Case Series of the Month

Robotic Partial Nephrectomy with Cold Ischemia and On-clamp Tumor Extraction: Recapitulating the Open Approach

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Abstract

We describe a reproducible technique for achieving cold ischemia with intraoperative tumor assessment during robotic partial nephrectomy (RPN) that recapitulates the open approach: intracorporeal cooling and extraction (ICE).

A total of seven patients underwent the ICE modification of RPN by transperitoneal \( n = 5 \) and retroperitoneal \( n = 2 \) approaches. A Gelpoint access port was used for the camera and assistant ports. Following hilar clamping, ice slush was introduced through the Gelport via syringes and applied over the kidney surface. The excised tumor was immediately extracted through the Gelport, allowing gross margin assessment by pathology during the renorrhaphy.

RPN was achieved in all cases with successful introduction of ice slush and tumor extraction while on clamp. Median RENAL nephrometry score was 8 (range: 6–10), and there was one solitary kidney. Mean cold ischemia time was 19.6 min (range: 8–37) and mean estimated blood loss was 296.4 ml (range: 50–1000). Renal parenchymal temperatures \( <16 \) °C were achieved within 7 min of cold ischemia and there was no drop in core body temperature \( >0.5 \) °C during any procedures. Intraoperative assessment of the excised tumor showed adequate gross margins in all cases and final pathology confirmed negative surgical margins.

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delivery on a porcine model using thermal needle probes to monitor renal parenchymal temperatures. In three porcine test cases, kidneys were cooled to a temperature <20 °C within 10 min and maintained the target temperature for the duration of hilar clamping >30 min (unpublished data).

Between April and September 2012, seven patients consented to a modification of our standard technique of RPN [7], called intracorporeal cooling and extraction (ICE). Initially, we offered the ICE–RPN technique to consenting patients with posterior tumors amenable to a retroperitoneal approach. We then expanded our technique to include patients undergoing transperitoneal surgery who consented to the ICE–RPN technique. In total, two patients underwent a retroperitoneal approach and a transperitoneal approach was used in five patients. Patient demographics are provided in Table 1.

A Gelpoint access port (Applied Medical Resources Corp, Rancho Santa Margarita, CA, USA) was used during RPN to permit placement of iced saline slush and rapid tumor extraction. The Gelpoint was inserted through an incision at the paramedian line or below the 12th rib for transperitoneal and retroperitoneal approaches, respectively. All patients were placed in the standard flank position. In the retroperitoneal approach, a 2-cm transverse skin incision was made below the tip of the 12th rib. The muscles were split bluntly to expose the thoracolumbar fascia, which was incised to enter the retroperitoneum. The retroperitoneal space was developed with blunt finger dissection and balloon dilation (US Surgical, Norwalk, CT, USA) under direct laparoscopic vision. The incision was extended to approximately 4–4.5 cm to accommodate placement of the Gelpoint wound retractor (Fig. 1). The camera and assistant ports were preplaced through the Gelpoint, maximizing separation, and the Gelpoint and trocars were attached to the wound retractor. Robotic working trocars were placed outside of the Gelpoint with an additional, medial, robotic trocar for the third robotic arm to provide lift on the kidney (Fig. 2A). In the transperitoneal approach, a paramedian incision was made lateral to the rectus muscle and the Gelpoint placed after gaining open entry to the peritoneum (Fig. 2B). A grasper for liver retraction in right-sided cases was placed directly through the Gelpoint without the need for a port.

Robotic instruments used included a fenestrated bipolar grasper in the nondominant hand and monopolar curved scissors in the dominant hand; the latter instrument was exchanged for a robotic needle driver for renorrhaphy. For both approaches, the kidney was mobilized and the renal vessels were dissected. The renal artery was encircled with a vessel loop to facilitate clamping and identification of the renal hilum after ice-slush delivery. Intraoperative ultrasound was performed to help delineate tumors and intended resection margins. Clamping of the renal artery was performed using robotic bulldog clamps (Scanlan Inc., St. Paul, MN, USA).

Sterile, iced, saline slush was created in a slush machine (Hush Slush System; Ecolab Inc., MN, USA). Disposable syringes (30 ml and 70 ml) were modified by cutting off the nozzle end to make a wider opening and were prefilled with ice slush in preparation for rapid injection (Fig. 3A). Following clamping of the renal artery, syringes were placed through the Gelpoint at the site of the removed assistant port, allowing injection of iced saline slush around the kidney (Fig. 3B). Repeated rapid injections of ice slush

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**Table 1 – Demographics and preoperative data on patients undergoing robotic partial nephrectomy with iced ischemia**

| Patients, no. | 7 |
| Age, yr, median (range) | 60 (48–69) |
| Side, right/left | 5/2 |
| BMI, kg/m², mean (range) | 32.84 (24.7–39.9) |
| Serum creatinine, mg/dl, mean (range) | 0.93 (0.7–1.3) |
| GFR, ml/min per 1.73 m², mean (range) | 80.5 (57–93) |
| Patients with prior abdominal surgery, no. | 4 |
| Patients with a solitary kidney, no. | 1 |
| Patients with bilateral masses, no. | 1 |
| Tumor size, cm, mean (range) | 2.5 (1.4–3.8) |
| Tumor location, no. | 2 |
| Upper pole | 2 |
| Interpolar | 3 |
| Lower pole | 2 |
| Median RENAL nephrometry score (range) | 8 (6–10) |

BMI = body mass index; GFR = glomerular filtration rate.
were performed to cover the kidney surface (Fig. 3B). Renal parenchymal and core body temperatures were measured by thermal probes (Mon-a-Therm; Covidien, Mansfield, MA, USA) placed in the kidney and esophagus, respectively. Upper and lower body warmers were used to maintain core body temperature. We optimized the efficiency of ice delivery as the study progressed. We used 30-ml syringes for ice delivery in the first three patients. We used rigid sigmoidoscopes for the next two patients, which were able to deliver 50 ml of ice per injection. For the final two patients, we used a large catheter-tipped syringe with the tip cut off, which delivered 70 ml of ice per injection. In total, approximately 400 ml of ice was delivered in all patients within 3–4 min. Renal parenchymal temperatures of <16 °C were achieved within 7 min of cold ischemia in a patient who underwent a transperitoneal procedure with cooling. There was no drop in core body temperature >0.5 °C during any procedures.

Tumor excision was performed immediately after ice delivery. Ice could be reapplied as needed while on clamp. Following tumor excision, the tumor was placed in a 10-mm retrieval bag (Endocatch; Ethicon Endosurgery, Norwalk, CT, USA) for tumor protection and immediately extracted through the Gelpoint (Fig. 4). This allowed the whole tumor to be examined on the OR table intraoperatively for gross margin assessment during renorrhaphy (Fig. 5).

An early unclamping technique was used with removal of the arterial clamp after suturing the inner layer of the renorrhaphy. Renorrhaphy was completed with outer, interrupted capsular sutures followed by application of hemostatic agents. Excess ice slush could be removed using saline irrigation at room temperature to help dissolve residual ice pieces and with intermittent suction.

Perioperative and postoperative data are provided in Table 2. One patient with a solitary kidney received an
intraoperative transfusion to maximize renal perfusion for bleeding during tumor resection. The patient had an uneventful postoperative course. There were no postoperative complications. Intraoperative assessment of the excised tumor showed adequate gross margins in all cases. All patients had at least 1-mo follow up with assessment of estimated glomerular filtration rate.

2. Discussion

Despite increased use of partial nephrectomy (PN) over the last decade, the vast majority of PN’s are still performed using an open approach. In the US Nationwide Inpatient Sample for 2008, LPN made up only 11.7% of PN procedures [8]. We believe one of the barriers to the broader uptake of minimally invasive PN is the concern that the operation cannot be done safely within reasonable time constraints of warm ischemia. Renal hypothermia may be necessary for prolonged warm ischemia times, particularly in patients with renal insufficiency [9]. Renal hypothermia lowers the metabolic rate and protects the kidney from ischemic damage, permitting longer periods of ischemia to accomplish PN. At present, there is no standardized method for inducing renal hypothermia during minimally invasive PN. Easy, reliable, and reproducible cold ischemia during minimally invasive PN remains an elusive puzzle that many investigators have tried to solve.

Although previous methods of renal hypothermia for LPN have demonstrated effective parenchymal cooling, most techniques require specific equipment or expertise and are too complex or impractical for routine use. Transarterial cold perfusion requires an interventional radiologist and predisposes the patient to risk of vascular injury or thrombosis [3]. An alternative method such as retrograde ureteral cooling involves retrograde catheter placement and need for a postoperative stent [2]. Also, incisions in the collecting system during this technique can compromise the degree of hypothermia and impair visualization. Irrigation with cold saline can lead to large amounts of fluid overflow into the peritoneum and could cause drops in the core temperature [4].

The gold standard for inducing renal hypothermia is surface cooling with crushed ice because this achieves significantly lower cortical temperatures [10]. However, standard ice slush for renal hypothermia during OPN is composed of dendritic ice crystals that do not flow well through small-caliber laparoscopic cannulae. Topical hypothermia using a microparticulate ice slurry during LPN has been described, which allows direct application onto the kidney through a modified 5-mm instrument [6]. However, this material is not yet available for commercial use.

With our ICE technique, we have demonstrated a modification of RPN that allows easy and reproducible introduction of iced saline slush to the kidney surface. The equipment needed is readily available, using the same slush machine required for OPN. Ice slush can be injected on to the kidney surface via the Gelpoint without losing insufflation or extending an incision. A further advantage is the ability to immediately retrieve the excised specimen through the Gelpoint for gross margin assessment by the surgeon while the surgery is in progress. If gross inspection of the early extracted tumor were to raise questions of inadequate resection, additional resection or biopsies could be performed before the operation is over. The ICE technique offers advantages typically reserved for OPN, namely, the ability to ice the kidney and valuate the resected specimen.

Gill and coworkers [5] described a technique for introducing ice slush for transperitoneal LPN through a laparoscopic (Endocatch) bag placed around the mobilized kidney. Although parenchymal temperatures <20°C were achieved, certain disadvantages of this technique have prevented it from becoming widely practiced. The kidney must be completely mobilized to enclose it within the bag. The bag is exteriorized through a port site to insert the ice slush externally. This requires removal and changing of ports, and enlargement of port-site incisions that can lead to air leakage. In addition, the bag can potentially compromise operative exposure, interfere with management of hilar clamps, and does not lend itself well to use in retroperitoneoscopic procedures due to space limitations.
The feasibility of ice-slush renal hypothermia for retroperitoneal LPN has already been demonstrated [11]. Prior to the advent of single-port access platforms, the technique required removal of the camera port and extending the incision to accommodate a custom-made cylindrical device for ice-slush delivery. Reinsertion of the port and closure of the incision was necessary, steps that considerably increased the time to deliver ice slush while the hilum was clamped. Gas leakage through the reinserted camera port was also a drawback. Our technique of ICE incorporating the Gelport is an improvement on the methods described by Gill et al. [5] and Wakabayashi et al. [11], and can be used for both transperitoneal and retroperitoneal approaches. The Gelport platform maintains insufflation while being a good conduit for the delivery of ice and specimen retrieval. Although the Gelport has been used during retroperitoneal laparoscopic nephrectomy [12] and LPN [13], it has not yet been reported in conjunction with the da Vinci robot for retroperitoneal RPN or with ice-slush hypothermia with early tumor extraction.

Other advantages of using the Gelport in this setting is that patients with prior abdominal surgery and adhesions pose less difficulty because open Hasson dissection with limited open adhesiolysis is feasible prior to Gelport insertion. This was particularly helpful for patient 6 in our series. The retroperitoneal approach for ICE–RPN facilitates management of posterior lesions and patients who have undergone extensive intra-abdominal surgery.

Following clamping of the renal artery and applying ice to the renal surface, we did not delay the excision of the tumor by formally waiting for the kidney to cool, as described in previous renal cooling techniques for PN [5,9]. The validity of this traditionally held concept of a waiting period has not been tested in any animal or human studies comparing cold ischemia with and without a waiting period. We feel that the renoprotective effect of ice is intended for the healthy kidney, not for the tumor and small margin being excised. Cold ischemia for RPN would be more likely to have a benefit for cases in which ischemia time is prolonged. In those cases, the kidney would have reached an appropriate temperature early in the ischemia time and would be sustained as time progresses, when protection is more important. We feel that unnecessary prolonging of the ischemia time, by any means, either cold or warm, should be avoided. In our technique, although we begin tumor excision immediately after applying the ice, 3–4 min are required to instill all the ice, which does represent a waiting period. Our technique is amenable to longer waiting periods according to the discretion of the surgeon.

Certain limitations of the ICE technique should be addressed. The syringes need to be modified by cutting the nozzles off, and it is time consuming to deliver larger quantities of ice slush (>1 l) as done during OPN. Longer syringes could allow greater volumes of slush to be delivered more quickly. We found the retroperitoneal approach to be more ideal for containing ice around the kidney compared to the transperitoneal route. Last, the present study is a single-arm observational study without control cohorts for comparison. Therefore, it can only be considered as a proof of concept of the applicability and feasibility of this approach.

In summary, the ICE–RPN technique allows for ice delivery and early specimen evaluation during RPN with acceptable operative times and short-term outcomes. Ice-slush cold ischemia during RPN is a promising new technique that has the potential to expand the limitations of RPN.

Conflicts of interest: The authors have nothing to disclose.

EU-ACME question

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Question:

Which of the following is not an established technique for obtaining renal hypothermia during minimally invasive nephron-sparing surgery?

A. Intra-arterial cold perfusion.
B. Iced saline slush placement.
C. Retrograde ureteral cold saline perfusion.
D. Argon injection.

References


