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Laparoscopic Ureterocalicostomy: Development of a Technique Simplified by Application of Nitinol Clips and a Wet Monopolar Electrosurgery Device

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ABSTRACT

***Purpose*: We developed a technique for laparoscopic ureterocalicostomy with the use of intracorporeal suturing and subsequently simplified the technique by application of experimental Nitinol® clips.**

***Materials and Methods*: We performed laparoscopic ureterocalicostomy on 16 domestic swine divided into four groups of four animals each. The kidney was exposed laparoscopically, and the renal artery was atraumatically clamped. The lower pole of the kidney was amputated to expose a lower-pole calix, and hemostasis of the cut renal surface was obtained with a wet monopolar electrosurgical device (Floating Ball device [FB]; TissueLink, Dover, NH). Anastomosis of the ureter to the lower-pole calix was performed over a guidewire using 3-0 Vicryl suture in group 1 and Nitinol clips in group 3. A double-J ureteral stent was then deployed retrograde under fluoroscopic guidance. In addition, we evaluated the use of fibrin glue as a sealant over the sutured or clipped anastomotic site (groups 2 and 4, respectively). Ureteral stents were removed after 3 weeks, and the animals were evaluated and sacrificed after an additional 3 weeks.**

***Results*: Laparoscopic ureterocalicostomy was completed in all 16 animals. In each case, excellent renal parenchymal hemostasis was obtained with the FB device, with a mean hemostasis time of 4.1 minutes. The mean anastomotic time with standard suture reconstruction was 37.1 ± 5.4 minutes, while the anastomotic time with the Nitinol clips was 29.0 ± 8.0 minutes ($P = 0.0339$). Retrograde pyelograms in groups 1 and 3 (no fibrin glue) showed a patent anastomosis with no hydronephrosis in three of the four animals in each group. One animal in group 1 and one animal in group 3 developed large urinomas secondary to anastomotic failure. The animals that received fibrin glue over the anastomotic site (groups 2 and 4) all showed narrowed anastomoses with severe hydronephrosis.**

***Conclusions*: With available instrumentation, laparoscopic ureterocalicostomy is technically feasible. Nitinol clip technology significantly reduces collecting-system reconstruction time. Application of fibrin glue as a urinary tract sealant resulted in an unexpected adverse outcome.**

INTRODUCTION

URETEROPELVIC JUNCTION (UPJ) OBSTRUCTION is functional or anatomic blockage of normal urine flow from the renal pelvis to the ureter. This can lead to hydronephrosis with resulting pain, pyelonephritis, urinary calculi, or destruction of renal parenchyma. Surgical correction is the mainstay of treatment to relieve symptoms and preserve the remaining renal function. Traditional surgical approaches involved a large open incision. At present, minimally invasive techniques for the management of UPJ obstruction, including endopyelotomy[1,2] and laparoscopic pyeloplasty,[3] offer patients an effective alternative.

Laparoscopic pyeloplasty was introduced by Schuessler and associates in 1993.[4] Results from large series confirm that the technique has efficacy equal to that of open pyeloplasty.[5] With increasing experience, laparoscopic pyeloplasty can be applied to more complex cases, which will certainly offer laparoscopic

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surgeons a greater challenge in the future. If the stenotic UPJ segment is too long for a tension-free anastomosis, or the area is too scarred to permit adequate surgical repair, surgical alternatives include nephrectomy or ureterocalicostomy.

To date, ureterocalicostomy has been performed via open surgical techniques with interrupted absorbable sutures.[6,7] The recently introduced hemostatic technologies such as atraumatic laparoscopic vascular clamps and a wet monopolar electrosurgical device (Floating Ball device [FB]; TissueLink, Dover, NH) allow better visibility and less blood loss during renal parenchymal transection.[8] We hypothesized that the combination of renal vasculature control and experience with laparoscopic suturing techniques will allow laparoscopic ureterocalicostomy to be performed safely and effectively. Furthermore, in an attempt to develop an efficient and simplified technique for laparoscopic ureterocalicostomy, we evaluated the application of an experimental Nitinol clip (U-clip; Coalescent Surgical, Sunnyvale, CA), which we have recently demonstrated to be compatible with application in the urinary tract.[9] The clips can be deployed laparoscopically and eliminate the need for intracorporeal knot-tying, making them very attractive for surgeons without extensive laparoscopic reconstructive experience.

Fibrin glue (Tisseal; Baxter, Deerfield, IL) has proven effectiveness during laparoscopic partial nephrectomy for controlling venous oozing from the transected parenchymal surface.[10] Its use as an anastomotic sealant during laparoscopic reconstruction of the urinary tract has also been suggested.[11]

Herein, we describe the technique we developed for simplified laparoscopic ureterocalicostomy in the porcine model. We compared the use of absorbable sutures for anastomotic reconstruction with the use of Nitinol clips. In addition, we evaluated the effectiveness of fibrin glue as an anastomotic sealant for this procedure.

MATERIALS AND METHODS

Approval for the experiments was obtained from the Washington University Department of Comparative Medicine. Use of 16 domestic pigs was approved for this study.

Laparoscopic technique

After general anesthesia was administered, 2% chlorohexidine was used to prepare the perineum and abdominal skin. The abdomen and perineum were draped separately to maintain a sterile field. Initially, cystoscopy was performed to facilitate retrograde ureteropyelograms. A ureteral catheter was left in the ureter such that during the procedure, retrograde instillation of sterile saline or placement of a guidewire could be performed. The animals were then placed in the lateral decubitus position, Veress needle access was gained, and a pneumoperitoneum of 15 mm Hg was established. Three trocars were placed, and the renal hilum, renal pelvis, and proximal ureter were dissected free of surrounding structures. The renal artery was occluded with a laparoscopic atraumatic vascular clamp (Aesculap, Center Valley, PA). The lower pole of the kidney was excised to expose a calix. Hemostasis of the renal parenchyma was achieved with the FB device, and the renal arterial clamp was removed. The proximal ureter was occluded at the UPJ with laparoscopic staples and divided 2 to 3 mm distal to the staples. The distal ureter was then spatulated for 1 cm. A guidewire was advanced through the distal end of the ureteral catheter and guided laparoscopically through the lower-pole calix and into the upper collecting system. The spatulated ureter was then anastomosed to the lower-pole calix with 3-0 Vicryl interrupted sutures (groups 1 and 2) (Fig. 1) or Nitinol clips (groups 3 and 4). With the guidewire still across the anastomosis, a double-J ureteral stent was advanced over the guidewire and properly positioned under fluoroscopic guidance with the proximal coil in the renal collecting system and the distal coil in the bladder.

Experimental design

The animals were divided into four groups of four animals each. All four groups had laparoscopic ureterocalicostomy performed with similar techniques except for the anastomosis of the ureter to the lower-pole calix, which was performed with absorbable sutures in groups 1 and 2 and Nitinol clips in groups 3 and 4. In order to standardize the technique for comparison, six interrupted 3-0 Vicryl sutures or six Nitinol clips were used for anastomotic reconstruction. Fibrin glue was placed over the anastomosis in groups 2 and 4.

The animals were allowed to recover for 3 weeks, at which time, the stents were extracted cystoscopically. After an additional 3 weeks (total of 6 weeks postoperatively), the animals underwent general anesthesia as previously described. Cystoscopy was performed with retrograde ureteropyelography and ureteroscopy on the side of the operation. Any evidence of leakage, ureteral narrowing, or hydronephrosis was documented. At this time, the contralateral kidney underwent laparoscopic ureterocalicostomy as previously described, and the same hemostatic and anastomotic techniques were applied for each pig. After the procedure was completed, each animal was sacrificed, and the renal units were harvested. Any evidence of urinoma was recorded, and a portion of the anastomotic site was sent for histopathologic analysis. Using Student's *t*-test, comparison was made between the suture groups and the Nitinol clip groups

FIG. 1. Completed acute laparoscopic ureterocalicostomy with interrupted absorbable sutures.

TABLE 1. SURGICAL TIMES (MIN) IN GROUPS HAVING SUTURES *vs* NITINOL CLIPS (MEAN ± SD)

	Suture (groups 1 & 2) (N = 8)	*Nitinol clip (groups 3 & 4) (N = 8)*	P *value*[a]
Parenchymal transection time	2.9 ± 0.4	3.5 ± 0.8	0.1399
Hemostatic time	4.0 ± 0.9	4.1 ± 0.8	0.6472
Warm ischemia time	6.6 ± 1.2	7.7 ± 1.5	0.1380
Anastomotic time	37.1 ± 5.4	29.0 ± 8.0	0.0339

[a]p value < 0.05 is statistically significant.

in terms of ischemia time, parenchymal transection time, hemostatic time, and anastomotic time.

RESULTS

Laparoscopic ureterocalicostomy was completed in all 16 animals, and all animals survived the study period. The operative times are listed in Table 1, where the operative times have been combined for groups 1 and 2 and for groups 3 and 4, as these groups differed only in the application or nonuse of fibrin glue. Anastomotic times were significantly shorter with application of the Nitinol clips.

Three of the four animals in Group 1 and three of the four animals in Group 3 had patent anastomoses (Figs. 2 and 3) with no evidence of fistula or hydronephrosis. These findings were confirmed radiographically (Fig. 4). One animal in each of these groups, however, developed a large urinoma as a result of anastomotic failure. All animals in which fibrin glue was applied (groups 2 and 4) developed a narrowed anastomosis with severe hydronephrosis. Retrograde studies on these pigs showed no urinoma or fistula formation.

Histopathologically, the renal parenchyma of groups 1 and 3 appeared normal, with no evidence of cellular infiltrate, glomerulosclerosis, or any other ischemic damage. The anastomotic site revealed suture granulomas in the suture group, a finding that was absent in the Nitinol-clip group. Although thin in some areas, the urothelium and muscularis propria had regenerated over the anastomotic scar in both groups. In groups 2 and 4, the renal parenchyma demonstrated mildly dilated tubules with mild acute and chronic cellular infiltrate and focal areas of fibrosis. The urothelium was intact; however, dense fibrosis was noted around the anastomotic site. More chronic inflammatory cells were seen around the anastomotic site in groups 2 and 4.

DISCUSSION

Open ureterocalicostomy has utility for challenging cases of UPJ obstruction. Until now, this procedure has been performed by traditional open techniques. However, technological advancements have provided surgeons with the tools to perform this operation laparoscopically. With the development of atraumatic vascular clamps, the renal hilum can be occluded temporarily, permitting essentially bloodless complex renal surgery. Additionally, with judicious application of energy tools such as the FB, hemostasis of the renal parenchyma can be achieved easily and expeditiously while the renal hilum is occluded. Identification and avoidance of the collecting system (lower-pole calix) during energy-based hemostasis permits removal of the renal vascular clamp prior to collecting-system reconstruction, thus minimizing renal ischemia times.

Interrupted absorbable suture has been the traditional method for reconstruction of the collecting system during open ureterocalicostomy. Laparoscopic suturing is technically challenging and requires advanced skills. Placement of sutures during laparoscopic ureterocalicostomy is particularly challenging, as the surgeon must insert sutures at difficult angles through delicate renal parenchyma. Recently, we evaluated the application of commercially available Nitinol clips (U-clip) for reconstruction of the urinary tract. In a chronic study, the clips were used for ureteroureterostomy in a porcine model and manifested

FIG. 2. Nephrectomy specimen 6 weeks after laparoscopic ureterocalicostomy.

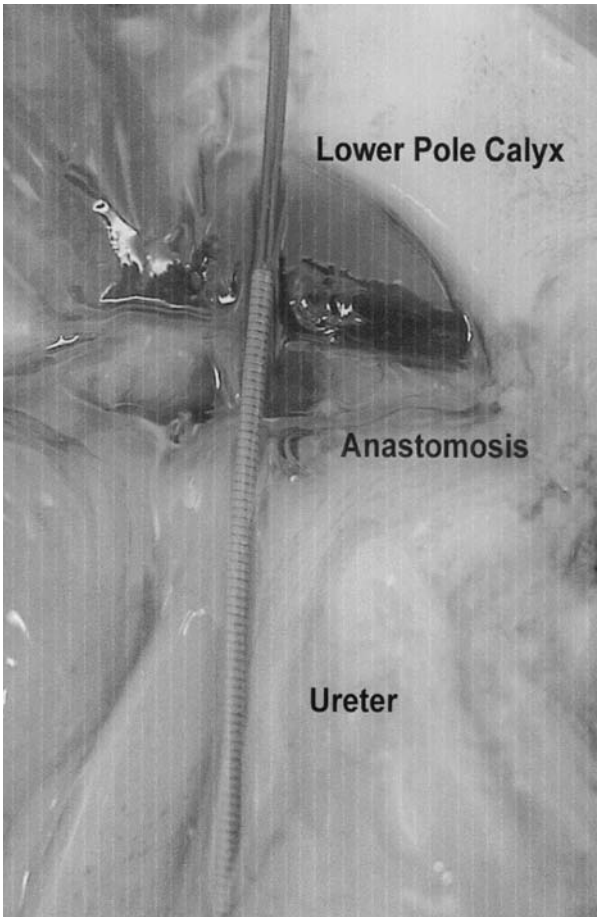

FIG. 3. Laparoscopic ureterocalicostomy completed with Nitinol clips. Partially epithelialized clips can be seen at anastomotic site.

no encrustation with follow-up of 1 year.[9] The surface of the clip consists almost entirely (>99%) of titanium, a metal shown to be compatible with normal human urinary tract.[12]

Application of the Nitinol clips in our study significantly reduced the anastomotic time and decreased the amount of technical skill needed to complete the procedures. The clips may also allow surgeons unfamiliar with intracorporeal knot-tying to perform urinary-tract reconstruction. One disadvantage of the Nitinol clip is that it must be placed precisely prior to deployment. As it is metal, a deployed clip cannot be cut and replaced with a new one.

Laparoscopic ureterocalicostomy was technically successful in three of four animals in groups 1 and 3. The two failures in these groups were felt to result from either inadequate suture/clip placement, predisposing to fistula formation, or from anastomotic disruption, which may have occurred during the animal's recovery from general anesthesia. Typically, in clinical application, a drain is left in the retroperitoneum near the anastomosis to prevent urinoma formation, but this is not feasible in the swine model. Application of drains in these animals might have resulted in a superior outcome.

Fibrin glue has been suggested as a sealant for complex urinary-tract reconstruction. However, to date, no prospective clinical data on such use have been published. Experimental ureteral reconstruction in the porcine model has yielded mixed results.[13,14] We applied fibrin glue to the anastomotic area in an effort to minimize urinary leakage. The fibrin glue resulted in an unexpected adverse outcome in all animals in which it was applied (groups 2 and 4), namely significant anastomotic fibrosis, which resulted in compromised urinary drainage and severe hydronephrosis. The etiology of this response is not clear. As the fibrin glue applied to the anastomosis was derived from human serum, it is conceivable than a xenograft reaction occurred: the porcine immune system responding to the human antigens. Because of the significant cost of this glue, further laboratory and clinical investigation is necessary prior to ad-

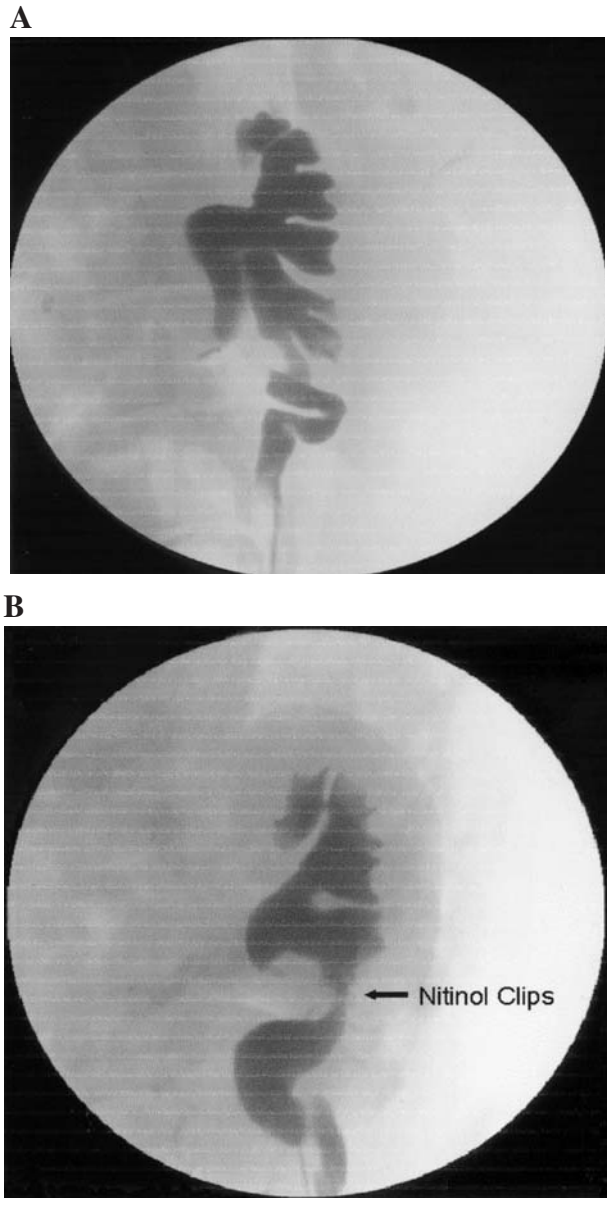

FIG. 4. Retrograde pyelograms confirm patent anastomoses in suture group **(A)** and clip group **(B)**. Nitinol clips can be seen faintly on fluoroscopic imaging.

vocating its application as a urinary-tract sealant in this procedure.

CONCLUSIONS

Laparoscopic ureterocalicostomy, although technically challenging, is feasible in the porcine model. Open surgical techniques can be duplicated with acceptable ischemia and anastomotic times. Application of available technologies such as atraumatic vascular clamps, energy-based hemostasis with the FB, and Nitinol clips may facilitate the procedure and minimize the need for advanced laparoscopic skills. Application of fibrin glue as a urinary-tract sealant resulted in an unexpected adverse outcome in this study. Clinical application of laparoscopic ureterocalicostomy will allow patients to enjoy the benefits of a minimally invasive approach when standard laparoscopic pyeloplasty is not technically feasible.

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