

Renal Subcapsular Saline Injection during Percutanoues Renal Cryoablation to Prevent Bowel Injury

Sompol Permpongkosol MD*,**,
Theresa L Nicol MD***, Frederico R Romero MD*,
Soroush Rais-Bahrami MD*, Niwat Aranyakasemsuk MD*,
Stephen B Solomon MD****, Louis R Kavoussi MD*****

* Department of Urology, James Buchanan Brady Urological Institute, Johns Hopkins University School of Medicine, Baltimore, Maryland, USA

** Department of Surgery, Ramathibodi Hospital, Mahidol University, Bangkok, Thailand

*** Department of Pathology, Johns Hopkins Bayview Medical Center, Baltimore, Maryland, USA

**** Department of Radiology, Memorial Sloan-Kettering Cancer Center, New York, USA

***** Institute for Urology, North Shore-LIJ Health System, Long Island, New York, USA

Introduction: To evaluate the feasibility of percutaneous injection of saline in the renal subcapsular space to prevent bowel injury and histopathologic effects of bowel cryolesion during renal cryoablation in a porcine model.

Material and Method: Six pigs underwent percutaneous renal cryoablation with two freeze cycles in the lower pole of both kidneys. Six kidneys were injected with 10 ml saline into the renal subcapsular space before cryoablation. The bowel was brought into contact with the edge of the ice ball with laparoscopic assistance during renal cryoablation, on the side with saline injection as well as on the control side. One of these animals was kept for survival follow-up and laparotomy for 7 days post cryoablation. The bowel cryolesion sites were observed and compared based on the presence or absence of renal subcapsular saline injection.

Results: The mean diameter of acute bowel injury with and without saline renal subcapsular injection was 7.25 ± 1.26 and 14.5 ± 0.58 mm, respectively. The influence of injecting a saline buffer, was a significant decrease in the bowel cryolesion compared to controls ($p = 0.0003$). In addition, a pig kept for follow-up confirmed no bowel perforation after 7 days at a site that was cryolesioned on the side with renal subcapsular saline injection, but sustained bowel perforation in another segment lesioned by contact with a kidney without a saline injection. Gross and microscopic pathological examination was consistent with these interpretations.

Conclusion: Preliminary results in a porcine model show that percutaneous renal subcapsular saline injection is a feasible and promising technique for preventing bowel complications of percutaneous image-guided renal cryoablation.

Keywords: Percutaneous renal cryoablation, Bowel injury, Subcapuar, Saline injection

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Since the 1960s, cryotherapy has been referred to the application of extreme cold to destroy disease tissue, including cancer cells in skin tumors^(1,2). Currently, clinical treatment is being analyzed to determine the

effectiveness of cryotherapy for tumors in the abdomen, namely in the liver, kidney, and uterus⁽³⁾. However, cryotherapy treatment within the abdomen needs to be carried out carefully around the bowel since damage may cause perforation of the bowel, releasing contents into the abdomen and secondary infection. Furthermore, laparoscopic and percutaneous image-guided renal cryoablation of renal tumors have been popularized for the treatment of small renal tumors⁽⁴⁾, but the study of

Correspondence to: Permpongkosol S, Division of Urology, Department of Surgery, Faculty of Medicine, Ramathibodi Hospital, Mahidol University, Rama 6 Rd, Bangkok 10400, Thailand. Phone: 0-2201-1315, Fax: 0-2201-1315, E-mail: permpongkosol@gmail.com

bowel injury due to renal cryoablation remains limited. Kaplan et al⁽⁵⁾ first reported the perforation of enteric lesions when the bowel was overlying the lesion undergoing cryoablation by liquid nitrogen. A limitation of this experiment model is that only one dog was selectively studied by suturing a loop of ileum over the fundus of the bladder directly over the central site of mucosal freeze.

With the colon in close proximity to the anterior aspect of both kidneys, some institutions perform renal cryoablation only as open or laparoscopic procedures. Thus, the development of percutaneous image-guided renal ablation of anterior renal masses has been gradual. However, bowel complication is potentially preventable. Hinshaw et al⁽⁶⁾ suggested a technique, during image-guided ablation of renal cell carcinoma, to increase the distance between the kidneys and colon by injecting sterile water into the anterior perirenal or pararenal spaces. This hypothesis was explained by the nonconductive nature of water, as an insulating agent, but a confirming experiment has not been reported.

The objective of the present study was to evaluate the feasibility of percutaneous renal subcapsular saline injection in preventing bowel injury during renal cryoablation in a porcine model. Furthermore, the authors demonstrated morphologic changes of the bowel wall when contacted to the edge of the ice ball during renal cryoablation in both the presence and absence of renal subcapsular saline injection.

Material and Method

Animals

Six female domestic pigs (50-60 kg) were used and anesthesia was induced with intramuscular ketamine. An intravenous line was inserted, sodium pentothal was administered, and the animals were intubated. At the conclusion of the procedure, euthanasia was performed with an overdose of sodium pentobarbital in all six pigs. However, one pig was kept alive for 7 days for follow-up analysis and laparotomy. Professional veterinarians and trained personnel provided comprehensive care for this animal throughout the present study period.

Saline renal subcapsular injection and cryotherapy

The animal was placed in the supine position, and the abdomen was prepped and draped in normal sterile fashion. A 2.4 mm cryoprobe (Endocare, Irvine, CA) was percutaneously introduced into the lower pole of each kidney under ultrasound guidance. The pigs

were randomized to which side kidney would have subcapsular saline injections. A 20 gauge needle was introduced through the renal parenchyma at the inferior pole of the randomly selected experimental kidney by ultrasound guidance, injecting 10 ml sterile saline just underneath the renal capsule. The needle was then carefully removed. A Veress needle was used to obtain pneumoperitoneum at 15 mm Hg, and a 12-mm midline trocar was placed at the umbilicus. Two additional 5-mm trocars were placed approximately 8 cm above and 8 cm below the umbilicus trocar. A transperitoneal approach was used to approach the kidneys, and the kidney with subcapsular saline was identified. The small bowel with black suture mark was brought into contact with the kidney 5 mm from the entry site of the cryoprobe, with bowel forceps. Then, a double freeze-thaw cycle was performed by using an argon gas-based Endocare cryosurgical unit (Endocare, Irvine, CA). Each cryoprobe was cooled to -140 C°, and the cryoprobe was then withdrawn at the end of cryoablation. Finally, the abdominal port sites were closed.

Necropsy and histologic evaluation of the isolated small bowel lesion segments were performed immediately in five pigs and 7 days after cryosurgery in the last pig. The bowel segments from each animal were preserved in TTC solution (Sigma Chemical Co) and then 10% neutral Formalin as previously reported⁽⁷⁾. After fixation, the diameter of cryolesion was identified and measured.

Results

The renal subcapsular saline injection was successful in all of the pigs as confirmed by laparoscopically visualization. The bowel cryolesion could be identified as an area of red hemorrhage with an abrupt transition at the border from necrotic to viable tissue after contacting the edge of the ice ball (Table 1). Acute cryolesions of 7.25 ± 1.26 and 14.5 ± 0.58 mm in a diameter were present in the bowel wall segments damaged with and without renal subcapsular saline injection, respectively. The influence of injecting

Table 1. Mean of diameter of acute macroscopic bowel necrosis (mm \pm SD)

Control	14.50 ± 0.58
Renal subcapsular saline injection	7.25 ± 1.26

Note: Student *t* test; T = 0.0003

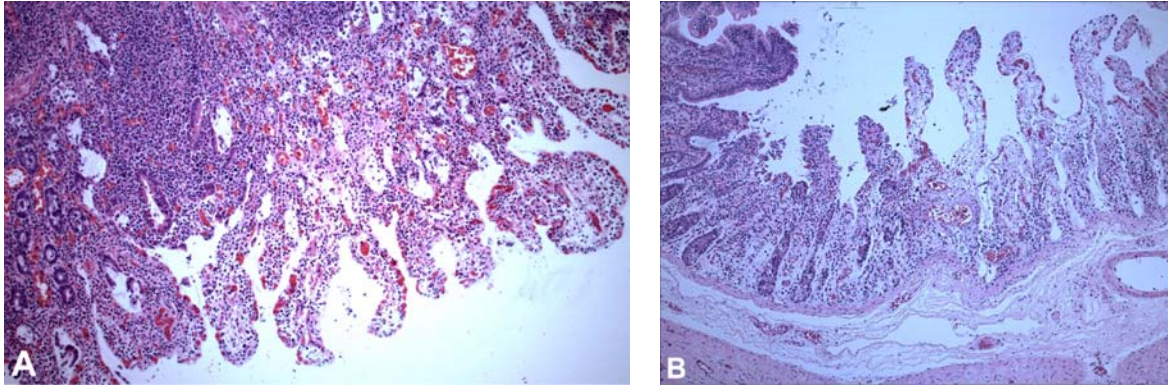


Fig. 1 Acute change of pathological result in bowel injury during renal cryoablation without (A) and with (B) subcapsular saline injection

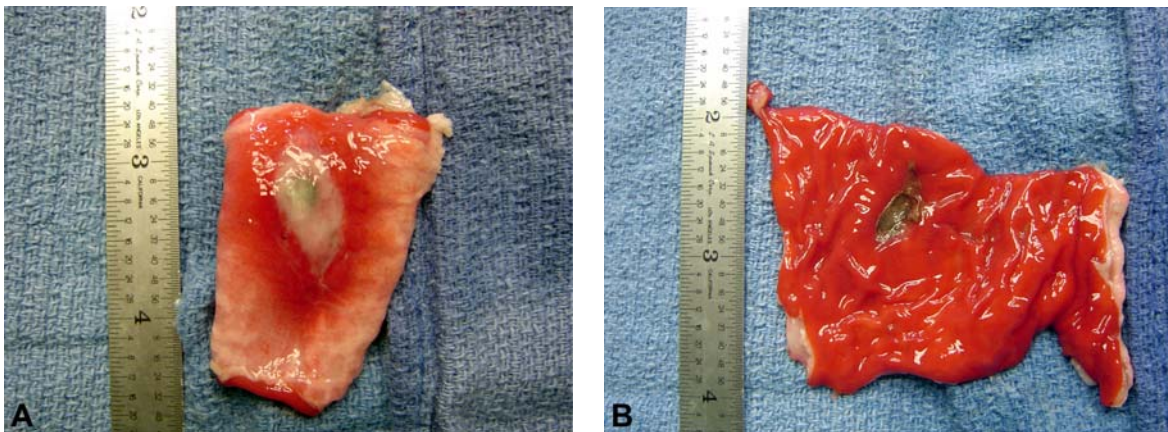


Fig. 2 The necrosis area of the bowel segment was demonstrated in serosa at 10 days (A) and after 10 days (B) contacted at the ice ball edge of renal cryoablation

a saline buffer, was a significant decrease in the bowel cryolesion compared to controls ($p = 0.0003$).

Acute change of pathological result in bowel injury seen with placement bowel close to a single cryoprobe is shown in Fig. 1A. However, saline injection did not significantly decrease the bowel injury histologically (Fig. 1B). The last pig suffered bowel injury and was euthanized 7 days after renal cryoablation. Transmural abscess formation with mucosal necrosis, muscle wall obliteration and serositis were seen pathologically, consistent with perforation in the segment lesioned by contact with a kidney without a saline injection (Fig. 2, 3). At another site that was cryolesioned on the side with renal subcapsular saline injection, the subacute bowel injury was demonstrated and confirmed no frank bowel perforation after 7 days.

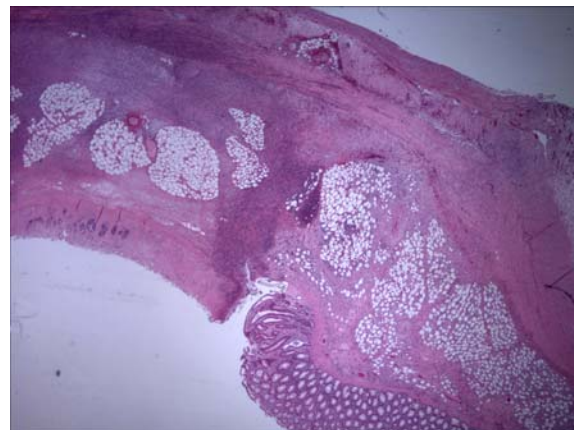


Fig. 3 Chronic change of pathological result in bowel injury during renal cryoablation

Discussion

Percutaneous imaged-guide renal cryoablation remains a treatment option for select patients with small renal tumors. In the case of anterior renal tumors, thermal injury to surrounding organs is a potential complication with the percutaneous technique⁽⁸⁾. Recently, Milner et al⁽⁹⁾ offered the idea of percutaneous CT guided saline mobilization of colon to facilitate renal cryoablation. They created a “salinoma” to mobilize the colon away from the tumor by injecting 500 cc of saline via a 22 gauge needle in the setting of CT-guided renal cryoablation where the descending colon was at risk of injury due to proximity with the tumor. However, this technique in one clinical case has not ever been performed in an animal model and the volume of saline used may increase the tendency of infection. In addition, we had two more experiences with separating the colon from the freeze site by injection of 10 ml of saline solution into the perinephric area with a 20-gauge needle allowing for complete tumor ablation in a single treatment session without any complication⁽⁸⁾. Herein, the authors evaluated the feasibility of percutaneous renal subcapsular saline injection to facilitate percutaneous renal cryoablation and the histopathologic effects of this procedure on bowel cryolesion in a porcine model.

Conversely, a measure of success has been achieved in cryopreservation of canine ileum was reported^(10,11). A method for the study of various factors pertaining to freeze-thaw injury was described along with an example of its application. Furthermore, the dog intestine tolerated transmural cryonecrosis without necrosis in Benson studies⁽¹²⁾ frozen by liquid nitrogen and healing spontaneously without major intestinal malformation. A temperature depression in the target tissue below -40°C was achieved. This attests to the relative biologic inertia of cryolesions and invites cautious use of this approach in palliative treatment of abdominal metastasis disease. However, the present results confirmed Kaplan et al's study that the perforation of enteric lesions can occur when the bowel overlays the area of freezing and that bowel complication can be potentially preventable during renal cryoablation.

The present study resulted in significantly decreased mean diameter of bowel injury on sides with renal subcapsular saline injection compared to control sides. These data confirmed that injection of saline increased the distance between the kidney and bowel, and was an insulating agent because of its nonconductive nature⁽¹³⁾. In controversy, the cryo-

preservation of the canine bowel study^(10,11) may also confirmed the cryolesion bowel was recovery after cryolesion if saline renal subcapsular injection was performed to prevent the cryoablation effect. The effects of freezing and frozen storage on histological characteristics of intestinal canine tissue were intermediate, and less than brain and liver⁽¹⁴⁾. The lung and kidney were affected least by freezing. In addition, the bowel injury was sustained at a distance of 5 mm from the cryoprobe, in the present study was supposed to be $-54.6 \pm 8.3^{\circ}\text{C}$ from the authors' previous animal experiment⁽¹⁵⁾. However, the limitations of this experimental model are the small number of animals in the present study and the limited long-term survival after use of this technique.

Conclusion

Preliminary results in a porcine model show that percutaneous renal subcapsular saline injection is feasible and confirmed by histopathologic changes of the bowel wall when contacted to the edge of the ice ball during renal cryoablation in both the presence and absence of renal subcapsular saline injection. This method is a promising technique for preventing bowel complications of percutaneous image-guided renal cryoablation in the future.

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การฉีดน้ำเกลือใต้ต่อเยื่อหุ้มรอบไตระหว่างการทำผ่าตัดเนื้องอกไตด้วย cryoablation ผ่านทางผิวหนังเพื่อป้องกันการบาดเจ็บต่อลำไส้

สมพล เพิ่มพงศ์โกศล, Theresa L Nicol, Frederico R Romero, Soroush Rais-Bahrami, นิวัฒน์ อรัญญาเกษมสุข, Stephen B Solomon, Louis R Kavoussi

จุดประสงค์: เพื่อศึกษาความเป็นไปได้ในการทำ percutaneous injection of saline เข้าใน renal subcapsular space เพื่อป้องกันลำไส้จากอุบัติเหตุและผลพยาธิวิทยาของลำไส้จาก cryoablation ในการทดลองในหมู

วัสดุและวิธีการ: หมูจำนวน 6 ตัวได้รับการทำ percutaneous renal cryoablation ด้วยการทำสอง freeze cycle ที่ไต ส่วนล่างทั้งสองข้าง โดยจะฉีด saline 10 มิลลิลิตร เข้าใน renal subcapsular space ก่อนการทำ cryoablation จำนวน 6 ไต หลังจากนั้นจะนำลำไส้เล็กมาติดกับขอบของ ice ball ด้วยการส่องกล้องช่วย (laparoscopic assistance) ระหว่างทำ renal cryoablation โดยมีข้างที่มี saline injection และอีกข้างเป็น control มีหมูจำนวนหนึ่งตัวที่เก็บไว้ให้มีชีวิตสำหรับการติดตามการรักษาและผ่าตัดตรวจอีก 7 วันถัดมา บริเวณ bowel cryolesion จะถูกสังเกต และ เปรียบเทียบระหว่างข้างที่ได้รับและไม่ได้รับ renal subcapsular saline injection

ผลการศึกษา: ค่าเฉลี่ยเส้นผ่าศูนย์กลางของ acute bowel injury ที่มีหรือไม่มี renal subcapsular injection เท่ากับ 7.25 ± 1.26 และ 14.5 ± 0.58 มิลลิลิตร, ตามลำดับ อิทธิพลการฉีด saline เข้า renal subcapsular ได้ลด bowel cryolesion ลงเมื่อเปรียบเทียบกับ control ($p = 0.0003$) นอกจากนั้นในหมูที่เก็บไว้ไม่มีลำไส้ทะลุ (bowel perforation) ในบริเวณที่ติดกับ renal subcapsular saline injection แต่มีลำไส้ทะลุบริเวณ control

สรุป: ผลการศึกษาในขั้นต้นแสดงว่า percutaneous renal subcapsular saline injection มีความเป็นไปได้ และ อาจเป็นการป้องกันการโรคแทรกซ้อนที่อาจเกิดขึ้นจากการทำ percutaneous image-guided renal cryoablation