Laparoscopic Pyeloplasty in the Animal Model

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ABSTRACT

Purpose: Laparoscopic pyeloplasty has been associated with long operative times. This study proposed to evaluate the feasibility of two different laparoscopic techniques for the performance of pyeloplasty repair of secondary ureteropelvic junction (UPJ) obstruction.

Materials and Methods: Sixteen female Yucatan mini-pigs underwent general anesthesia for cystoscopy, retrograde pyelography, urine culture and a baseline renal scan. Unilateral UPJ obstruction was created by ligating the UPJ over a 5F catheter. Six weeks later a laparoscopic pyeloplasty was performed utilizing an intracorporeal suturing technique and the Lapra-Ty suture clip or the Endostitch device with intracorporeal knot tying. Four control animals underwent only cystoscopy and in/out ureteral catheterization. In the study animals the ureteral stent was maintained for six weeks and at six weeks, three months and six months post-pyeloplasty the animals underwent the previously mentioned studies. At six months post-pyeloplasty the animals were euthanized and the UPJ was calibrated. Histopathology was obtained on the ureter below the anastomosis, at the anastomosis, above the anastomosis and on a renal biopsy.

Results: All planned laparoscopic pyeloplasties were completed. However, the stricture model was too severe in that most animals developed 40-45% decrease in renal function in the kidney following ipsilateral UPJ ligation. There was no significant difference between the two pyeloplasty techniques with respect to operative time to perform the pyeloplasty (mean of 40 minutes), post-pyeloplasty ureteral caliber (7.5-8.0 F), serum creatinine or healing scores at, above or below the anastomosis.

Conclusion: Laparoscopic pyeloplasty can be performed equally successfully with the Endostitch device and intracorporeal knot tying or with the intracorporeal suturing technique and Lapra-Ty clips. The resultant pyeloplasty is also equivalent for the two techniques.

Key Words: Pyeloplasty, Laparoscopy, Ureteropelvic junction obstruction.

INTRODUCTION

Ureteropelvic junction (UPJ) obstruction may be due to extrinsic or intrinsic pathology. Intrinsic abnormalities of the UPJ are the most common cause of obstruction and may result in loss of a functioning renal unit. The occurrence of extrinsic compression may also be associated with intrinsic abnormalities of the UPJ. Traditional therapy, in children and adults, is an open surgical reconstruction of the stenotic UPJ.1 However, in adults, endopyelotomy has all but replaced open pyeloplasty for the management of most UPJ obstruction due to its good success rate, shorter operative time, reduced postoperative morbidity and quicker return to regular activities.2,3

Nonetheless, the endourologic surgical management of UPJ obstruction with reported success rates of 64% to 86% for antegrade and retrograde endopyelotomy is still less than the 90% to 95% success rate cited for open pyeloplasty.1-4 Recently, there have been anecdotal reports of laparoscopic pyeloplasty in an attempt to emulate the success rate for open surgery while maintaining the benefits of a minimally invasive procedure.5,6 However, the laparoscopic pyeloplasty has been associated with long operative times: five to seven hours, largely due to the difficulty of intracorporeal suturing. The introduction of new laparoscopic technology may simplify the procedure to improve its feasibility as an option in the management of a patient with UPJ obstruction.7

As such, this study proposed to evaluate the feasibility of two different laparoscopic techniques for the performance of pyeloplasty repair of secondary UPJ obstruction: a semi-automatic suturing device (Endostitch, US Surgical Corporation, Norwalk, CT) and the use of a suture clip knot (Lapra-Ty, Ethicon Endo-Surgery, Inc., Cincinnati, OH). In addition, the study compared the healing results using the two different techniques for performing the laparoscopic pyeloplasty.

MATERIALS AND METHODS

Sixteen female Yucatan mini-pigs were entered into the study. Under standardized general endotracheal anesthesia the animals underwent cystoscopy, retrograde pyelography, and urine collection for culture and sensitivity.

Unilateral UPJ obstruction, the side determined by prospective randomization, was created by ligating the UPJ with a suture ligature. A 5F ureteral catheter was cystoscopically...
passed retrograde to the renal pelvis on the experimental side. A CO₂ pneumoperitoneum was established at 15 mm Hg and a 12 mm port was placed at the level of the umbilicus on the lateral border of the ipsilateral abdominis rectus muscle to the proposed side of UPJ obstruction. Two additional 5 mm ports were placed on the anterior axillary line just below the costal margin and just above the anterior iliac crest, respectively. The 30-degree, 10 mm laparoscope was placed through the 12 mm port and grasping forceps and scissors were passed through the two 5 mm ports. The peritoneum was incised at the level of the lower pole of the kidney and extended caudally to expose the proximal ureter. The proximal ureter was circumferentially dissected from the retroperitoneal tissues minimizing the use of electrocautery in this area. A six-inch length of an absorbable (0-Chronic) ligature was passed twice around the ureteropelvic junction, at the level of the lower pole of the kidney, and tied in position using an intracorporeal knot-tying technique. The retrograde catheter was maintained for 30 minutes and then removed and the animal was recovered.

Six weeks following creation of the ureteropelvic junction obstruction, all animals underwent standardized general anesthesia, and the following evaluations were performed: serum creatinine, cystoscopy and bilateral retrograde pyelography with collection of urine for culture and sensitivity, renal scan and insertion of a 0.055 inch Bentzon guidewire into the upper collecting system. Twelve animals then underwent a laparoscopic pyeloplasty utilizing an intracorporeal suturing technique and Lapra-Ty (Ethicon Endo-Surgery, Inc., Cincinnati, OH) suture clip or the EndoStitch (U.S. Surgical Corp., Norwalk, CT) device with intracorporeal knot tying. The technique used was determined in a randomized fashion. In both techniques a 4-0 absorbable (polyglactin) suture was utilized. The Lapra-Ty (Ethicon Endo-Surgery, Inc., Cincinnati, OH) suture clip is made of absorbable polydioxanone material. No further surgical manipulation, following creation of the stricture, was performed on the four animals which served as a control model.

The laparoscopic pyeloplasty was performed in the following manner. After establishment of a 15 mm Hg pneumoperitoneum, using Veress needle insufflation, four ports were placed: a 12 mm port along the midclavicular line at the level of the umbilicus, a 12 mm port along the anterior axillary line just below the costal margin, a 12 mm port along the anterior axillary line approximately 3 cm below the umbilicus, and a 5 mm port on the posterior axillary line midway between the costal line and the iliac crest. A 10 mm, 30-degree laparoscope was positioned through the 12 mm midclavicular line port. The animal was placed in a lateral decubitus position with the operated flank exposed. Using electrosurgical scissors and grasping forceps the peritoneum was incised along the line of Toldt and this was mobilized medially, thereby similarly mobilizing the bowel medially to expose the ureter and kidney in the retroperitoneum. The region of the previously strictured UPJ was identified and dissected. The ureter and renal pelvis, 2 cm below and 2 cm above the area of stricture, were freed sufficiently to allow excision of the strictured area. Mechanical "cold" cutting scissors were used to transect the ureter and the renal pelvis removing the strictured segment of tissue. The posterior aspect of the ureter was spatulated for approximately 5 mm.

After randomization to either the free hand, intracorporeal suturing or EndoStitch group, a six-inch length of the polyglactin suture material was utilized with a preformed loop tied at the end of the suture. After passing the needle and suture full thickness, to ensure incorporation of the urothelium, through the posterior renal pelvis and spatulated ureteral side of the anastomosis the suture was passed through the preformed loop securing the initial closure. A continuous running suturing technique was utilized to approximate the renal pelvis to the ureter with full thickness suturing. In the pig model the size of the renal pelvis effectively makes this anastomosis similar to an uretero-ureterostomy. Following completion of the anastomosis using the intracorporeal technique a Lapra-Ty suture clip was placed on the suture to secure the anastomotic closure in six animals. In the case of the EndoStitch device an intracorporeal knot-tying technique was used with the Endostitch device to secure the final anastomotic closure in six animals. In both techniques satisfactory positioning of a ureteral guidewire in the renal pelvis was accomplished before completion of the closure. An indwelling 6F double pigtail, ureteral stent was passed over the guidewire fluoroscopically and left in position in the upper collecting system. No external, retroperitoneal drain was placed; the retroperitoneum was not re-established. The ports were removed and the animal was recovered and received Tribrissen antibiotic, 48 mg/kg q.d. for seven days. The ureteral stent was maintained for six weeks. A urethral Foley catheter was maintained for two to three days.

Six weeks following the laparoscopic pyeloplasty, under a standardized general anesthetic, cystoscopy and a gravity cystogram were performed. If there was no extravasation at the ureteropelvic junction region, the ureteral stent was removed cystoscopically.

At three months and six months post-pyeloplasty all the animals underwent standardized general anesthesia and the following evaluations were obtained: serum creatinine, urine for culture and sensitivity and renal scan. At the six
months post-pyeloplasty evaluation all the animals were euthanized and the ureteropelvic junction was calibrated using ureteral catheters sized from 4F to 10F. Hematoxylin and eosin (H&E) staining for histopathology was performed on the ureter below the anastomosis, at the anastomosis, and above the anastomosis at the renal pelvis. In addition, renal biopsies were performed for H&E histopathologic evaluation.

The H&E histopathologic evaluation assessed each harvested specimen for the following characteristics: urothelial resurfacing, degree of urothelial inflammation, fibrosis in the lamina propria, inflammation in the lamina propria, fibrosis in the muscle layer, and integrity of the muscle. Each characteristic was given a score of 0 to 3, with 0=normal histopathology and 3=worst histopathologic effect. Therefore, the total healing score could range from 0=normal histopathology to 15=worst effect in all five histopathologic categories.

Comparison of the two study groups and the control group was statistically evaluated using one-way analysis of variance (ANOVA). Comparison within each study group for changes following pyeloplasty was statistically evaluated using nonparametric, unpaired (Mann-Whitney) testing.

RESULTS

The tie-down technique of the ureteropelvic junction, over a 5F catheter, was completed successfully on all 16 animals. The mean ureteral diameter on retrograde pyelography prior to the tie-down procedure was 3.5 mm. At the time of pyeloplasty there was complete obstruction of the study ureter on retrograde pyelography in 6 of the 12 study animals; the remaining study ureters had a mean diameter of 1.7 mm, indicative of significant reduction of the ureteral lumen following the tie-down. On follow-up renal scan this model was found to be too severe in its effect of obstruction. The average decrease in renal function of the experimental kidney was 37%, indicating almost complete ureteral obstruction and resultant loss of renal function. In the EndoStitch group the average decrease was 42%, while the Lapra-Ty group had an average reduction of 36% and in the control group of animals the reduction in renal function was 33%. At six months follow-up there had been no improvement in the renal function despite imaging evaluation that confirmed patency of the ureter following pyeloplasty (Figure 1).

Pyeloplasty was completed successfully in all 12 experimental animals. The mean time for laparoscopic pyeloplasty using the Lapra-Ty surgical clip closure was 39.7 minutes (range 25-57 minutes). The mean surgical time for laparoscopic pyeloplasty utilizing the EndoStitch closure device was 39.5 minutes (range 20 - 75 minutes) (Table 1). The time for dissection in the two study groups was also similar, ranging between 14 minutes and 60 minutes, depending on the degree of retroperitoneal fibrosis secondary to the ureteral tie-down procedure.

The change in ureteral diameter, as evaluated by retrograde pyelography, pre-pyeloplasty and post-pyeloplasty in the EndoStitch pyeloplasty repair, was a reduction of the diameter by 0.48 mm (range -2.6 - 3.2 mm). In the Lapra-Ty surgical clip pyeloplasty closure the mean change in ureteral diameter was an increase in the ureteral diameter of 0.85 mm (range -1.4 - 4.0 mm). On statistical analysis there was no significant difference in the change in the ureteral diameter on comparison of the Lapra-Ty clip and EndoStitch pyeloplasty closure. In all the study animals and the con-
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Figure 2. Comparison of the change in ureteral diameter, as measured on retrograde pyelography, and the change in serum creatinine in the EndoStitch and Lapra-Ty clip laparoscopic pyeloplasty groups after six months of follow-up.

Figure 3. Comparison of the healing scores at the pyeloplasty anastomosis six months following the laparoscopic pyeloplasty in the EndoStitch and Lapra-Ty clip study groups and at the stricture site in the control group.

Figure 4. A retrograde pyelogram demonstrating the diverticulum (arrow) formation at the pyeloplasty anastomotic site six weeks following laparoscopic pyeloplasty. This was a significant finding in all the pyeloplasty study animals.

trol animals at six months post-pyeloplasty the UPJ calibrated to 8F easily.

The mean healing score in the EndoStitch pyeloplasty group was 4.17 (range 2 - 8), and in the Lapra-Ty surgical clip group the mean healing score was 5.92 (3 - 9.5) (Figure 3). The mean healing score in the control group of animals was 4.17 (range 4 - 4.5). There was no statistically significant difference among the EndoStitch, Lapra-Ty clip pyeloplasty ureters and the control ureters on comparison of healing scores. The primary histopathologic features effecting a higher healing score in the study ureters included fibrosis and inflammation of the lamina propria and muscle layer. The integrity of the musculature was intact and appeared otherwise normal. The mean increase in serum creatinine in the EndoStitch pyeloplasty group was 0.38 mg/dl (range 0.20 - 0.80 mg/dl), in the Lapra-Ty suture clip pyeloplasty group was 0.12 mg/dl (range -0.20 - 0.50 mg/dl) (Figure 2). The difference in serum creatinine for the EndoStitch and Lapra-Ty groups was not statistically significant.

An interesting observation in both study groups was the frequent formation of a diverticulum at the site of pyeloplasty repair. This was observed at the six-week post-pyeloplasty, three-months post-pyeloplasty and the six-months post-pyeloplasty retrograde pyelography imaging. In the EndoStitch group, three animals demonstrated diverticular formation ranging between 7.8 mm and 16 mm in diameter (mean 12.5 mm). In the Lapra-Ty suture clip pyeloplasty group, four of the six animals demonstrated ureteral diverticular formation ranging between 5 mm and 13.8 mm in diameter (mean 10.7 mm). In two of the EndoStitch pyeloplasty animals the diverticulum was noted to persist at six month follow-up evaluation and in four of
the Lapra-Ty suture clip pyeloplasty animals this phenomenon also persisted until the completion of the study (Figure 4).

**DISCUSSION**

The model developed for creating UPJ obstruction was not difficult to perform. However, the technique created too severe a ureteral obstruction, with a resultant significant permanent reduction in the renal function. After six weeks duration the compromise to renal function did not resolve despite creating a patent UPJ region with the pyeloplasty technique. This severe effect on renal function may alter the normal excretion of growth factors from the kidney and ultimately affect the results of the pyeloplasty. We are planning to retest our technique using a larger ureteral catheter for performing the chromic suture tie-down. Again the goal would be the creation of a radiographically visible stricture. As such it was not possible to assess ureteral obstruction by renal scan T 1/2 evaluation due to the compromised function of the kidney. However, retrograde pyelography and calibration of the ureteropelvic junction using graduated catheters from a 4F to an 8F allowed evaluation for UPJ patency at six months following pyeloplasty. The EndoStitch device and Lapra-Ty suture clip were equally efficacious in performing a successful laparoscopic pyeloplasty. The two techniques had a similar surgical time and no particular intraoperative or postoperative complications associated with either.

The operative times for the pyeloplasty were relatively short for both anastomotic techniques. The techniques used with both instruments was a continuous, circumferential suturing of the anastomosis. The suture was initially secured by passing the needle and suture through a preformed loop at the end of the suture and then tightened down, obviating the need for a knot-tying technique at this point. Following completion of the anastomosis, the suture was finally secured with either the Lapra-Ty clip or the knot-tying technique with the Endostitch device. The surgeon performing the pyeloplasty anastomosis had considerable clinical experience with laparoscopic suturing, which may have also contributed to the short operative time for the intracorporeally sutured anastomosis.

Overall, there was no significant change in the percent function by renal scan of the treated kidneys comparing the pyeloplasty scan to the six-month follow-up scan in the EndoStitch, Lapra-Ty suture clip and control group of animals. Similarly, there was no significant change in the serum creatinine in the EndoStitch or Lapra-Ty suture clip groups at six-month follow-up compared to their serum creatinine at the time of pyeloplasty. The control group showed similar changes in the serum creatinine, suggesting that the creatinine probably represented the function of unobstructed kidney and had minimal effect from the study.

The slight increase in creatinine noted in all animals may also be associated with a general increase in their muscle mass over the six-month study period.

The diverticular formation at the site of the pyeloplasty may be a feature unique to this animal model. However, the observation of a diverticulum in a large number of the study animals suggests that it may be a component of the reparative process following the pyeloplasty. The significance of this diverticular formation with respect to clinical pyeloplasty remains undetermined.

There was a trend towards a slightly higher healing score in the Lapra-Ty suture clip group as compared to the EndoStitch suture technique, albeit not statistically significant. Interestingly, the mean healing score in the control group was similar to that in the EndoStitch group. However, there was no statistically significant difference between the healing score in the Lapra-Ty suture clip group compared to the EndoStitch or control group of animals. At the time of harvest there was no evidence of the Lapra-Ty clip, and the fibrosis at the anastomotic site in both the study groups was grossly similar.

The management of adult ureteropelvic junction obstruction encompasses a wide variety of surgical options. Traditionally these patients have been treated with open-pyeloplasty with a 90-95% success rate. The development of fiberoptic instrumentation and associated cutting modalities has resulted in the development of the antegrade and retrograde endopyelotomy. Review of the literature has shown success rates close to that of an open pyeloplasty, particularly with the antegrade endopyelotomy, 85-88% success. The more recent addition to the endourologist's armamentarium, the Acucise cutting balloon catheter, has resulted in satisfactory success rates ranging between 67% and 81% while providing the patient with a minimally invasive technique associated with reduced postoperative discomfort, a short hospital stay, and a quick return to normal activities.

The controversy as to the adverse impact of a crossing vessel on the success rate of endopyelotomy has raised the question as to whether these patients may be more appropriately managed with pyeloplasty. As a result the application of the laparoscopic approach to pyeloplasty repair of the UPJ obstruction has been proposed. The most challenging aspect of this technique is the required intracorporeal suturing and knot tying for completion of the re-anastomosis when dismembered pyeloplasty is performed. Indeed these clinical procedures may require as much as five to seven hours of operative time, with most of it devoted to reconstructing the dismembered UPJ. The recent advances in reconstructive technology, including the Lapra-Ty suture clip and the EndoStitch device, have significantly reduced operative times for laparoscopic procedures. This.
animal study suggests that there is no significant difference in the time to perform the laparoscopic pyeloplasty with the EndoStitch device or Lapra-Ty suture clip technique for a running laparoscopic pyeloplasty. Although this study did not specifically address the option of the combination of the EndoStitch device to complete the anastomosis and the Lapra-Ty suture clip to secure the suture, in our clinical experience the combination of these two instruments further simplifies and reduces the laparoscopic procedural time.

Kavoussi and colleagues have reported on their clinical experience with the laparoscopic pyeloplasty. They have also noted a significant reduction in their operative time with the use of the EndoStitch suturing device, albeit they have less extensive experience with this device. They have reported excellent postoperative success rates with patency by renal scan in 100% of their patients with short term follow-up. Nonetheless, even with this advance in laparoscopic technology, endopyelotomy provides an effective form of minimally invasive management for UPJ obstruction with shorter operative time, less morbidity, minimal hospital stay, reduced postoperative discomfort and a quicker return to normal activities compared to the laparoscopic pyeloplasty. However, in those patients who have failed an endopyelotomy or in whom a ureteropelvic junction crossing vessel is felt to be responsible for the obstructive process, the laparoscopic pyeloplasty may be an appropriate surgical option, providing reduced postoperative morbidity and recovery time compared to the open pyeloplasty technique.

CONCLUSION

The laparoscopic pyeloplasty can be efficiently performed using an intracorporeal suturing technique and the Lapra-Ty suture clip or the EndoStitch device for performing the sutured anastomosis and knotting technique. Both techniques result in good anastomotic patency and minimal fibrosis or inflammatory process at the site of the anastomosis.

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