

Case Report

The “Lightning bolt” Sign on Computed Tomography during Percutaneous Renal Mass Cryoablation

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ABSTRACT

Ice-ball fracture is a rare and often overlooked entity that may lead to intraprocedural hemorrhage after percutaneous cryoablation of renal masses. There is scant literature on ice-ball fractures associated with percutaneous renal cryoablation. Immediate recognition of the *lightning bolt* sign during intraprocedural computed tomography can help identify patients who may have developed this complication.

KEYWORDS: *Computed tomography, cryoablation, ice-ball fracture, renal cell carcinoma, renal hemorrhage*

INTRODUCTION

Over the past decade, image-guided percutaneous cryoablation of renal tumors has gained popularity due to its minimally invasive nature and nephron-sparing characteristics. On the one hand, it exceeds laparoscopic approaches due to its accurate planning of treatment margins based on ultrasound, computed tomography (CT), and magnetic resonance imaging (MRI); on the other hand, compared to radiofrequency ablation, which is another option for treating renal masses, it is less likely to cause ureteral strictures while requiring fewer repeated ablations.^[1,2] However, one phenomenon that may occur during the cryoablation of large tumors is ice-ball fracture, which might lead to postprocedural bleeding and hematoma.^[2] Here, we describe a case of ice-ball fracture resulting from percutaneous cryoablation of a renal tumor with a depiction of a radiological sign that we have termed the *lightning bolt* sign that may aid in immediate recognition of an ice-ball fracture.

CASE REPORT

A 65-year-old male with Stage 3 chronic renal disease and hypertension underwent a left-sided nephrectomy

in 2011 for renal cell carcinoma (RCC), proven to be clear cell carcinoma on pathology. In 2015, he had percutaneous cryoablation of an upper-pole renal mass, which was biopsy proven to be an RCC. In October 2017, a new right renal upper-pole lesion was found on surveillance imaging and was also treated with percutaneous cryoablation. In February 2018, MRI follow-up demonstrated evidence of recurrence of the lesion ablated in 2015. This enlarging mass, measured 5.8 cm × 5.2 cm × 5.5 cm, had a R.E.N.A.L. Nephrometry Score^[3] of 10 [Figure 1]. A decision was made to proceed again with percutaneous cryoablation.

Under general anesthesia, eight 17G cryoneedles (Galil Medical, Yokneam, Israel) were used to completely encompass this endophytic right renal lesion with a surgical margin of 1 cm [Figure 2]. A 12–5/8–4 min freeze–thaw/freezing–thaw cycle was

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performed. Intraoperative CT was performed using a Siemens Somatom Definition AS 64-MDCT (Siemens AG, Munich, Germany) during the second freeze–thaw cycle and demonstrated adequate ice-ball coverage of 7.3 cm × 6.8 cm × 6.2 cm [Figure 3]. Postprocedural noncontrast-enhanced CT demonstrated hyperdense material adjacent to the right kidney and within the renal pelvis consistent with blood products [Figure 4]; otherwise, the patient was hemodynamically stable. His postprocedural period was significant for hematuria with clots, followed by anuria and rising creatinine (creatinine: from 2.23 to 6.76 mg/dL and hemoglobin: from 15.0 to 11.5 g/dL). After a retrograde ureteral stent was placed by the urologist, the patient regained his baseline renal function and resumed normal diuresis without hematuria (creatinine: 3.12 mg/dL and hemoglobin: 11.8 g/dL). In retrospect, the intraoperative noncontrast CT performed in the middle of the second freeze–thaw cycle did reveal a *lightning bolt* or “crack-like” linear hypodensity consistent with ice-ball fracture; however, this finding was overlooked intraoperatively [Figure 5].

DISCUSSION

Percutaneous renal cryoablation consists of inserting cryoprobes, needle-like shafts, into the target lesion, inducing the formation of an enlarging ice ball by cooling the cryoprobes with cryogens such as argon, followed by thawing with helium for at least two cycles.^[4,5] At the cellular level, the ice crystals formed during the freezing phase disrupt the cell membrane, causing rupture, whereas ischemia due to microthrombus formations during the thawing phase induces necrosis.^[1,4,6] Since the size of the ice ball depends on temperature of the freezing phase, larger tumors tend to require more cryoprobes, longer freezing time, and lower temperatures to form an ice ball with adequate size for effective treatment. During the cryoablation of large tumors, however, ice-ball fracture often occurs in the renal parenchyma during the thawing and second freezing phases.^[2,7] Theories regarding the causes of ice-ball fracture include warm expansion of cryoprobes mechanically traumatizing the frozen tissue, shearing forces among different growing ice balls, and the large temperature gap between the colder center of the ice ball and the warmer surrounding environment.^[2,7,8] Clinically, ice-ball fractures of the kidney hold an incidence of 0%–8.1% in laparoscopic surgery, and they occur more frequently when using larger cryoprobes, a longer freezing phase, and multiple overlapping probes.^[8–13]

The incidence of ice-ball fracture in percutaneous cryoablation has not been studied, and there is only one previous article reporting two cases of ice-ball fractures during percutaneous cryoablation of renal lesions.^[2] In

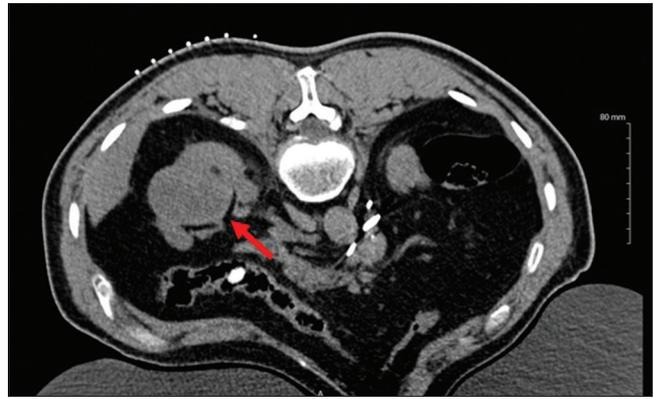


Figure 1: A 65-year-old man with renal cell carcinoma recurrence underwent percutaneous cryoablation. The mass was discovered during follow-up after a prior renal mass cryoablation 3 years ago. Preprocedural noncontrast enhanced axial computed tomography demonstrates an endophytic 5.8 cm × 5.2 cm × 5.5 cm renal mass with a significant involvement of the collecting system and renal sinus.

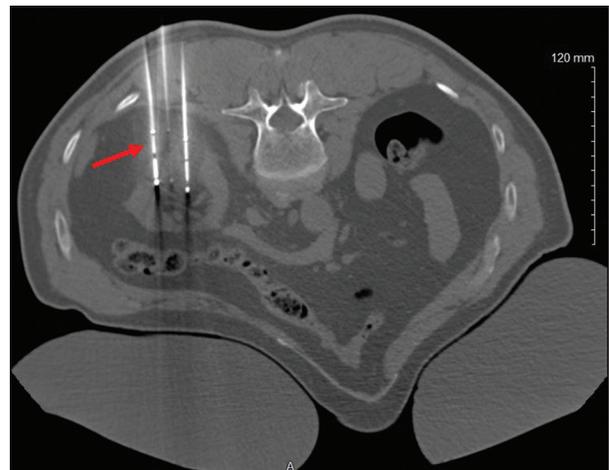


Figure 2: A 65-year-old man with renal cell carcinoma recurrence underwent percutaneous cryoablation. The mass was discovered during follow-up after a prior renal mass cryoablation 3 years ago. Noncontrast enhanced axial computed tomography showing the cryoneedle arrangement within the target mass and developing iceball formation.

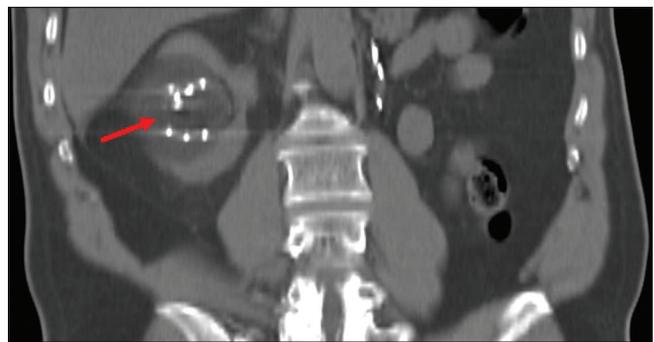


Figure 3: A 65-year-old man with renal cell carcinoma recurrence underwent percutaneous cryoablation. The mass was discovered during follow-up after a prior renal mass cryoablation 3 years ago. Noncontrast enhanced coronal computed tomography demonstrating the eight cryoneedle arrangement and associated iceball formation seen as a spherical hypodensity centered within the renal parenchyma.



Figure 4: A 65-year-old man with renal cell carcinoma recurrence underwent percutaneous cryoablation. The mass was discovered during follow-up after a prior renal mass cryoablation 3 years ago. Postprocedural non-contrast enhanced axial computed tomography showing hemorrhage filled and enlarged renal pelvis (*) with adjacent perirenal hemorrhage (arrow).

one patient, eight cryoprobes were inserted to cover an 8.3-cm maximal diameter mass in the posterior right kidney with a 12–5–6-min freeze–thaw–freeze cycle. In the other patient, four cryoprobes were utilized to treat a 4.4-cm renal mass in the medial upper pole with a 12–5–10-min cycle. In both cases, ice-ball cracks were identified during the refreezing cycles through noncontrast and triphasic contrast-enhanced CT scans, followed by the development of bleeding and hematoma along the cracks shortly. In our case, the ice-ball fracture can be seen with higher resolution in images obtained using a Siemens Somatom Definition AS 64-MDCT (Siemens AG, Munich, Germany) as compared to the two cases mentioned above which were obtained using a Siemens Somatom Sensation 40-MDCT (Siemens AG, Munich, Germany). Just like in our case, a crack-like, starburst-like, or tree branch-like linear hypodensity was seen in the ablation ice ball during the second freeze–thaw cycle as well. We believe that the term *lightning bolt* sign accurately describes this imaging finding on intraprocedural CT. Interventional radiologists performing renal mass cryoablations should become familiar with the timeline and imaging pattern of this potential complication.

In terms of clinical outcomes, the first patient from the two case reports suffered from major blood loss despite preprocedural embolization; by contrast, our patient was rather hemodynamically stable despite significant hemoglobin drop and recovered 3 days after ureteral stent placement and conservative management. Nevertheless, the two cases resembled ours in that multiple cryoprobes were placed to cover tumors larger than 4.0 cm. Whereas a previous review article

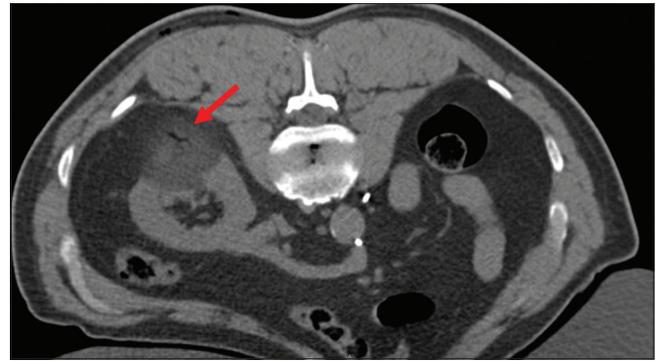


Figure 5: A 65-year-old man with renal cell carcinoma recurrence underwent percutaneous cryoablation. The mass was discovered during follow-up after a prior renal mass cryoablation 3 years ago. Non-contrast enhanced axial computed tomography showing a thunderbolt like iceball fracture along the posterior aspect of the iceball represented by a spherical hypodensity along the posterior aspect of the kidney.

suggested 3.0 cm to be an ideal threshold for patients to benefit from percutaneous renal cryoablation and avoid hemorrhage.^[1] A retrospective study of forty tumors with a mean diameter of 4.2 cm suggested that cryoablation could still be effective, feasible, and safe if managed with proper technique.^[4] Yet, neither study discussed ice-ball fractures' role in determining clinical outcome.

CONCLUSION

Renal hemorrhage is a well-described complication of percutaneous renal mass cryoablation, especially of larger tumors.^[2] However, to what extent ice-ball fractures may contribute to this complication remains unknown. Considering that some patients may not report any overt clinical signs when confronting ice-ball fracture-associated hemorrhage, it is crucial to be cognizant of this potential complication during renal mass cryoablation and promptly recognize the linear hypodensity of *lightning bolt* sign on intraprocedural CT.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Conflicts of interest

There are no conflicts of interest.

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