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RENAL HYPOTHERMIA ACHIEVED BY RETROGRADE ENDOSCOPIC COLD SALINE PERFUSION: TECHNIQUE AND INITIAL CLINICAL APPLICATION

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ABSTRACT

We describe the technique and initial clinical results with application of a novel method to achieve renal parenchymal hypothermia using retrograde ureteral access. A 38-year-old man was scheduled to undergo an open right partial nephrectomy for renal cell carcinoma. Before the open procedure, a ureteral access sheath was advanced to the ureteropelvic junction under fluoroscopic guidance; through the access sheath, a 7.1F pigtail catheter was also advanced. After clamping the renal artery and vein, ice-cold saline (−1.7°C) was circulated through the access sheath and drained via the 7.1F pigtail catheter; renal cortical and medullary parenchymal temperatures were measured using thermocouples. This technique of intrarenal cooling achieved a renal cortical temperature of 24°C and a medullary temperature of 21°C. The endoscopic procedure required an additional 35 minutes of operation time to complete. Histopathologic investigation of the specimen revealed no associated damage to the ureteral urothelium from access sheath placement or to the collecting system urothelium from exposure to ice-cold saline irrigation. Retrograde endoscopic renal hypothermia is feasible and effective. The technique requires no novel equipment or special surgical skills. This method can be applied to patients undergoing open or laparoscopic complex renal ablative and reconstructive procedures that require renal hypothermia. UROLOGY **61:** 1023–1025, 2003. © 2003, Elsevier Inc.

Application of renal hypothermia with transient interruption of the renal vasculature has made complex renal ablative surgical procedures feasible. Renal hypothermia during vascular clamping protects the kidney from ischemia-induced nephron loss. In 1975, Ward[1] determined the optimal temperature for regional renal hypothermia for renal preservation to be 15°C.

During open surgical procedures, renal hypothermia is commonly and efficiently achieved by clamping of the renal artery and packing the kidney within the surgical field in ice-slush. This technique results in adequate cooling, but exposes the entire surgical field and surrounding structures to the cooling effects of the ice. Traditional application of ice-slush for renal hypothermia is also presently impossible with laparoscopic access. As such, several techniques for achieving renal hypothermia during laparoscopic procedures have been described.[2–6] However, these approaches have had clinical limitations as they proved cumbersome and all involved cooling of the outer surface of the kidney.

Jones and Politano[7] successfully accomplished renal parenchymal hypothermia using cold saline irrigation of the renal collection system. However, due to limitations in available technology at the time, their approach required violation of the urinary tract by ureterotomy to achieve adequate renal irrigation for renal parenchymal cooling.

Recently, we reported successful application of a novel approach for renal cooling using endourologic techniques in a porcine model to cool the kidney from the inside out.[3] We now report the clinical technique and preliminary results of efficacy of renal hypothermia achieved by high-flow retrograde instillation of ice-cold saline.

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MATERIAL AND METHODS

Permission for this study was obtained from the human studies committee of the Washington University School of

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Medicine. After obtaining informed consent, a 38-year-old man, presenting with gross hematuria and found to have bilateral complex multiple cystic renal masses suspicious for malignancy on CAT scan, underwent cystoscopy with placement of a 12/14 ureteral access sheath (Applied Medical Resources, Rancho Santa Margarita, Calif). The sheath was advanced over an Amplatz superstiff guidewire to the right ureteropelvic junction under fluoroscopic guidance. A sidearm adaptor (Cook Urological, Spencer, Ind) was twisted into the distal end of the access sheath, and a 7.1F pigtail catheter (Cook Urological, Bloomington, Ind) was passed through the access sheath into the renal pelvis. Fluoroscopy revealed no pyelovenous or pyelolymphatic reflux upon irrigation with contrast at a pressure of 120 cm H_2O. A 12F Foley catheter was placed alongside the access sheath for bladder drainage. The access sheath was secured to the Foley catheter to prevent dislodgment during repositioning of the patient into the lateral decubitus position. An open flank incision was created, and intraoperative ultrasound of the right kidney confirmed multiple complex cysts suspicious of tumor that required radical nephrectomy.

Immediately after clamping the renal artery and renal vein separately, ice-cold (−1.7°C) 0.9% saline from a 3-L bag suspended 120 cm above the kidney was irrigated through the access sheath into the renal collection system. To ensure the lowest possible temperature, the 3-L bag of saline was frozen overnight and left to thaw on the day of surgery. At the time of application, the bag was "ice-slush"; half the bag was ice and the other half was liquid. The efflux returning from the 7.1F pigtail catheter in the pelvis was collected. The volume and temperature of the influx and efflux fluids were measured and recorded. The cortical and medullary temperatures from areas of normal renal cortical and medullary parenchymal tissue were measured 15 minutes after clamping of the renal artery and vein and initiation of retrograde irrigation. Parenchymal temperatures were determined using two needle thermocouples (Omega Engineering, Stamford, Conn). The patient's core temperature was also measured and recorded. After this portion of the study, a radical nephrectomy was performed after removal of the thermocouples and access sheath.

RESULTS

The application of the ureteral access sheath and 7.1F pigtail catheter resulted in the circulation of 85 mL/min of ice-cold saline. The temperature of the ice-cold saline irrigant was −1.7°C in the 3-L bag, and the mean temperature of the effluent leaving the system through the 7.1F pigtail catheter was 11°C.

With renal artery and vein occlusion, the renal parenchymal cortical and medullary temperatures were decreased to 24°C and 21°C, respectively. As anticipated, the renal medullary temperature was reduced by more than the renal cortical temperature. The patient's core temperature remained normal (37°C) and stable throughout the entire procedure.

Histopathologic study of specimens of the renal parenchyma, collecting system, and ureteral tissue demonstrated only a small focus of minor cortical tubular abnormality in one area in a midpole segment of the renal specimen after an ischemic time of 35 to 40 minutes with the intrarenal cooling technique. The patient recovered uneventfully and was discharged home on postoperative day 3.

COMMENT

After the report of the first laparoscopic nephrectomy in 1991[8] there has been rapid expansion of the number and type of laparoscopic urologic procedures performed worldwide. Presently, with better instrumentation and technology, complex procedures like partial nephrectomy are routinely performed in many specialized centers.[9–12] However, laparoscopic nephron-sparing surgery has not had widespread success due to technical difficulties in achieving reliable hemostasis and closure of the collecting system. A number of techniques have been employed to facilitate partial nephrectomy, including cable ties, laparoscopic tourniquets, hand-assist devices, and electrosurgical snares.[9,10,13,14] Although laparoscopic hemostatic techniques and technology are still evolving, renal vascular clamping allows for a safe and a relatively bloodless field during partial nephrectomy. However, preserving nephrons during transient interruption of the renal vasculature is critical. In general, a warm ischemia time of less than 30 minutes is the goal; longer times are associated with either delayed return of function or permanent loss of function. As such, atraumatic renal vascular control combined with renal parenchymal hypothermia would allow the experienced laparoscopist to perform increasingly complex, minimally invasive nephron-sparing surgery reproducing the traditional open techniques, and would allow for a safe ischemia time in excess of 30 minutes.[3]

When evaluated in a porcine model, our technique of retrograde irrigation of ice-cold saline resulted in renal hypothermia of 21.3°C and 27.3°C in the renal medulla and cortex, respectively, with renal arterial control exclusively.[3] In this study, renal hypothermia by traditional ice-slush cooling with renal arterial control resulted in temperatures of 28.8°C and 23.7°C in the renal medulla and cortex, respectively. Neither technique achieved the optimal temperature for preservation of renal parenchymal tissue of 15°C as described by Ward. However, in our porcine study, both techniques resulted in gross and histologic preservation of renal parenchyma with an ischemic time of 30 minutes. In contrast, renal parenchymal tissue subjected to the 30-minute ischemia time without hypothermic protection manifested a significant medullary and cortical inflammatory response, and periarteriolar hemorrhage.

Retrograde endoscopic hypothermia is appealing as it requires only application of currently available operating room supplies (access sheath, pigtail catheter, and sidearm adaptor) and standard endourologic techniques. In addition, in the animal model, there was rapid onset and resolution of cooling using this approach.

In this first clinical application, the results of the endoscopic retrograde perfusion technique to achieve hypothermia were similar to the porcine model. There was a decrease in temperature of both the renal cortex and medulla to 24°C and 21°C, respectively, after renal artery and vein clamping. The irrigant flow was 85 mL/min at an irrigant pressure of 120 cm H_2O; there was no evidence of renal backflow.

The retrograde endoscopic irrigation technique has some limitations. The irrigation rate would have to be temporarily decreased when the integrity of the renal collection system is violated to prevent peritoneal irrigation with the ice-cold saline. However, as soon as the collection system is closed, full irrigation could be resumed. In addition, concerns over potentially exposing a repair to excess pressure are more theoretical than real. Indeed, in our animal studies, when using this approach for ureteroscopy, despite irrigant pressures of 200 cm H_2O, intrapelvic pressure never exceeded 20 cm H_2O, well below the threshold for renal backflow or the pressure that would be needed to disturb properly placed sutures. However, in the present situation, flow was through the ureteroscope and drainage was through the sheath, which is the reverse of the situation for intrarenal cooling. In addition, in theory, traditional ice-slush cooling could be superior to intrarenal cooling, as it results in better cooling of the renal cortex. The renal cortex contains the brush border of renal proximal tubule, which is the portion of the kidney most sensitive to ischemia. Despite this theoretical concern, histopathologic assessment showed good preservation of the renal cortex and medulla in our porcine study and in this clinical example after renal vascular clamping and retrograde intrarenal hypothermia. Furthermore, we hypothesize that the cooling of the kidney may increase over time as the fluid is constantly being replenished with ice-cold saline. In addition, this initial clinical trial was completed at an irrigant pressure of only 120 cm H_2O, which resulted in a flow of 85 mL/min. At an irrigant pressure of 200 cm H_2O, we believe that the resulting flow would increase to over 100 mL/min and cooling would thus be more rapid in onset and perhaps of greater magnitude. In our animal model, efflux changed from 46 to 80 to 127 mL/min when irrigant pressure was increased from 50 to 100 to 200 cm H_2O with corresponding pressure within the renal pelvis of only 10, 14, and 18 cm H_2O, respectively.[15] It is of note that, in the clinical application, the flow of efflux at 120 cm H_2O (ie, 85 mL/min) was quite similar to the flow of efflux (ie, 80 mL/min) in our porcine model at 100 cm H_2O, despite the fact that the influx and efflux in this clinical model were the reverse of our animal model.

Another theoretical concern is the exposure of the collection system to ice-cold saline irrigation. In both our animal model and in the patient studied herein there was no damage to the renal collection system or the ureter on histopathologic evaluation.

CONCLUSIONS

Our preliminary clinical experience with retrograde endoscopic renal hypothermia is promising and has shown the technique to be feasible and effective. The technique is simple and can be performed with commonly available endourologic equipment. Further evaluation of this technique is in progress at our institution.

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