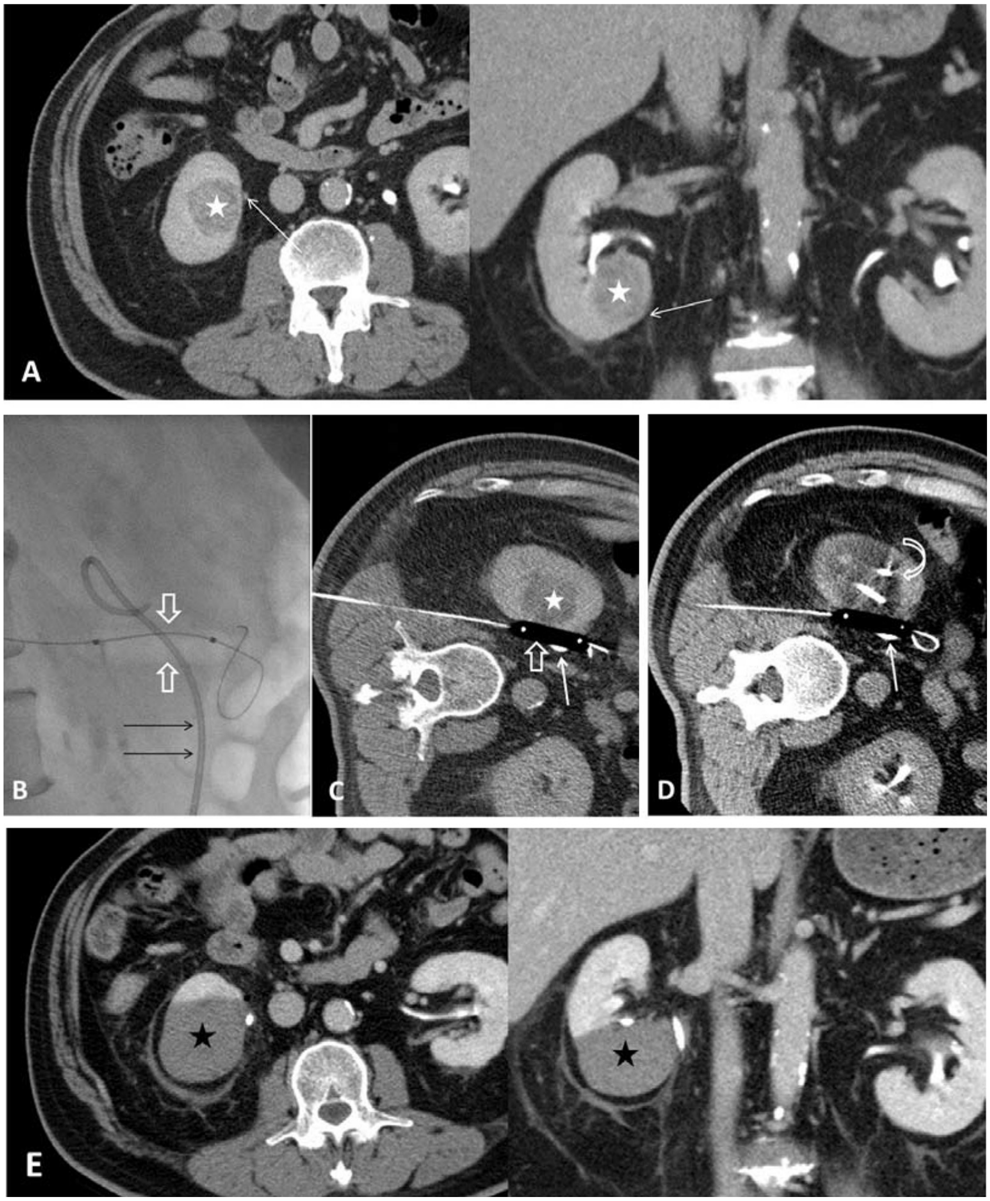

Figure 1. The 62-year-old male patient had a renal tumor at the lower pole of the right kidney. (A) Axial (left) and coronal (right) postcontrast computed tomography (CT) images show a renal tumor at the lower pole of the right kidney (white stars in A and C) contacting the ureter (thin white arrows). (B) Retrograde double J ureteral stent placement was prescribed prior to the procedure (black arrows in B and thin white arrows in C and D). During the procedure, a balloon catheter was inserted between the tumor and double J ureteral stent under fluoroscopic guidance, and inflated with air (open arrows in B and C). (C) Intraprocedural contrast enhanced CT scan demonstrates that the inflated balloon displaced the ureter from the tumor. (D) Monitoring CT scan during freezing demonstrates the ice ball as a low-density area surrounding the cryoprobes (curved arrow) and covering the tumor. (E) Two days after the procedure, axial (left) and coronal (right) postcontrast CT images show nonenhancing area at the lower pole of right kidney (black stars), indicating postcryoablation change. Note that the collecting system is not dilated.

Technical success was defined as the completeness of the freeze−thaw−freeze cycle with an ice ball extension 5 mm beyond the tumor margin, which indicated a −20° isotherm. The procedure time and probe numbers were recorded.

2.2. Postprocedure follow-up

Hemoglobin, creatinine, and glomerular filtration rate (GFR) before and after cryoablation (3−6 months after the procedure), hospital stay, and complications were recorded. Immediate complications were classified and recorded according to the Clavien−Dindo classification (Table 1).[7]

Outpatient follow-up was arranged 1 month after the procedure, followed by subsequent visits at 3 months, 6 months, and 1 year, and subsequently at 1-year intervals thereafter. Routine follow-up included a renal function test and a CT or an MRI study. For those with renal insufficiency, MRI was performed instead of CT. If the GFR was < 30 mL/min/1.73 m^2, a gadolinium containing contrast was not given. The presence of viable or recurrent tumors was diagnosed

Table 1
Clavien−Dindo classification of surgical complications in the study group.

Grade	Definition	Patient number (total patient number 30)		
I	Any deviation from the normal postoperative course without the need for pharmacological treatment or surgical, endoscopic, and radiological interventions. Allowed therapeutic regimens include drugs as antiemetics, antipyretics, analgesics, diuretics, electrolytes, and physiotherapy. This grade also includes wound infections opened at the bedside.	2	Local hematoma Ileohypogastric nerve thermal injury	1 1
II	Requiring pharmacological treatment with drugs other than such allowed for Grade I complications. Blood transfusions and total parenteral nutrition are also included.	4	Hemoglobin decrease Urinary tract infection Acute cholecystitis	2 1 1
III	Requiring surgical, endoscopic or radiological intervention. Grade IIIa: Intervention not under general anesthesia. Grade IIIb: Intervention under general anesthesia.	1	Vascular injury with pseudoaneurysm	1
IV	Life-threatening complication (including CNS complications)[a] requiring IC/ICU management. Grade IVa: Single organ dysfunction (including dialysis). Grade IVb: Multiorgan dysfunction.			
V	Death of a patient.			
Suffix "d"	If the patient suffers from a complication at the time of discharge, the suffix "d" (for "disability") is added to the respective grade of complication. This label indicates the need for a follow-up to fully evaluate the complication.			

[a] Brain hemorrhage, ischemic stroke, subarachnoidal bleeding, but excluding transient ischemic attacks.

according to the nodular enhanced part or gradually increased tumor size. Incomplete ablation was defined as a locally enhanced tumor at the margin of the treated area on follow-up images within 6 months after cryoablation. If the enhanced nodule or gradually increased tumor size was noted at the treated area at least 6 months after cryoablation, local recurrence was diagnosed.

2.3. Statistical analysis: renal function change

We recorded the pre- and postprocedure serum creatinine. The nadir value of postprocedure creatinine 3−6 months after treatment was recorded as the postprocedure creatinine, when the renal function should be stabilized from the treatment event. GFR was calculated using the Modification of Diet in Renal Disease GFR equation, because Modification of Diet in Renal Disease was more accurate than the Cockroft and Gault formula for predicting GFR in patients with chronic renal disease.[8] The percentage change of renal function was defined as (postprocedure GFR − preprocedure GFR) divided by preprocedure GFR. We used a paired-samples t test and SPSS 15.0 software (IBM SPSS software; IBM Corp., Armonk, NY, USA) to compare the preprocedure and postprocedure GFR. A p value > 0.05 was considered significant.

3. Results

We recruited 30 patients, comprising 28 men and two women. The mean age of patients was 73.7 years (range, 34−89 years), with 14 patients (46.7%) older than 80 years and 21 patients (70.0%) older than 70 years. The mean body mass index was 25.7. Excluding one patient lost to follow-up, the mean follow-up period (the date of cryoablation to the last OPD follow-up) was 15.2 months (range, from 32 days to 47.4 months). The patients were referred for percutaneous cryoablation because of patient refusal of surgery, old age, or comorbidities (Table 2). Among the seven patients with renal cell carcinoma (RCC), four received radical nephrectomy of the contralateral kidney (Fig. 2), three received partial nephrectomy of the contralateral or ipsilateral kidney, and one received radiofrequency ablation of the ipsilateral kidney with recurrence.

The 32 tumors (1 patient had 3 tumors) comprised 30 RCCs and two angiomyolipomas. Three patients (5 tumors) with a history of RCC received cryoablation without a preprocedure biopsy. They were diagnosed as recurrent RCC because of newly found renal tumor with classical imaging presentation in the kidney either ipsilateral or contralateral to the one that had a previous surgery. The remaining 27 tumors received biopsies. Seven tumors were biopsied and were pathologically

Table 2
Indications of cryoablation in the study group.

Indication	Number of patients[a]
Old age	21
Other malignancies	8[b]
Hepatocellular carcinoma	4
Lymphoma	2
Colon cancer	2
Lung cancer	1
Previous renal cell carcinoma after treatment	8
Previous nephrectomy	4
Previous partial nephrectomy	3
Previous radiofrequency ablation	1
Poor cardiopulmonary reserve	5
Chronic renal disease	4
Coronary artery disease	3
Diabetes mellitus	3
Cerebrovascular accident	1
Personal preference	2

[a] Each patient may have more than one comorbidity.
[b] One patient had both colon cancer and lung cancer.

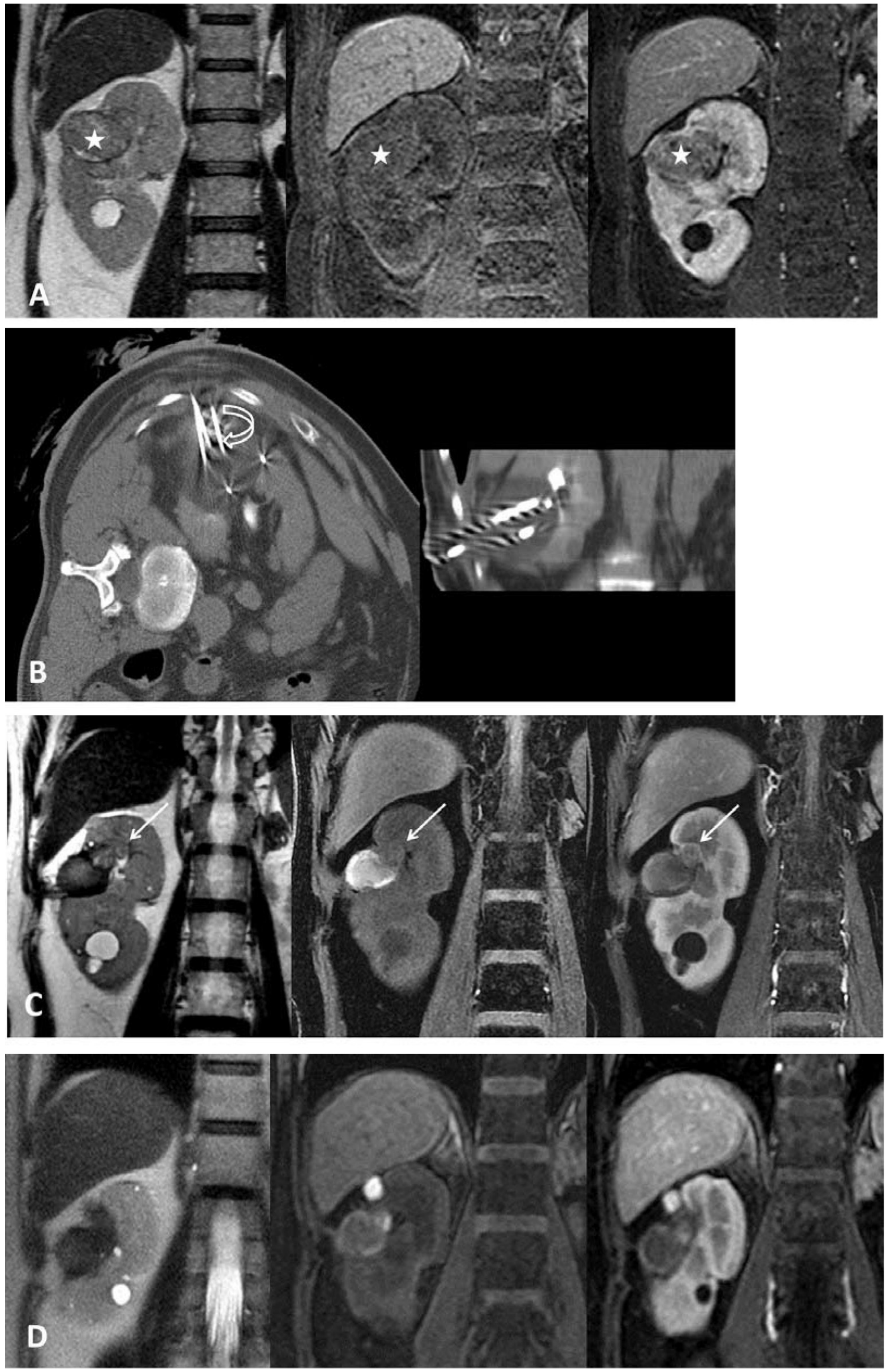

Figure 2. A 65-year-old male patient received left radical nephrectomy for renal cell carcinoma (RCC) 16 years ago and had a recurrent tumor in right kidney on follow-up magnetic resonance imaging (MRI). He also had other comorbidities including coagulopathy (factor VII deficiency), hypertension, arrhythmia, and chronic renal insufficiency. (A) MR scan shows a tumor at the interpolar region of the right kidney (stars), with heterogeneous signal intensity on T2-weighted imaging (left), iso signal intensity on T1-weighted imaging (middle) and modest heterogeneous enhancement on T1-weighted postcontrast enhanced imaging (right). (B) Intraprocedure CT scan during freezing (left: axial scan, right: coronal reformatted image) demonstrates multiple cryoprobes (curved arrow) and the surrounding low density area covering the tumor. (C) MR study 4 months after the procedure (from left to right: T2-weighted imaging, T1-weighted imaging, and T1-weighted postcontrast enhanced imaging) reveal recurrent tumor (arrows) at medial superior aspect of the ablated region, which shows different signal intensity and contrast enhancement in contrast to the ablated area, indicating inadequate ablation. (D) Repeat cryoablation was performed for the recurrent tumor. The MR study 9 months after the first procedure shows complete ablation of the tumor (from left to right: T2-weighted imaging, T1-weighted imaging, and T1-weighted postcontrast enhanced imaging).

confirmed prior to the cryoablation procedure. The other 20 tumors were biopsied during the cryoablation procedure immediately prior to freezing. Three biopsies revealed an indeterminate result, which resulted in a noncontributive biopsy rate of 11.1% (3/27). Those three tumors were diagnosed as RCC according to the classical imaging findings and clinical course.

All patients received cryoablation in a single session, including the patient with three tumors in the bilateral kidneys. The mean probe number was 2.5 (range, 1–5) and the mean procedure time was 136 minutes (range, 58–234 minutes). The mean size of the 32 tumors was 31 mm (range, 14–49 mm). Nine tumors were located at the posterior aspect of the kidney, 14 tumors at the lateral aspect, six tumors at the anterior aspect, and three tumors at the medial aspect. Three tumors abutted the renal pelvis, and two were in contact with the ureter. A preprocedure double J ureteral stent placement was conducted in two patients (Fig. 1). For tumors in close contact with vulnerable organs, hydrodissection and the balloon displacement technique were used for three patients. Some of these techniques were combined in the same patient.

3.1. Complications

Seven of 30 patients experienced complications, which resulted in a complication rate of 23.3%. Based on the Clavien–Dindo classification, two Grade I, four Grade II, and one Grade III complications occurred. No Grade IV or V complications occurred. One Grade I complication was a local hematoma at the posterior pararenal space that did not require treatment. In another Grade I complication, the patient had a thermal nerve injury to the iliohypogastric nerve. His tumor was close to the abdominal wall and he experienced dysesthesia of the abdominal wall after the procedure. The symptom subsided within 6 months without medical treatment. Two of the four Grade II complications were urinary tract infection and acute cholecystitis, which were not a direct consequence of the procedure. The other two Grade II complications were a hemoglobin decrease noted on the postprocedure follow-up and the patient received a blood transfusion of 2 units of packed red blood cells. The mean decrease of hemoglobin in 20 patients with available preprocedure and postprocedure data was 0.77 g/dL (range, from + 1.1 to −3 g/dL). The only patient with a Grade III complication experienced vascular injury with pseudoaneurysm and hematoma formation, requiring radiology intervention for stent deployment (Grade IIIa).

The mean hospitalization stay following cryoablation therapy was 2.2 days (range, 1–10 days). In the absence of complications, the mean hospitalization stay after cryoablation therapy was 1.7 days (range, 1–5 days).

3.2. Oncologic outcomes

All our patients achieved actual technique success. For the purpose of analyzing oncological outcomes, six of the 28 RCC patients with follow-up period shorter than 6 months were excluded. For the remaining 22 patients with RCCs (24 tumors), enhanced tumors on the follow-up image in 6 months were noted in two patients, considered as incomplete ablation. One of them received repeated cryoablation and achieved successful local control (Fig. 2). The other patient did not receive repeat ablation because he was diagnosed with concurrent bone and lymph node metastasis and received target therapy afterward. Local tumor recurrence after 6 months was noted in two patients (2/22, 9.1%). The overall local tumor control rate was 86.4% (19/22).

Of the 22 cancer patients, one patient was known to have bone metastasis at the time of presentation before cryoablation. He received embolization and radiotherapy for his spine metastasis and had been receiving target therapy. One patient developed lung metastasis 1 year after the procedure. Another patient developed local recurrence, and lymph node and bone metastasis 6 months after cryoablation. One patient died because of another cause (hepatocellular carcinoma). None of the patients died because of the disease. The disease-free survival rate for our patient population was 80.9% (17/21), and the overall survival rate was 95.2% (20/21).

3.3. Renal function

The preprocedure GFR was 57.18 ± 23.42 mL/min/1.73 m^2 (range, 19.34–122.93 mL/min/1.73 m^2). The GFR of 20 of the 30 patients (66.7%) was < 60 mL/min/1.73 m^2, that of 17 patients (56.7%) was between 30 mL/min/1.73 m^2 and 60 mL/min/1.73 m^2, and that of three patients (10.0%) was < 30 mL/min/1.73 m^2. Postprocedure GFR was 57.42 ± 23.24 mL/min/1.73 m^2 (range, 17.53–110.24 mL/min/1.73 m^2). The percentage change was 1.9% (range, from +45.97 to −52.05%). The paired-samples t test comparing preprocedure and postprocedure GFR revealed no statistical significance ($p = 0.94$).

Four patients had preprocedure creatinine of > 2 mg/dL. One of them had a Grade III complication and deteriorated renal function (creatinine level from 2.9 mg/dL to 3.9 mg/dL). The other three patients had stable creatinine afterward. Four patients had a solitary kidney, and one of them had a creatinine level > 2 mg/dL. All of them had stable renal function. The patient with a creatinine level > 2 mg/dL changed from 2.13 mg/dL to 2.16 mg/dL.

4. Discussion

Partial nephrectomy has been proven to be an effective method for treating renal tumors. Ablation techniques, as an alternative to partial nephrectomy, were initially limited to the following specific clinical scenarios: (1) patients with comorbidities that preclude a major surgical intervention, (2) patients with renal insufficiency, (3) patients with solitary kidneys, and (4) patients with recurrent tumors secondary to hereditary disorders such as von Hippel–Lindau disease.[9] Recent studies have demonstrated a low complication profile and a high efficacy of ablative techniques.[2] According to the recommendations of the American Urology Association and the European Association of Urology, thermal ablation techniques (radiofrequency and cryoablation) are used as an alternative to partial nephrectomy to manage renal tumors up to 4 cm when surgery is considered risky or contraindicated. In our practice, increasingly more cases were referred for percutaneous ablation when partial nephrectomy was surgically difficult because of specific tumor factors, such as large size or central location. Percutaneous ablation can be a safe and effective method for treating these tumors, avoiding radical nephrectomy.

Percutaneous cryoablation can be performed under US, CT, or MRI guidance. US provides real-time imaging, which is helpful for targeting lesions in moving organs such as the kidney, and is also radiation-free. The disadvantage of US is its limitation in monitoring the freezing process. Although the surface of the ice ball near the probe could be clearly visualized, the opposite side of the ice ball was obscured by the acoustic shadow. MR is excellent for monitoring the freezing process because the ice ball has an extremely low signal intensity area with a sharp margin. However, it is not commonly available and is time consuming. CT guidance is the most popular method for performing the procedure. The ice ball as a hypodense area enables monitoring of its expansion process, and changes shape by altering the freezing time and power of the ablation probes. This is particularly crucial for achieving the synergistic effect of multiple probes and adequate tumor coverage in irregular-shaped tumors.[2] The safety margin was recommended to be at least 3 mm or 6 mm beyond the tumor margin.[2,10,11] Studies have suggested a 10-mm margin to ensure complete ablation because irregular-shaped tumors and probe artifacts can make visualizing the margin difficult.[2] A larger probe requires a larger safety margin because of the temperature distribution within the ice ball. A smaller probe allows enhanced shaping of the ice ball and a smaller safety margin, but carries the potential risk of sublethal zones between the probes, and risk of hemorrhage caused by increased numbers of probes.[12] In our case series, we achieved 100% technique success under CT guidance and a 5-mm safety margin. However, two of our patients had incomplete ablation. Therefore, we recommend a safety margin that exceeds 5 mm, which indicated a -20° isotherm at the tumor margin.

Although cryoablation is a lower invasive alternative for partial nephrectomy, it is not free of complications. In a meta-analysis of case series studies, the overall complication rate of percutaneous cryoablation was 19.9% (0−71.4%).[13] In our series, the overall complication rate was 23.3%, with only 3.3% major complications. Hemorrhage was the most common complication in our series, which concurs with a previous study.[14] The only Grade III complication occurred at the initial stage of our study—the probe slid during the procedure and caused vascular injury. The two patients who had decreased hemoglobin noted on the postprocedure follow-up and received blood transfusion showed no hematoma formation during the procedure. Therefore, we speculated that delayed bleeding during the postprocedure follow-up period was possible. Several risk factors have been suggested to increase complications, including using multiple probes, increased RENAL score, larger tumor size, and an increased age-adjusted Charlson Comorbidity Index.[12,14−16] Complication was not significantly related to age, sex, total freezing time, preoperative creatinine, American Society of Anesthesia class, and body mass index.[12] The number of patients was too small for us to comment on the risk factor of bleeding. Coaxial occlusion of the pathway with hemostatic agents and preprocedure angiographic embolization were suggested to prevent massive bleeding in previous studies.[2,5,6] Although we did not use these methods in our series, they can be applied in high-risk patients.

Cryoablation is known to have less urinary tract complications compared with radiofrequency ablation because cryoablation is less damaging for the collecting system.[4,5] The procedure is considered safe even for a centrally located tumor.[4,5,17,18] Most nontarget structures can be adequately protected with appropriate manipulation.[2] In our series, when treating a centrally located lesion, we used protection methods, including preventive placement of a double J ureteral stent, hydrodissection, or balloon displacement. Hydrodissection was used in 10% of patients in our series, which is less than that in a previous study (15−20%).[19] The balloon displacement technique was used more frequently in the retroperitoneum, where hydrodissection is typically inapplicable. No patient experienced urinary collecting system complications such as urinary tract rupture or stricture, or received temporary ureteric stenting for an obstruction caused by sloughed material.

Thermal ablation carries an increased risk of local recurrence compared with partial nephrectomy.[20] A previous study reported that nearly a 70% recurrence was detected in 3 months[21]; therefore, follow-up at the 1st−3rd months is generally recommended.[2] In our experience, a tumor recurrence at the margin of the tumor that occurs within 6 months implies inadequate ablation. Local recurrence that occurs after 6 months typically implies true local recurrence.[15] Previous studies have revealed that percutaneous cryoablation provides local control rates of 88−99%.[2] Recurrence-free, overall, and disease-specific (based on radiographic follow-up and biopsy) survival rates were 96.2%, 98.1%, and 100%, respectively.[12] We achieved a final local control rate of 86.4%, a disease-free survival rate of 80.9%, and an overall survival rate of 95.2%. The local control rate in our series is less satisfactory as compared with other reports. Although it may be influenced by various indications between institutes and patient factors, it also prompts us to adopt a more aggressive strategy toward tumor treatment in the future.

Biopsy is a crucial issue for patients receiving percutaneous ablation. Our study demonstrated a noncontributive biopsy rate of 11.1%, which is similar to previous studies.[22,23] Although biopsy and cryoablation performed in the same treatment section is convenient for patients, particularly those under anticoagulant or with a bleeding tendency, the possibility of a noncontributive biopsy should be informed and thoroughly discussed with the patient before the procedure. In our practice, cryoablation after biopsy confirmation is generally suggested. Technically, for those receiving biopsy and cryoablation at the same section, biopsy was performed after placing all the cryoprobes and immediately prior to freezing, because even a small amount of perinephric blood after biopsy can obscure the target lesion.[2]

Preserving renal function is a primary advantage of cryoablation over surgery. Nephron-sparing surgeries, such as open, laparoscopic, or robot-assisted partial nephrectomy, incur a small but significant risk of hemorrhage, urinary leakage, and warm ischemic injury, and can further contribute to worsening renal function.[24] A previous study indicated that cryoablation was more effective than robot-assisted partial nephrectomy in preserving renal function.[25] In our series, although most patients had chronic renal insufficiency, the percentage change in GFR 3–6 months after the procedure compared with preprocedure data was not significant. This result is in accordance with previous studies.[6] For patients with preprocedure creatinine exceeding 2 mg/dL, the serum creatinine level remained stable after the procedure if no major complication occurred. A solitary kidney was not related to worsening renal function, which is consistent with the result of a previous study.[6] In certain patients, the GFR might even increase after the procedure. We speculate that this could result from improved renal function caused by the decreased steal phenomenon of the renal tumor, although further evidence is required before a conclusion can be offered.

This study had several limitations. First, our case numbers were relatively small and follow-up intervals were relatively short compared with other studies.[14] The patient number was limited for analyzing risk factors for complication and recurrence. Second, certain cases lack pathological proof. A further randomized controlled trial is necessary to compare cryoablation and other treatment modalities, such as radiofrequency ablation and partial nephrectomy, prior to establishing its role as a curative therapy and part of treatment guidelines. In conclusion, CT-guided percutaneous cryoablation is a safe and effective technique for treating renal tumors. Our study demonstrated that, because this technique offers excellent preservation of renal function, it should be recommended for patients with solitary kidney or chronic kidney disease. The appropriate use of a protection technique is essential to reduce the complication rate.

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References

1. Cornu JN, Roupret M, Lang H, Long JA, Neuzillet Y, Patard JJ, et al. Kidney cancer management in 2007: news and recommendations. *Prog Urol* 2008;**18**(Suppl. 4):S81–7.
2. Georgiades C, Rodriguez R. Renal tumor ablation. *Tech Vasc Interv Radiol* 2013;**16**:230–8.
3. Truesdale CM, Soulen MC, Clark TW, Mondschein JI, Wehrenberg-Klee E, Malkowicz SB, et al. Percutaneous computed tomography-guided renal mass radiofrequency ablation versus cryoablation: doses of sedation medication used. *J Vasc Interv Radiol* 2013;**24**:347–50.
4. Rosenberg MD, Kim CY, Tsivian M, Suberlak MN, Sopko DR, Polascik TJ, et al. Percutaneous cryoablation of renal lesions with radiographic ice ball involvement of the renal sinus: analysis of hemorrhagic and collecting system complications. *AJR Am J Roentgenol* 2011;**196**:935–9.
5. Janzen NK, Perry KT, Han KR, Kristo B, Raman S, Said JW, et al. The effects of intentional cryoablation and radio frequency ablation of renal tissue involving the collecting system in a porcine model. *J Urol* 2005;**173**:1368–74.
6. Buy X, Lang H, Garnon J, Sauleau E, Roy C, Gangi A. Percutaneous renal cryoablation: prospective experience treating 120 consecutive tumors. *AJR Am J Roentgenol* 2013;**201**:1353–61.
7. Dindo D, Demartines N, Clavien PA. Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. *Ann Surg* 2004;**240**:205–13.
8. Michels WM, Grootendorst DC, Verduijn M, Elliott EG, Dekker FW, Krediet RT. Performance of the Cockcroft–Gault, MDRD, and new CKD-EPI formulas in relation to GFR, age, and body size. *Clin J Am Soc Nephrol* 2010;**5**:1003–9.
9. Shingleton WB, Sewell Jr PE. Cryoablation of renal tumours in patients with solitary kidneys. *BJU Int* 2003;**92**:237–9.
10. Young JL, McCormick DW, Kolla SB, Sountoulides PG, Kaufmann OG, Ortiz-Vanderdys CG, et al. Are multiple cryoprobes additive or synergistic in renal cryotherapy? *Urology* 2012;**79**. 484 e1–6.
11. Georgiades C, Rodriguez R, Azene E, Weiss C, Chaux A, Gonzalez-Roibon N, et al. Determination of the nonlethal margin inside the visible "ice-ball" during percutaneous cryoablation of renal tissue. *Cardiovasc Intervent Radiol* 2013;**36**:783–90.
12. Vricella GJ, Haaga JR, Adler BL, Dean N, Cherullo EE, Flick S, et al. Percutaneous cryoablation of renal masses: impact of patient selection and treatment parameters on outcomes. *Urology* 2011;**77**:649–54.
13. El Dib R, Touma NJ, Kapoor A. Cryoablation vs radiofrequency ablation for the treatment of renal cell carcinoma: a meta-analysis of case series studies. *BJU Int* 2012;**110**:510–6.
14. Sisul DM, Liss MA, Palazzi KL, Briles K, Mehrazin R, Gold RE, et al. RENAL nephrometry score is associated with complications after renal cryoablation: a multicenter analysis. *Urology* 2013;**81**:775–80.
15. Atwell TD, Callstrom MR, Farrell MA, Schmit GD, Woodrum DA, Leibovich BC, et al. Percutaneous renal cryoablation: local control at mean 26 months of followup. *J Urol* 2010;**184**:1291–5.
16. Finley DS, Beck S, Box G, Chu W, Deane L, Vajgrt DJ, et al. Percutaneous and laparoscopic cryoablation of small renal masses. *J Urol* 2008;**180**:492–8. discussion 498.
17. Breen DJ, Bryant TJ, Abbas A, Shepherd B, McGill N, Anderson JA, et al. Percutaneous cryoablation of renal tumours: outcomes from 171 tumours in 147 patients. *BJU Int* 2013;**112**:758–65.
18. Brashears 3rd JH, Raj GV, Crisci A, Young MD, Dylewski D, Nelson R, et al. Renal cryoablation and radio frequency ablation: an evaluation of worst case scenarios in a porcine model. *J Urol* 2005;**173**:2160–5.
19. Wile GE, Leyendecker JR, Krehbiel KA, Dyer RB, Zagoria RJ. CT and MR imaging after imaging-guided thermal ablation of renal neoplasms. *Radiographics* 2007;**27**:325–39. discussion 339–40.
20. Campbell SC, Novick AC, Belldegrun A, Blute ML, Chow GK, Derweesh IH, et al. Guideline for management of the clinical T1 renal mass. *J Urol* 2009;**182**:1271–9.
21. Matin SF, Ahrar K, Cadeddu JA, Gervais DA, McGovern FJ, Zagoria RJ, et al. Residual and recurrent disease following renal energy ablative therapy: a multi-institutional study. *J Urol* 2006;**176**:1973–7.
22. Truesdale MD, Mues AC, Sartori S, Casazza CN, Hruby GW, Harik LR, et al. Comparison of two core biopsy techniques before and after laparoscopic cryoablation of small renal cortical neoplasms. *JSLS* 2011;**15**:509–16.
23. Tayal S, Kim FJ, Sehrt D, Miano R, Pompeo A, Molina W. Histopathologic findings of small renal tumor biopsies performed immediately after cryoablation therapy: a retrospective study of 50 cases. *Am J Clin Pathol* 2014;**141**:35–42.
24. Fergany AF, Hafez KS, Novick AC. Long-term results of nephron sparing surgery for localized renal cell carcinoma: 10-year followup. *J Urol* 2000;**163**:442–5.
25. Tanagho YS, Bhayani SB, Kim EH, Figenshau RS. Renal cryoablation versus robot-assisted partial nephrectomy: Washington University long-term experience. *J Endourol* 2013;**27**:1477–86.