Robotic pyeloplasty: experience with three robotic platforms

Christopher Nguan, MD, Kevin Kwan, MD, Mohammed Al Omar, MD, Kenneth A. Beasley, MD, Patrick P. W. Luke, MD

Division of Urology, London Health Sciences Centre, Canadian Surgical Technologies and Advanced Robotics, The University of Western Ontario, London, Ontario, Canada

NGUAN C, KWAN K, AL OMAR M, BEASLEY KA, LUKE PPW. Robotic pyeloplasty: experience with three robotic platforms. The Canadian Journal of Urology. 2007;14(3):3571-3576.

Purpose: *Laparoscopic pyeloplasty is a technically challenging procedure. Currently, several robotic surgical systems exist to overcome laparoscopic technical challenges confronted during pyeloplasty. We present a clinical comparison between three robotic surgical systems (Aesop, Zeus and da Vinci) in assisting laparoscopic pyeloplasty procedures.*

Methods: *From January 2002 to August 2005, 32 dismembered laparoscopic pyeloplasties were performed using three robotic surgical systems. The results of the initial six, five and nine laparoscopic robotic pyeloplasty procedures performed using the Aesop, Zeus and da Vinci platforms were compared. Data relating to the subsequent 12 pyeloplasties using the da Vinci system were also analyzed.*

Results: *The da Vinci robot required significantly more time to set up initially than the Aesop platform (12.5 min versus 39 min, $p < 0.05$) but the time was similar to that for the Zeus robot. Despite the longer setup time, laparoscopic robotic pyeloplasties performed using the da Vinci robot required 168 min and 35 min for operating time and anastomotic time, respectively. This was significantly faster than that for Aesop (262 min and 75 min) and Zeus (225 min and 71 min) robots ($p < 0.05$). There were no intra-operative complications. There was only one postoperative complication in the Zeus group involving a delayed urine leak. Narcotic requirements were low and duration of hospital stay was short for all patients.*

Conclusions: *We show that not all advanced robotic platforms are equal. In this study, procedures performed using the da Vinci robotic system resulted in decreased anastomotic and operating times. With emerging surgical technologies, the role of the robot in surgery continues to be defined.*

Key Words: renal, laparoscopic, robotic, pyeloplasty

Introduction

The open pyeloplasty repair provides durable long-term results in the treatment of ureteropelvic junction (UPJ) obstruction. However, it is associated with significant postoperative pain and prolonged convalescence in adult patients. Recently, laparoscopic repair of the UPJ has been shown to reduce the morbidity of the open procedure, while maintaining the durability of the results of the open procedure.[1] However, this procedure is technically challenging and associated with a steep learning curve.

Over the last decade, several systems including Aesop (Intuitive Surgical Inc., Sunnyvale, California), Zeus (Intuitive Surgical Inc., Sunnyvale, California) and da Vinci (Intuitive Surgical Inc., Sunnyvale, California) have been developed to facilitate complex laparoscopic surgical procedures. Some of the robotic systems provide elimination of tremor, increased precision and dexterity and superior three-dimensional vision to the surgeon.

Accepted for publication April 2007

Address correspondence to Dr. Patrick Luke, London Health Sciences Centre - University Campus, 339 Windermere Road, London, Ontario N6A 5A5 Canada

To date, there are only a limited number of studies that have compared the impact of these robotic systems on overall surgical efficiency.

We and others have demonstrated that these robotic platforms can improve surgical performance in the dry lab setting.[2,3] Sung et al showed that pyeloplasties performed using the da Vinci platform were completed faster than those using the Zeus robotic system in the porcine model.[4] To our knowledge, the comparison between different telesurgical platforms in the performance of clinical urologic procedures has yet to be described. In this study, one of the largest series of robot-assisted pyeloplasties to date, we compare the operative outcomes of laparoscopic robotic pyeloplasty using the Aesop, Zeus and da Vinci robotic systems in the treatment of UPJ obstruction.

Patients and methods

Between January 2002 and June 2005, robotic laparoscopic pyeloplasties were performed on 32 patients with primary UPJ obstructions. With data being tracked prospectively, the Zeus and Aesop-assisted procedures were performed during the same era (January 2002 to October 2003). However, the da Vinci procedures were performed between October 2003 and June 2005. A single surgeon (PL) with previous experience in laparoscopic pyeloplasty performed all procedures. The preoperative diagnosis of UPJ obstruction was confirmed using history and physical examination, computerized tomographic (CT) imaging, lasix renography and retrograde pyelography. As well, nuclear renography demonstrated differential renal function of a minimum of 20% on the affected sides of all patients. Data from a minimum follow-up of 6 months was obtained for all patients except one who was lost to follow-up.

Robots and preparation

Aesop

The single-arm Aesop robot holds the laparoscopic camera using a collar with the surgeon controlling the robot through either touch-pad, manual or voice control. The robot is directly mounted to the bedside rail on the operating table, and the position of the arm can be adjusted to avoid contact with the free-standing laparoscopic instruments used to perform the operation. This device is meant to give the operating surgeon precise control of the camera and removes inherent tremor and inadvertent movements that occurs when a surgical assistant is used to drive the laparoscopic camera.

Zeus

The Zeus robot is a surgical platform that utilizes three table-mounted robotic arms and a separate surgeon console station wired to control the arms. The description of this robot as well as its attributes have been previously described by our group.[5]

da Vinci

The da Vinci platform is a single free-standing unit that has four separate arms anchored to a central stalk. The entire unit is rolled towards the operating bed and docked in place prior to use. Like the Zeus robot, a separate surgeon console is wired to the active unit. Unlike the Zeus robot, the surgeon peers into a chamber on the side of the console in order to visualize three-dimensional intra-corporal images provided by two separate lenses from the camera.

Surgical technique

The surgical technique used to perform dismembered pyeloplasty was described in detail in our previous publication.[5] Briefly, patients were stented with a 30 cm 6-French double-J stent under fluoroscopic guidance, and a 3-way Foley catheter inserted. Patients were then placed in direct flank position without bed flexion with the obstructed kidney facing upwards towards the ceiling. Three to four laparoscopic ports were positioned around the intraperitoneal working space as previously described, and the robot arm(s) were then positioned and "locked" into place. The ureter was dissected to the UPJ, and if a crossing vessel was encountered, the UPJ and renal pelvis were dissected free, transected and transposed anterior to the crossing vessel. After a 1 cm-2 cm spatulation of the ureter, the redundant renal pelvis along with the UPJ was sharply excised. Using the Anderson-Hynes approach to repair of the UPJ, a 4.0-5.0 15 cm absorbable suture on an RB-1 needle was used to secure the "heel" of the ureter to the dependent portion of the renal pelvis and a running continuous stitch was sewn along the posterior wall of the repair. Upon completion of the posterior wall, the anterior wall of the anastomosis was closed with a running repair. A 7 mm close-suction drain was placed through the lateral most port. Port sites and skin incisions were closed; and the robot arms were dismounted from the OR table. Clinical follow-up was scheduled at 3-6 weeks for stent removal, 6 weeks for lasix renography/clinical assessment and lasix renography/clinical assessment was performed once again 6 months post-operatively.

Statistical analysis

Comparisons between groups were assessed using 2-way Analysis of Variance (ANOVA) for continuous

variables, and the Fisher Exact test was used for categorical variables. Statistical significance was assumed when the p-value was < 0.05.

Results

Patient characteristics

Comparative patient demographics are provided for the first 5, 6, and 9 patients that underwent Aesop-, Zeus-, and da Vinci-assisted pyeloplasty, respectively, Table 1. The next 12 patients who underwent da Vinci pyeloplasty were not directly compared with the other platforms, since these cases were performed outside of our initial 20 study patients. However, operative data for the 21 da Vinci cases are provided in Figure 1 and in the long-term outcomes section.

Operative parameters

The results of the study are summarized in Table 1. The laparoscopic robotic pyeloplasties were technically successful in all cases without mechanical failure or open conversion. The setup time was defined as the time used to mount and adjust the arms into position to prevent collisions and protect the patient against injury from external robotic arm movements during the surgical procedure. Not surprisingly, the mean times for robotic surgical system setup were significantly shorter for the single-arm Aesop platform versus the da Vinci platform, Table 1. During our early experience with the da Vinci robotic platform, the setup time decreased with time, and we required no longer than 15 minutes in our last 10 cases, Figure 1.

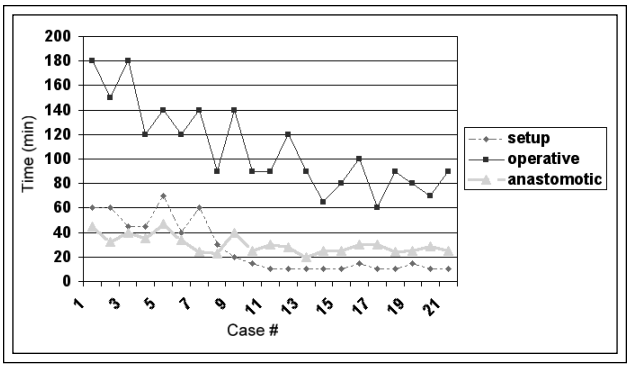

Figure 1. Sequential operative times: da Vinci.

The operating time was calculated from the time of initial port insertion to the time of last port closure. The mean operating times were similar between the cases using Aesop and Zeus platforms and are consistent with other laparoscopic pyeloplasty series.[6,7] Operating times were significantly shorter ($p < 0.05$) using the da Vinci platform compared with the other robotic surgical systems. Furthermore, the anastomotic times were significantly shorter using the da Vinci platform ($p < 0.05$) compared with either the Aesop or Zeus platforms, Table 1. In fact, it took half the time to complete the anastomoses in the da Vinci group compared with either of the other two platforms. The times fell dramatically through all portions of the da Vinci experience, Figure 1, but were stable throughout the Zeus and Aesop experiences, Figures 2 and 3. By the last 12 cases in the da Vinci

TABLE 1. **Demographics and surgical results**

Platform	**a. Aesop n = 6**	**b. Zeus n = 5**	**c. da Vinci n = 9**	**p-value**
Mean age, years	29	38	48	NS
Gender	4M, 2F	3M, 2F	3M, 6F	NS
Body mass index	27	27	30	NS
Side	3R:3L	3R:2L	5R:4L	NS
Crossing vessel: intrinsic	2:4	2:3	7:2	NS
Setup time, min	12.5±6	30±17	39±13	< 0.05 a versus c
Operating time, min	262±41	225±48	168 ±46	< 0.05 c versus a and b
Anastomotic time, min	75±8	71±16	35±7	< 0.05 c versus a and b
Excessive blood loss, ml	110	68	63	NS
Complications	Nil	1 delayed leak	Nil	NS
MSO_4, mg	96±74	22±10	45±36	NS
Hospital stay, hours	77±11	58±10	48±11	< 0.05 a versus c

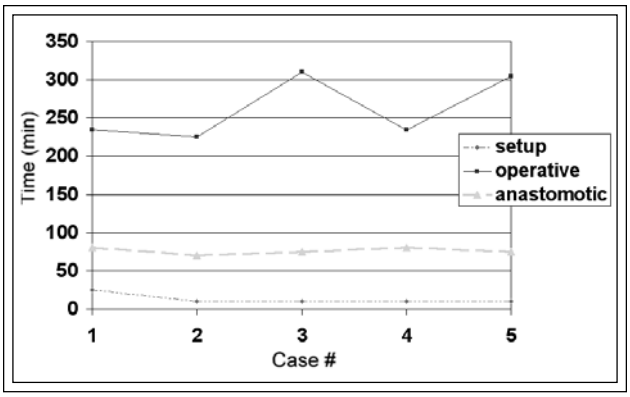

Figure 2. Sequential operative times: Aesop.

experience, operating times were consistently between 60 and 100 minutes, and anastomotic times were consistently less than half an hour, Figure 1.

Consistent with other laparoscopic series, the mean estimated blood loss was low and not significantly different between the three groups, Table 1. Furthermore, no blood transfusions were performed. No intraoperative complications or robotic failures were noted in this series.

Postoperative parameters

Requirements for postoperative narcotics were minimal and not significantly different between for all three groups, Table 1. As with previous laparoscopic pyeloplasty series, the mean postoperative hospital stay was short in all three groups, although slightly shorter for patients who underwent da Vinci robot pyeloplasty compared with patients who underwent Aesop pyeloplasty ($p < 0.05$).

Complications

Despite the absence of operative technical difficulties and minimal postoperative drain output, one patient from the Zeus group developed a delayed urinary leak 2 weeks postoperatively and was treated conservatively with a percutaneous drain. The urinoma resolved within 2 weeks. There were no technical failures or postoperative complications in the Aesop and da Vinci groups.

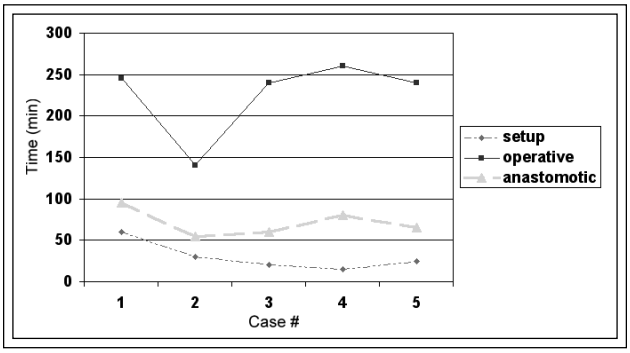

Figure 3. Sequential operative times: Zeus.

Extended follow-up

At the 12-week follow-up, 31 of 32 patients (97%) were pain-free and 28 of 32 patients (87%) had no obstruction or improved dynamics according to lasix renogram. At the 6-month follow-up, 30 of 31 patients (97%) patients were pain free and all 31 patients did not have definite evidence of obstruction on lasix renography. One patient in the Zeus group was lost to follow-up at the 6-months time-point. Another patient in the da Vinci group developed recurrent pain beyond the 1-year postoperative time-point with an equivocal lasix renogram. Although a retrograde pyelogram revealed a wide-open anastomosis, balloon dilatation of the UPJ was still performed with planned clinical reevaluation in the near future.

Discussion

Like the laparoscopic radical prostatectomy procedure, the laparoscopic pyeloplasty is an operation that requires a significant amount of laparoscopic experience in order to obtain excellent operative results within a reasonable amount of operating time. With various features that potentially improve surgical ergonomics and efficiency, each robotic platform has the capability to help the surgeon master laparoscopic suturing and knot-tying. The single-arm Aesop robot replaces the surgical assistant as the cameraman. It allows the surgeon to have complete control over camera position and eliminates inadvertent camera motion during critical stages of the operation (needle loading, suturing and knot-tying). Although the Aesop arm may eliminate camera movement and may minimally improve surgical ergonomics, we do not believe that this platform has great advantages over standard laparoscopic pyeloplasty without robotic assistance.

Despite increased dexterity with an extra degree of freedom (instrument wrist flexion), motion filters, and three-dimensional vision, the operative times of the three-arm Zeus group were no better than that of the Aesop group. These results are consistent with our previous findings that surgeons/trainees made considerably more errors and required more time to complete suturing and knot-tying tasks in the dry lab activities with Zeus-assistance compared with Aesop.[2] Despite spending more than 100 hours in the lab with

Computer Motion Inc. specialists to prepare for clinical cases, the surgeon (PL) was unable to improve upon the results obtained with free-hand laparoscopic suturing. Furthermore, operating times were not falling on a case-to-case basis. Our group's original intent was to compare the performance of Aesop-assisted versus Zeus-assisted pyeloplasty in 20 patients, and after 11 procedures it was clear that the Zeus platform was not improving surgical performance. Midway through our study, Computer Motion Inc. was acquired by Intuitive Surgical Inc., and the Zeus system was no longer well-supported by the parent company. At that time, we acquired the da Vinci platform.

Of the three systems, the pyeloplasty procedures with the da Vinci robot were clearly faster, and subjectively, it required very little effort to complete the cases. It is not clear whether the surgical advantage was associated with improved surgical ergonomics, the extra sixth-degree-of-freedom in instrument wrist flexion, or superior optics. A nonvalidated subjective Likert-score from our previous study indicated that 12 surgeons and trainees found that the da Vinci platform was superior to both the Zeus and Aesop platforms with respect to visualization, fluidity, precision, dexterity, coordination, and tremor.[2] As well, knot-tying and suturing exercises were performed faster and with fewer errors using da Vinci compared with Zeus or Aesop.[2] Therefore, our clinical results support our dry-lab assessment of the different platforms.

It is possible that our results may have been biased by the fact that the da Vinci cases were performed after the Zeus and Aesop cases had been completed and that the surgeon was on a later stage of his laparoscopic learning curve. However, the surgeon had established experience with the laparoscopic pyeloplasty procedure and operative times were not falling during the Zeus and Aesop experiences, Figures 2 and 3. The shorter suturing and knot-tying times with the da Vinci robot recorded in the dry lab also support the contention that the da Vinci robot can augment surgical efficiency.

Consistent with our findings, Gettman also found that da Vinci-assisted pyeloplasty decreased operative time compared with standard laparoscopic pyeloplasty.[8] However, with a clinical experience of more than 100 laparoscopic pyeloplasty procedures, Kavoussi stated that the da Vinci robot did not improve his surgical results or significantly reduce laparoscopic operative time.[9] Furthermore, another group with sizable experiences with laparoscopic prostatectomy found that the surgical robot did not improve their surgical efficiency compared with standard laparoscopic techniques.[10] In our dry-lab study, we showed that the da Vinci robot greatly improved the skills of medical students to a greater extent than that seen with staff surgeons.[2] In a similar fashion, it is possible that the surgical robot may not improve the skills of highly experienced laparoscopic surgeons, but it may aid the performance of the surgeon with less extensive laparoscopic experience.[11,12]

Patients undergoing da Vinci pyeloplasty also had reduced hospitalization times. As these cases were performed after the initial Zeus and Aesop cases had been performed, the minimal but statistically significant reduction in hospitalization is likely due to concurrent institution of clinical pathways used to prepare patients for discharge after undergoing laparoscopic procedures at our institution. In fact, other than reduced operative time and hospital stay, patients undergoing da Vinci pyeloplasty did not have improved outcomes compared with the other groups. At the current state of the art, it is unclear whether we can anticipate other tangible benefits from robotic-assisted pyeloplasty to offset the significant cost of the procedure.[13] However, these machines are early-generation robots with excessive bulk and expense. With eventual improvements in surgical ergonomics to reduce surgical stress, the capacity to enhance vision using adjunctive imaging sources, the introduction of haptics to surgical platforms, and the capacity to perform telementoring/surgery,[14] the authors believe that a new era in surgery will emerge.

Conclusion

Although modern technology has led to the development of sophisticated robotic surgical tools, not all advanced robotic platforms are created equal. In this study, procedures performed with the da Vinci robotic system resulted in decreased anastomotic and operating times. With further evolution of surgical technology, the role of the robot will continue to be redefined. □

References

1. Baldwin DD, Dunbar JA, Wells N, McDougall EM. Single-center comparison of laparoscopic pyeloplasty, acucise endopyelotomy, and open pyeloplasty. *J Endourol* 2003;17:155-160.
2. Girvan A, Nguan C, Kwan K, Luke P. Robotic Surgery vs. laparoscopy: a comparison between 1st and 2nd generation systems versus conventional laparoscopy. *Can J Urol* 2005;12:2642.

3. Dakin GF, Gagner M. Comparison of laparoscopic skills performance between standard instruments and two surgical robotic systems. *Surg Endosc* 2003;17:574-579.
4. Sung GT, Gill IS. Robotic laparoscopic surgery: a comparison of the DA Vinci and Zeus systems. *Urology* 2001;58:893-898.
5. Luke PP, Girvan AR, Al Omar M, Beasley KA, Carson M. Laparoscopic robotic pyeloplasty using the Zeus Telesurgical System. *Can J Urol* 2004;11:2396-2400.
6. Jarrett TW, Chan DY, Charambura TC et al. Laparoscopic pyeloplasty: the first 100 cases. *J Urol* 2002;167:1253-1256.
7. Rubinstein M, Finelli A, Moinzadeh A et al. Outpatient laparoscopic pyeloplasty. *Urology* 2005;66:41-43.
8. Gettman MT, Peschel R, Neururer R, Bartsch G. A comparison of laparoscopic pyeloplasty performed with the daVinci robotic system versus standard laparoscopic techniques: initial clinical results. *Eur Urol* 2002;42:453-457.
9. Bhayani SB, Link RE, Kavoussi LR. Man vs. machine: pure laparoscopic pyeloplasty vs. Da Vinci Pyeloplasty. *J Urol* 2005;173(4s):228.
10. Joseph JV, Vicente I, Madeb R et al. Robot-assisted vs pure laparoscopic radical prostatectomy: are there any differences? *BJU Int* 2005;96:39-42.
11. Menon M, Shrivastava A, Tewari A et al. Laparoscopic and robot assisted radical prostatectomy: establishment of a structured program and preliminary analysis of outcomes. *J Urol* 2002;168:945-949.
12. Ahlering TE, Skarecky D, Lee D, Clayman RV. Successful transfer of open surgical skills to a laparoscopic environment using a robotic interface: initial experience with laparoscopic radical prostatectomy. *J Urol* 2003;170:1738-1741.
13. Bhayani SB, Link RE, Varkarakis JM, Kavoussi LR: Complete daVinci versus laparoscopic pyeloplasty: cost analysis. *J Endourol* 2005;19:327-332.
14. Luke PPW, Rayman R, Carson M et al. Assessment of long distance telerobotics using a unique surgical model based on the Zeus platform. *J Urol* 2004;171(4s):336.