Symposium

Robotic single port surgery: Current status and future considerations

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ABSTRACT

Introduction and Objectives: It has been established that robotic-assisted laparoscopic surgery has several advantages when compared with standard laparoscopic surgery. Optics, ergonomics, dexterity and precision are all enhanced with the use of a robotic platform. For these reasons, it was postulated that the application of robotics to laparoendoscopic single-site surgery (LESS) could overcome some of the constraints seen with the conventional laparoscopic approach. Issues such as instrument clashing, inability to achieve effective triangulation for dissection and difficulties with intracorporeal suturing have limited the widespread adoption of conventional LESS. The application of robotics has eliminated many of the constraints experienced with conventional LESS; however, challenges still remain.
Materials and Methods: A systematic literature review was performed using PubMed to identify relevant studies. There were no time restrictions applied to the search, but only studies in English were included. We used the following search terms: Robotic single site surgery, robotic single port surgery, robotic single incision surgery and robotic laparoendoscopic single site surgery.
Results: A number of centers have published their experience with robotic-laparoendoscopic single-site surgery (R-LESS); however, no prospective studies exist. What is clear is that R-LESS minimizes several of the difficulties experienced with conventional LESS, including intracorporeal suturing and triangulation during dissection. Outcomes are comparable to standard robotic surgery, with a trend toward improved cosmesis and reduced pain. However, a significant advantage with regard to these two factors has yet to be demonstrated.
Conclusions: R-LESS is technically feasible and the benefits of robotic surgery eliminate many of the challenges seen with conventional LESS. However, despite the advantages of the robotic platform, R-LESS is not free of challenges. Instrument clashing remains an issue due to the bulky profile of the current robotic system. Other issues include lack of space for the assistant at the bedside, inability to incorporate the 4th robotic arm for retraction and difficulties with triangulation. Although solutions for some of these issues are currently under development, R-LESS is still very much in its infancy.

Key words: Laparoendoscopic single-site surgery, robotics, single port surgery

INTRODUCTION

Laparoendoscopic single-site surgery (LESS) has been developed to further minimize the morbidity associated with laparoscopic surgery. By reducing the number and length of skin incisions, it was hypothesized that this would lead to less pain, faster convalescence and improved cosmesis following minimally invasive surgery. The first LESS procedure was reported by Hirano *et al.*[1] in 2005. They performed a retroperitoneoscopic adrenalectomy through a single incision with standard laparoscopic instruments. Subsequently, the LESS approach was applied to a range of urologic procedures, including radical nephrectomy and prostatectomy.[2-4] There have since been a number of comparative analyses comparing standard laparoscopic urologic procedures to their LESS counterparts.[5-9] Overall, these studies suggest that LESS is not inferior to conventional laparoscopic surgery with regard to perioperative outcomes, with a trend toward improved cosmesis and less post-operative pain. However, it has been found that LESS is significantly more challenging,

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especially when complex reconstruction or intracorporeal suturing is required. The need to cross instruments at the abdominal wall to facilitate dissection results in a significant mental challenge due to the resulting reverse handedness. Other challenges include instrument collision, lack of triangulation and in-line vision. Using Guilloneau *et al.*'s scoring system for laparoscopic operations in urology,[10] Autorino *et al.*[11] determined a degree of difficulty for a number of LESS urologic procedures. Both radical prostatectomy and cystectomy were classified as "Extremely Difficult." A number of strategies were developed to combat these difficulties, including curved and articulating instruments, flexible endoscopes and needlescopic accessory ports/instruments to allow triangulation.[12] Despite these advances, conventional LESS remains challenging and requires extensive surgeon experience in laparoscopy and stringent patient selection to achieve successful outcomes.[13]

It has been established that robotic-assisted laparoscopic surgery has several advantages when compared with standard laparoscopic surgery. Optics, ergonomics, dexterity and precision are all enhanced with the use of a robotic platform for a number of urologic procedures. For these reasons, it was postulated that the application of robotics to LESS (R-LESS) could overcome some of the aforementioned constraints. We reported the first experience with R-LESS in 2008[14] (radical prostatectomy and nephrectomy, pyeloplasty), and found that intracorporeal suturing and dissection were easier as compared with standard LESS. Since then, there have been numerous reports and refinements in technique from our center for a number of different urologic procedures.[15-17]. Typically standard robotic instruments and ports have been used [Table 1]. However, despite the advantages of the robotic platform, R-LESS is not free of challenges, which is similar to conventional LESS. Instrument clashing remains an issue due to the bulky profile of the current robotic system. Other issues include lack of space for the assistant at the bedside, inability to incorporate the 4th robotic arm for retraction and difficulties with triangulation. Although solutions for some of these issues are currently under development,[18,19] R-LESS is still very much in its infancy. The aim of this paper is to review the current status of R-LESS and explore future directions.

MATERIALS AND METHODS

We performed a literature review on PubMed using the following search terms in free-text protocol: Robotic single site surgery, robotic single port surgery, robotic single incision surgery and robotic laparoendoscopic single site surgery. We only included English publications. Review articles, editorials, commentaries and letters to the editor were included only if deemed to contain relevant information.

Table 1: Commonly used instrumentation for R-LESS

Instrument	Features	Benefits	Drawbacks
8-mm EndoWristmonopolar shears (Intuitive Surgical)	7 degrees of freedom 90 degrees of articulation tremor reduction and motion scaling	EndoWrist technology allows for effective dissection	Bulky external profile leads to instrument clashing
8-mm EndoWrist hook cautery	7 degrees of freedom 90 degrees of articulation tremor reduction and motion scaling	EndoWrist technology allows for effective dissection	Bulky external profile leads to instrument clashing
8-mm EndoWristPrograsp grasper	7 degrees of freedom 90 degrees of articulation tremor reduction and motion scaling	EndoWrist technology allows for effective dissection and retraction	Bulky external profile leads to instrument clashing
8-mm EndoWrist Hem-o-lok applier	Gives operating surgeon control of clip placement	Access to difficult angles for clip placement	Bulky external profile leads to instrument clashing
5-mm EndoWristSchertel grasper	Motion scaling and tremor reduction	Lower profile Increased triangulation d/t instrument deflection	No instrument articulation
SILS port (Covidien)	Flexible Three-port design	Easy to insert Utilization of different-sized ports	Difficult to use with large abdominal walls Robotic trocars must be tunneled
GelPoint port (Applied Medical)	GelSeal cap and Alexis wound retractor with self-retaining trocars	PseudoAbdomen platform allows for increased instrument spacing and restored triangulation	Gas leakage during longer procedures
Robotic Harmonic Scalpel (Ethicon Endosurgery)	Non-wristed instrument Cuts and coagulates simultaneously	Applied by the operating surgeon	Lack of articulation Bulky external profile

Table 1 adapted from White MA, Autorino R, Spana G, *et al.* Robotic laparoendoscopic single-site radical nephrectomy: Surgical technique and comparative outcomes. Eur Urol 2011;59:815-22. SILS: Single Incision Laparoscopic Surgery

RESULTS

Access devices and port placement

An important distinction must be made with regard to access in LESS, and that is single port versus single site. Single port access utilizes a single skin and fascial incision through which a multi-channel access platform is placed [Figure 1]. The endoscope and instruments are all placed through the access platform. Single site access also utilizes a single skin incision; however, multiple fascial incisions are made through which the access platform and low profile ports are placed [Figure 2]. The point of access can be umbilical or extra-umbilical. The umbilical access point has been most commonly utilized[13] as the scar can more easily be hidden and cosmesis maximized. Pneumoperitoneum can be achieved by either a standard or a modified veress needle technique or by the open Hassan technique.

The SILS port (Covidien, Mansfield, MA, USA) is made of foam and expands after insertion to prevent air leakage. It is placed through a 2-cm incision and can accommodate three 5-mm ports or two 5-mm ports and a 10-12 mm port. The SILS port was used by White *et al.*[17] in one of the larger R-LESS radical prostatectomy series. The GelPort (Applied Medical, Rancho Santa Margarita, CA, USA) was used by Stein *et al.*,[15] to perform a number of upper tract R-LESS procedures. The GelPoint is smaller than the GelPort and has an insufflation port on the side. It also lacks perforations in the gel cap and attaches to the wound protection device with a suture to facilitate removal. Experience with a home-made device was also reported,[20] A standard surgical glove was stretched over an Alexis wound retractor (Applied Medical) after it had been placed in the peritoneal cavity. Trocars were then inserted through the fingers of the glove and fixed in place. All of the procedures performed in these series were on the upper urinary tract [i.e., partial nephrectomy (PN), nephroureterectomy, etc.].

One of the biggest issues with R-LESS is instrument clashing due to the coaxial arrangement of instruments and the bulky external profile of the current generation robot. This problem was also encountered with standard LESS, and one solution that was proposed was to cross the instruments at the abdominal wall. As a result of this, the external handles of the instruments were separated in space extracorporeally thus reducing "sword fighting." However, as a result, the instruments were crossed intracorporeally and the left instrument on the video screen was actually controlled by the surgeon's right hand and vice versa. This created a mental challenge for the operating surgeon and added another level of complexity to the case. Joseph *et al.*[18,21] applied this concept to R-LESS in the laboratory setting and in a porcine model. The robotic instruments were crossed at the abdominal wall to minimize collision. However, the controls at the console were switched such that the left actuator was driving the right arm, and vice versa. This eliminated the confusion that was experienced with crossed instruments and standard LESS.

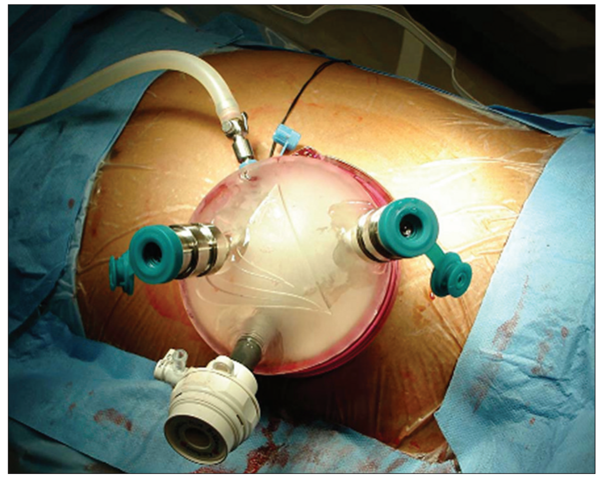

Figure 1: Single-port access and GelPoint

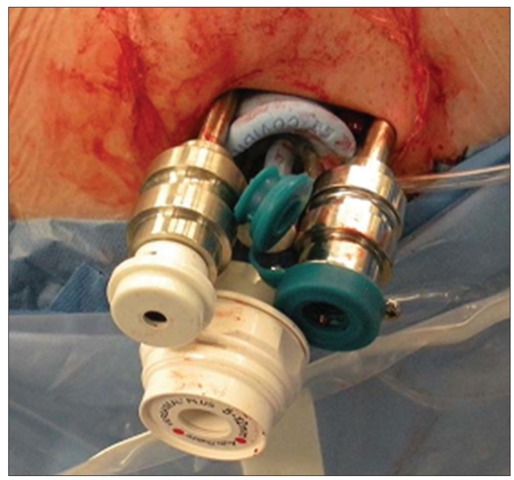

Figure 2: Single-site access and SILS port

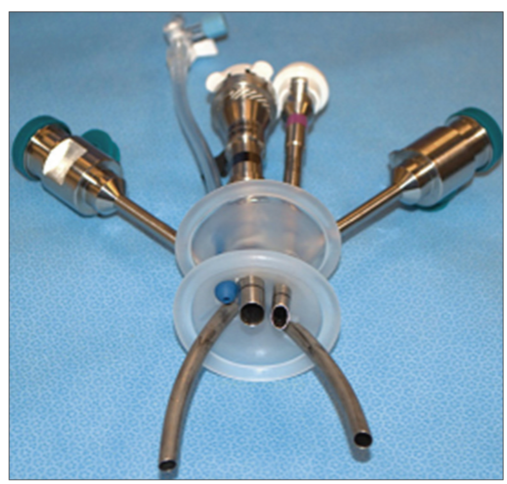

Figure 3: daVinci single-site instrumentation

Intuitive Surgical Inc. has also addressed the problem of instrument collision and developed a set of R-LESS-specific instruments. The set consists of a multi-channel access platform with channels for four ports and an insufflation valve [Figure 3]. The ports themselves consist of two ports with curved cannulas for the robotic instruments, and two ports with straight cannulas for the endoscope and assistant instruments. The robotic instruments are also curved and are designed to cross at the abdominal wall, effectively separating the arms in space extracorporeally. Furthermore, the design of the system also minimizes internal instrument collision with the camera as they are not arranged in parallel. We described the first urologic applications in the laboratory at our center,[19,22] Both the porcine model and the human cadavers were used to perform a number of upper tract procedures (i.e., pyeloplasty, PN, etc.). Set up and docking times were comparable with the standard robotic system and there were no significant complications. All procedures were completed successfully without the need for completion. Major limitations included collision with the assistant instruments, which at times limited suction and retraction, and the lack of articulation of the robotic instruments, which made suturing difficult when required. The majority of clinical experience with the single-site instruments has been with cholecystectomy[23,24]; however, Cestari *et al.*[25] reported their experience in a highly selected group of nine patients with a ureteropelvic junction obstruction UPJO. Exclusion criteria included body mass index (BMI) > 30 kg/m^2, a large renal pelvis, previous abdominal/renal surgery and concomitant stone disease. All procedures were performed successfully without the need for conversion or additional ports. The mean operating room (OR) time was 166 min.

Upper tract urologic surgery

There has been considerable experience with upper tract urologic surgical procedures, including radical nephrectomy, PN, donor nephrectomy and dismembered pyeloplasty. We reported the first experience with robotic single-port upper tract surgery at our center in 2008[14] using the DaVinci S robot. A radical nephrectomy and pyeloplasty were performed without complication and minimal clashing of the robotic arms. Pediatric instruments and a 30 upward-directed lens were used. For the nephrectomy, the specimen was extracted through the umbilical incision. White *et al.*[16] performed a retrospective, comparative analysis of 10 patients who underwent R-LESS radical nephrectomy. They were matched to a similar cohort of 10 patients who underwent conventional laparoscopic radical nephrectomy. Patients were similar at baseline, with no significant difference in ASA score, BMI or tumor size. The SILS port and the GelPort were both used and the robot was docked in a three-arm approach. There was no difference between R-LESS and conventional laparoscopy nephrectomy with regard to median operative time, estimated blood loss, visual analogue scale or complication rate. The R-LESS group had a lower median narcotic requirement during hospital admission (25.3 morphine equivalents vs. 37.5 morphine equivalents; $P = 0.049$) and a shorter length of stay (2.5 days vs. 3.0 days; $P = 0.03$). Stein *et al.*[15] described using the GelPort device for R-LESS radical nephrectomy, which they found was beneficial for specimen extraction.

PN has become the gold standard for the treatment of small renal mass and, as a result of this, there has been more published series with R-LESS PN. Lee *et al.*[20] described 68 consecutive R-LESS procedures using a home-made port, 51 of which were R-LESS PN. The mean tumor size was 3.0 cm and the mean estimated blood loss EBL was 322 mL. The authors noted that the transfusion rate was 14%, largely due to bleeding during tumor resection, and a single renal vein injury. Also, two patients required conversion to a mini-incisional open procedure, one due to persistent hilar bleeding post resection and the other for inability to access the tumor. Arkoncel *et al.*[26] compared a “hybrid” R-LESS PN technique in 35 patients with 35 patients who underwent standard robotic PN. The “hybrid” technique consisted of a home-made port (surgical glove stretched over a wound retractor) at the umbilicus, which housed the two 8-mm robotic ports and a 12-mm camera port, and a separate 12-mm assistant port. Patients were similar at baseline, with equivalent tumor complexity. The OR time (187.5 min vs. 171.7 min, $P = 0.110$), warm ischemia time (29.5 min vs. 28.8 min, $P = 0.209$), blood loss (257 mL vs. 242.5 mL, $P = 0.967$), complication rate (17.1% vs. 11.4%, $P = 0.495$) and transfusion rate (8.6% vs. 2.9%, $P = 0.303$) were comparable in both groups. Furthermore, pain scores, length of hospitalization and morphine equivalents used were also comparable. There was no significant difference in complication rates or need for conversion. Of note, the authors found that there was noticeable restriction of the robotic arms with the R-LESS approach, which required timely adjustment and angulation by the bedside assistant for successful completion of the case.

R-LESS nephroureterectomy has also been described, although in smaller numbers. Lee *et al.*[20] included 12 patients in their aforementioned R-LESS series of 68 patients. The mean OR time was 227 min and EBL was 248 mL. There were no complications or conversions to standard robotics, laparoscopy or open surgery. The ureter was dissected down to the bladder, clipped and divided and then a cuff of bladder was resected. The bladder was then closed in two layers with absorbable suture. No repositioning/re-docking of the robot was required for the pelvic portion according to the authors. R-LESS adrenalectomy has also been reported by Park *et al.*[27] They performed a retroperitoneoscopic R-LESS adrenalectomy for benign adrenal adenoma. The access port was a surgical glove, and was placed below the 12th rib, after the retroperitoneal space had been developed.

It has been postulated that patients undergoing minimally invasive pyeloplasty might be ideal candidates for LESS as they are usually young with benign pathology and the procedure is non-extirpative, thereby not requiring a larger incision for specimen extraction. To overcome the challenges associated with standard LESS, the robotic platform has been applied (R-LESS). Despite the fact that the current generation robotic system was not designed for single-site surgery, surgeons noticed that dissection and suturing were easier.[14] We described our early experience with R-LESS pyeloplasty[14] and since then there have been a number of other series using various access ports.[15,25,28] The unifying conclusion from all authors is that use of the robotic system helps to reduce the technical difficulty of LESS pyeloplasty and shortens the learning curve associated with the procedure. Olweny *et al.*[29] compared 10 patients who underwent conventional LESS (C-LESS) pyeloplasty with 10 patients who underwent R-LESS. Perioperative outcomes were analyzed, including OR time, EBL, complications, Morphine usage and length of stay in hospital (LOS). Cosmetic and long-term functional outcomes were not included in the analysis. There was no significant difference between R-LESS and C-LESS except for OR time, which was significantly longer for R-LESS (226 min vs. 188 min, $P = 0.007$). Additionally, there were two conversions to standard laparoscopy in the C-LESS group as compared with none in the R-LESS group. Despite there being no clear advantage for R-LESS with regard to outcomes, the authors found the superior optics and endo-wrist technology of the robotic system beneficial. Cestari *et al.*[25] tested the feasibility and short-term perioperative outcomes of the DaVinci single site surgery platform in nine patients with a UPJO. The system uses a novel single port access device with curved cannulas and robotic instruments. Additionally, the instruments are crossed at the abdominal wall to minimize clashing and improv triangulation. All cases were completed successfully, without any complication or conversion. However, the authors noted that the main limitation of the system was the lack of articulation of the instruments, which is the principal advantage gained with the application of the robotic system to LESS.

Pelvic urologic surgery

A number of groups have reported their experience with R-LESS radical prostatectomy,[30,31] the largest including 20 patients by White *et al.*[17] They used a single-site approach, with a SILS port and two 8 mm standard robotic trocars (or one 8 mm and one 5 mm trocar) placed through separate fascial incisions. Standard 8 mm EndoWrist (Intuitive Surgical) monopolar shears and a 5 mm EndoWristSchertel grasper were used during dissection. The majority of patients were D'Amico low risk (45%). The mean age of the patients was 60.4 years and the mean BMI was 25.4 kg/m^2. Because the fourth arm was not used, retraction was accomplished by assistant suction or marionette sutures. The mean OR time was 187.6 min and EBL was 128.8 mL. There was one conversion to standard robotic prostatectomy because of a large median lobe and need for more effective retraction. Also, two cases required an additional 8 mm port placed outside of the umbilical incision due to issues with triangulation and leakage of gas from the SILS port. There were four positive margins, but no patients experienced biochemical recurrence at 1-year follow-up. The authors also reported a trend toward improved urinary continence, with five patients completely pad free over the follow-up period. Three patients underwent an interfascial nerve sparing technique and one had Sexual Health Inventory for Men SHIM score of >21 at 3 months post-operatively. Five patients had a leak at the urethrovesical anastomosis on cystogram performed 1 week post-surgery and required an additional week of catheterization. One patient experienced urosepsis and was admitted to the Intensive Care Unit (ICU) 45 days post-operatively, but recovered with intravenous antibiotics. The authors concluded that R-LESS is feasible and less challenging than conventional LESS. Instrument clashing was virtually eliminated by staggering the robotic trocars, and marionette sutures allowed for effective retraction despite inability to use the 4th arm. Assistant-driven retraction with the suction was also important and was facilitated by placing a 15-30 downward bend in the distal 1/3rd of the instrument.

The open simple prostatectomy remains the gold standard in surgical therapy for prostates larger than 80 g. However, there is still the potential for significant morbidity associated with this procedure, including significant hemorrhage. A number of centers have recently reported their experience with single-port transvesicalenucleation of the prostate (STEP) as a minimally invasive alternative. For this procedure, ports are placed through the bladder and the prostate adenoma is enucleated. Fareed *et al.*[32] reported their experience with STEP using the DaVinci surgical robot. Nine patients underwent R-STEP with a GelPort (Applied Medical) as the access platform. Robotic instruments consisted of a 5-mm Schertel grasper and a harmonic scalpel. The mean gland size was 146.4 mL (83-304 mL) based on trans-rectal ultrasound. The mean OR time was 3.8 h (2.75-4.75 h) and EBL was 584.4 mL (150-1200 mL). One patient required conversion to an open prostatectomy and was excluded from the analysis. Two patients required cystoscopy, fulguration and clot evacuation post-operatively for clot retention. Additionally, one patient developed a deep vein thrombosis DVT that required anti-coagulation and one patient suffered a peri-operative myocardial infarction, requiring admission to the ICU. At 1-month follow-up, the mean International Prostate Symptom Score IPSS was 4.83 (2-15), Q_{max} was 20.1 mL/s (6-36) and post void residual PVR was 75.75 m (0-360). The authors concluded that although R-LESS is technically feasible and effective in treating bladder outlet obstruction, they found a high rate of complications in their study.

Future directions

While the application of robotics to LESS has been beneficial, there are still several drawbacks, such as instrument clashing and reduced space for the bedside assistant. This is largely due to the fact that the current DaVinci system has not been specifically designed for the single site application. Additionally, the R-LESS-specific robotic platform lacks the endo-wrist technology, which has obvious limitations. It is clear that an R-LESS-specific design would incorporate a low external profile and articulating instruments and allow sufficient space for the bedside assistant. There are currently a number of LESS-specific robotic prototypes under development, including one that is completely deployed into the peritoneal cavity.[33-35] However, R-LESS remains in its infancy and much development is needed for a flawless, task-specific system that effectively mimics standard robotic surgery.

CONCLUSION

The application of robotics to LESS (R-LESS) has addressed many of the limitations seen with the conventional technique. The endowrist technology allows for superior dissection, triangulation and intra-corporeal suturing. However, R-LESS is still in its infancy as the current iteration of the DaVinci robotic platform has not been designed for LESS. As a result of the bulky extracorporeal profile, instrument clashing and limited space at the bedside remain important issues. Solutions such as the DaVinci Single-site™ platform have been designed to address these challenges; however, their full clinical potential has not yet been reached as further testing is required. The ideal robotic platform for R-LESS would be low profile and task specific and would allow for deployment through a single incision. Additionally, the instruments would be articulating and there would be effective triangulation and retraction. Further advancements in the field of robotic surgery are necessary before truly scarless LESS becomes widely adapted.

REFERENCES

1. Hirano D, Minei S, Yamaguchi K, Yoshikawa T, Hachiya T, Yoshida T, *et al*. Retroperitoneoscopic adrenalectomy for adrenal tumors via a single large port. J Endourol 2005;19:788-92.
2. Raman JD, Bensalah K, Bagrodia A, Stern JM, Cadeddu JA. Laboratory and clinical development of single keyhole umbilical nephrectomy. Urology 2007;70:1039-42.
3. Autorino R, Stein RJ, Lima E, Damiano R, Khanna R, Haber GP. *et al*. Current status and future perspectives in laparoendoscopic single-site and natural orifice transluminal endoscopic urological surgery. Int J Urol 2010;17:410-31.
4. Kaouk JH, Goel RK, Haber GP, Crouzet S, Desai MM, Gill IS. Single port laparoscopic radical prostatectomy. Urology 2008;72:1190-3.
5. Raman JD, Bagrodia A, Cadeddu JA. Single-incision, umbilical laparoscopic versus conventional laparoscopic nephrectomy: A comparison of perioperative outcomes and short-term measures of convalescence. Eur Urol 2009;55:1198-206.
6. Tracy CR, Raman JD, Bagrodia A, Cadeddu JA. Perioperative outcomes in patients undergoing conventional laparoscopic versus laparoendoscopic single-site pyeloplasty. Urology 2009;74:1029-34.
7. Raybourn JH 3rd, Rane A, Sundaram CP. Laparoendoscopicsinglesite surgery for nephrectomy as a feasible alternative to traditional laparoscopy. Urology 2010;75:100-3.
8. Jeong BC, Park YH, Han DH, Kim HH. Laparoendoscopic single-site and conventional laparoscopic adrenalectomy: A matched casecontrol study. J Endourol 2009;23:1957-60.
9. Canes D, Berger A, Aron M, Brandina R, Goldfarb DA, Shoskes D, *et al*. Laparo-endoscopic single site versus standard laparoscopic left donor nephrectomy: Matched-pair comparison. Eur Urol 2010;57:95-101.
10. Guilloneau B, Abbou CC, Doublet JD, Gaston R, Janetschek G, Mandressi A, *et al*. Proposal for a European scoring system for laparoscopic operations in urology. Eur Urol 2001;40:2-7.
11. Autorino R, Cadeddu JA, Desai MM, Gettman M, Gill IS, Kavoussi LR, *et al*. Laparoendoscopic single site and natural orifice transluminal endoscopic surgery in urology: A critical analysis of the literature. Eur Urol 2011;59:26-45.
12. Haber GP, Autorino R, Laydner H, Yang B, White MA, Hillyer S, *et al*. SPIDER surgical system for urologic procedures with laparoendoscopic single-site surgery: From initial laboratory experience to first clinical application. Eur Urol 2012;61:415-22.
13. Kaouk JH, Autorino R, Kim FJ, Han DH, Lee SW, Yinghao S, *et al*. Laparoendoscopic single-site surgery in urology: Worldwide multi-institutional analysis of 1076 cases. Eur Urol 2011;60:998-1005.
14. Kaouk JH, Goel RK, Haber GP, Crouzet S, Stein RJ. Robotic single-port transumbilical surgery in humans: Initial report. BJU Int 2008;103:366-9.
15. Stein RJ, White WM, Goel RK, Irwin BH, Haber GP, Kaouk JH. Robotic laparoendoscopic single-site surgery using GelPort as the access platform. Eur Urol 2010;57:132-6.
16. White MA, Autorino R, Spana G, Laydner H, Hillyer SP, Khanna R, *et al*. Robotic laparoendoscopic single-site radical nephrectomy: Surgical technique and comparative outcomes. Eur Urol 2011;59:815-22.
17. White MA, Haber GP, Autorino R, Khanna R, Forest S, Yang B, *et al*. Robotic laparoendoscopic single-site radical prostatectomy: Technique and early outcomes. Eur Urol 2010;58:544-50.
18. Joseph RA, Goh AC, Cuevas SP, Donovan MA, Kauffman MG, Salas NA, *et al*. Chopstick surgery: A novel technique improves surgeon performance and eliminates arm collision in robotic single-incision laparoscopic surgery. Surg Endosc 2010;24:1331-5.
19. Haber GP, White MA, Autorino R, Escobar PF, Kroh MD, Chalikonda S, *et al*. Novel robotic da Vinci instruments for laparoendoscopic single-site surgery. Urology 2010;76:1279-82.
20. Won Lee J, Arkoncel FR, Rha KH, Choi KH, Yu HS, Chae Y, *et al*. Urologic Robot-Assisted Laparoendoscopic Single-Site Surgery Using a Homemade Single-Port Device: A Single-Center Experience of 68 Cases. J Endourol 2011;25:1481-5.
21. Joseph RA, Salas NA, Johnson C, Goh A, Cuevas SP, Donovan MA, *et al*. Chopstick surgery: A novel technique enables use of the da Vinci robot to perform single-incision laparoscopic surgery [video]. Surg Endosc 2010;24:3224.
22. Kaouk JH, Autorino R, Laydner H, Hillyer S, Yakoubi R, Isac W, *et al*. Robotic single-site kidney surgery: Evaluation of second-generation instruments in a cadaver model. Urology 2012;79:975-9.
23. Morel P, Hagen ME, Bucher P, Buchs NC, Pugin F. Robotic single-port cholecystectomy using a new platform: Initial clinical experience. J Gastrointest Surg 2011;15:2182-6.
24. Konstantinidis KM, Hirides P, Hirides S, Chrysocheris P, Georgiou M. Cholecystectomy using a novel Single-Site (1) robotic platform: Early experience from 45 consecutive cases. Surg Endosc 2012; 26:2687-94.
25. Cestari A, Buffi NM, Lista G, Lughezzani G, Larcher A, Lazzeri M, *et al*. Feasibility and preliminary clinical outcomes of robotic laparoendoscopic single-site pyeloplasty using a new single-port platform. Eur Urol 2012;62:175-9.
26. Arkoncel FR, Lee JW, Rha KH, Han WK, Jeoung HB, Oh CK. Two-port robot-assisted vs standard robot-assisted laparoscopic partial ne-phrectomy: A matched-pair comparison. Urology 2011;78:581-5.
27. Park JH, Walz MK, Kang SW, Jeong JJ, Nam KH, Chang HS, *et al*.

Robot-assisted posterior retro-peritoneoscopic adrenalectomy: Single port access. J Korean Surg Soc 2011;81 Suppl 1:S21-4.
28. Seideman CA, Tan YK, Faddegon S, Park SK, Best SL, Cadeddu JA, *et al*. Robot-Assisted Laparoendoscopic Single-Site Pyeloplasty: Technique Using the da Vinci Si Robotic Platform. J Endourol 2012;26:971-4.
29. Olweny EO, Park SK, Tan YK, Gurbuz C, Cadeddu JA, Best SL. Perioperative Comparison of Robotic Assisted Laparoendoscopic Single-Site Pyeloplasty Versus Conventional LESS Pyeloplasty. Eur Urol 2012;61:410-4.
30. Barret E, Sanchez-Salas R, Cathelineau X, Rozet F, Galiano M, Vallancien G. Re: Initial complete laparoendoscopic single-site surgery robotic assisted radical prostatectomy. Int Braz J Urol 2009;35:92-3.
31. Leewansangtong S, Vorrakitkatorn P, Amornvesukit T, Taweemonkongsap T, Nualyong C, Sujijantararat P. Laparo-endoscopic singlesite robotic radical prostatectomy in an Asian man withprostate cancer: An initial case report. J Med Assoc Thai 2010;93:383-7.
32. Fareed K, Zaytoun OM, Autorino R, White WM, Crouzet S, Yakoubi R, *et al*. Robotic single port suprapubictransvesicalenucleation of the prostate: Initial experience. BJU Int 2012;110:732-7.
33. Wortman TD, Strabala KW, Lehman AC, Farritor SM, Oleynikov D. Laparoendoscopic single-site surgery using a multi-functional miniature *in vivo* robot. Int J Med Robot 2011;7:17-21.
34. Sekiguchi Y, Kobayashi Y, Watanabe H, Tomono Y, Noguchi T, Takahashi Y, *et al*. *In vivo* experiments of a surgical robot with vision field control for single port endo- scopic surgery. Conf Proc IEEE Eng Med Biol Soc 2011;2011:7045-8.
35. Kobayashi Y, Tomono Y, Sekiguchi Y, Watanabe H, Toyoda K, Konishi K, *et al*. A surgical robot with vision field control for single port endoscopic surgery. Int J Med Robot 2010;6:454-64.

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