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ORIGINAL ARTICLE

Ergonomic principles and techniques in facilitating advanced laparoendoscopic single site (LESS) urinary tract reconstruction with conventional laparoscopic instruments

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Background/Purpose: The technical and ergonomic details of laparoendoscopic single site (LESS) reconstruction have not been reported. In this study, we explored the feasibility and safety of performing advanced LESS upper urinary tract reconstruction with conventional laparoscopic instruments.

Methods: Between September 2010 and March 2011, we retrospectively reviewed prospectively collected data from five patients who underwent LESS urinary tract reconstruction. The LESS reconstruction included pyeloureterostomy ($N = 1$), dismembered pyeloplasty ($N = 2$), ureteroneocystostomy ($N = 1$), and ureteroplasty for bifid blind ending ureter ($N = 1$). The perioperative and postoperative parameters were collected for analysis. The ergonomic principles and techniques are detailed.

Results: All reconstructive LESS procedures were completed successfully without open conversion or laparoscopic conversion. Ancillary ports or ancillary instruments were not applied in

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any of the patients. The mean patient age was 40.4 years. The mean operative time was 213 ± 69 minutes, the estimated blood loss ranged from minimal to 50 mL, and the mean hospital stay was 4.4 ± 4 days. No operation-related complication occurred.
Conclusion: Based on our ergonomic principles and suturing/knotting techniques, conventional laparoscopic instruments are feasible and safe for LESS urinary reconstructive procedures.

Introduction

The safety and feasibility of laparoendoscopic single site (LESS) surgery has been approved for various urological operations.[1–6] In experienced hands, LESS surgery can be successfully performed for most indications, and it has comparable short-term outcomes as conventional laparoscopy. The clinical advantages of LESS surgery over conventional laparoscopy is still under debate; however, the initial randomized control trials regarding LESS surgery reveal inspiring convalescent advantages, in addition to appealing cosmetic results.[1,7–9] This novel technique theoretically reduces multiple trocar-related parietal trauma and the possibility of multiple trocar-related complications.

However, the LESS approach is hampered by its original design: a single skin entry, parallel and extremely close instrument arrangements, and a very limited instrument triangulation, which is an essential part of laparoscopy suturing. The common solutions for intracorporeal suturing in LESS surgery are incorporating an accessory 2-mm port, and articulating needle holders, or prebent laparoscopic instruments. The drawbacks are extra skin incisions, crossing manipulation, and using nondurable, expensive commercial instruments.[2,10–16] To date, the technical and ergonomic details have not been reported. We report in this paper our technical principles and techniques in facilitating pure LESS intracorporeal suturing and knot tying with conventional laparoscopic instruments, and we report our early results in various advanced LESS urinary tract reconstruction procedures.

Materials and methods

Ergonomic principles

The advantages of triangulation in laparoscopic surgery are the enhancement of a surgeon's spatial perception, ergonomic feasibility, decreased instrument fighting, and thus improved procedure efficiency. In LESS surgery, when all the instruments have to point to the same target (i.e, not crossing each other), instrument triangulation is nearly lost. An angle-viewed or flexible laparoscope is a common solution because the angle-viewed scope can be positioned in a different direction from the target and thus can cross with instruments so that the working instruments regain room for manipulation during LESS surgery.

Intracorporeal suturing and knotting

Laparoscopic suturing and knotting is a crucial part of urinary tract reconstruction. Because of the parallel arrangement of instruments and instrument clashing, reconstruction is challenging when using articulating instruments and even more challenging when using conventional instruments during LESS surgery. Based on our experience, instrument triangulation is an essential part of LESS suturing and knotting, although triangulation is very limited. Thus, maintaining mini-triangulation with the endoscope at the top of the triangle and the other instruments at the top left and top right of the triangle is the principle of reconstruction with conventional instruments (Fig. 1). Because of the parallel arrangement of the working instruments, the needle could be easily loaded perpendicularly in the needle holder, which is ready for suturing (Fig. 2). The spatial limitation and the fixed single skin incision inevitably limits the freedom of suturing. To place sutures at a right angle to the line of anastomosis, the direction of anastomosis line should be adjusted with the assistant instrument or with a stay suture.

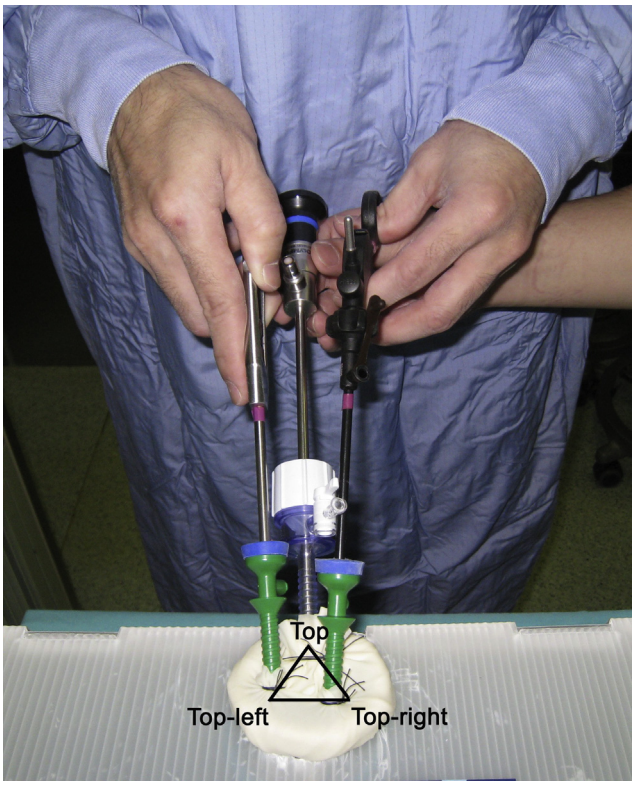

Figure 1 The configuration of mini-triangulation—with the endoscope at the top and the instruments at top-left and top-right of the triangle—is maintained during the whole course of suturing and knotting.

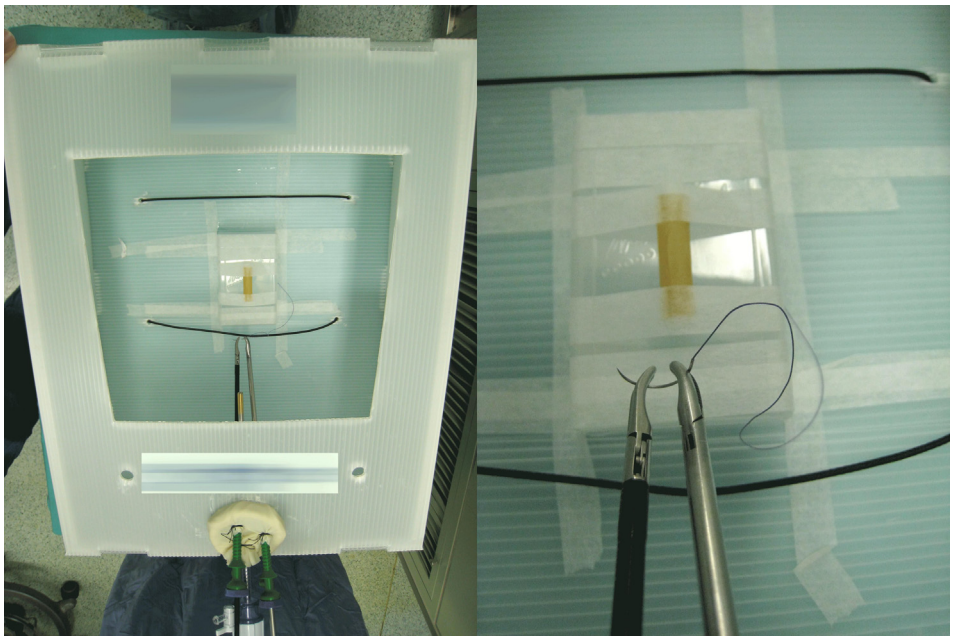

Figure 2 The needle is easily loaded perpendicularly in the needle holder because the two instruments are parallel.

For efficient knotting, the length of the suture thread should be 15 cm or longer. Two long-curved or right-angled jaw dissecting forceps are especially useful for making loops under the parallel arrangement of the instruments. After the needle passes through the tissue, the end of the thread without the needle should be shorter than the opposite thread, and grasped with the contralateral forcep to make loops for knotting (Fig. 3). The end of the thread is then grasped with the other forcep and the knot is secured by pulling the two instruments in opposite directions (Fig. 4). The configuration of triangulation should be carefully maintained during the whole course of knotting.

Patients and procedures

Between September 2010 and March 2011, we retrospectively reviewed prospectively collected data from five patients who underwent LESS urinary tract reconstruction performed by a single surgeon. The LESS reconstruction procedures included pyeloureterostomy ($N = 1$), dismembered pyeloplasty ($N = 2$), ureteroneocystostomy ($N = 1$),

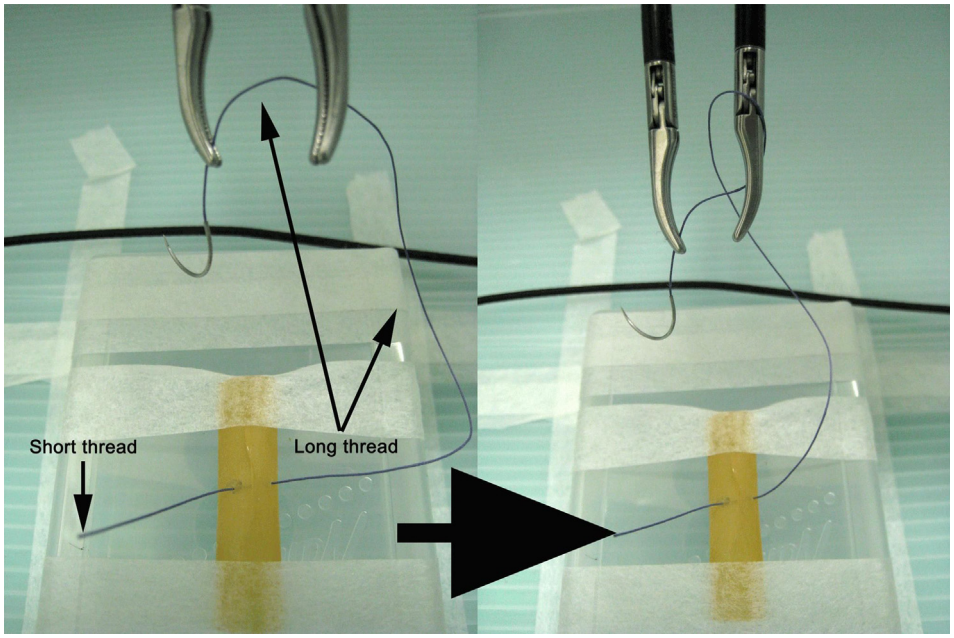

Figure 3 The thread distal (i.e., short thread) to the needle should remain shorter than the thread proximal to the needle. To make loops for knotting, the long thread is grasped with the forceps that is contralateral to the needle.

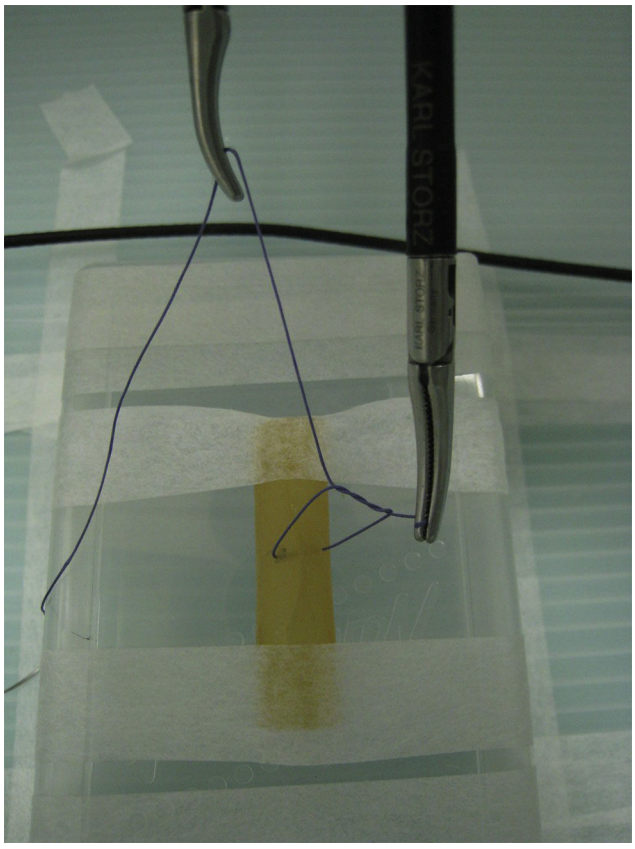

Figure 4 The distal end of the thread is grasped by the other forceps and the knot is secured by pulling the two instruments in opposite directions.

and ureteroplasty for bifid blind ending ureter ($N = 1$). Table 1 lists the detailed surgical indications and procedures. The perioperative and postoperative parameters were collected for analysis.

All procedures were performed by a homemade single access platform—using an Alexis wound retractor (Applied Medical, Rancho Santa Margarita, CA, USA)—which has been described previously.[17] After the skin incision, a wound retractor was inserted. Double-layered sterile surgical gloves were then snapped onto the retractor with the upper finger parts truncated. The trocars were inserted through the glove and secured by ligatures. For all procedures, a 2-cm periumbilical incision was created and an extra-small Alexis wound retractor was used for primary access. Sutures (4-0 Monocryl) (Applied Medical, Rancho Santa Margarita, CA) required for reconstruction were delivered into the peritoneal cavity by penetrating the gloves on the homemade port and vice versa.[3] A ureteral stent was placed in an antegrade fashion in all patients. Table 2 lists the detailed laparoscopic instruments and consumables. All instruments were conventional straight laparoscopic instruments, except an extended length 5-mm laparoscope. The curved needle was introduced into the abdominal cavity through the glove part of the homemade single port. For the double-layered design, air leakage was not significant after needle puncturing. The perioperative and postoperative data were recorded and analyzed. The drainage status of the reconstructed upper tracts was confirmed by intravenous pyelography or computed tomography (CT) scan.

Results

All LESS urinary tract reconstruction procedures were completed successfully without open conversion or laparoscopic conversion. Ancillary ports or ancillary instruments were not applied in all patients. Table 1 lists the demographic data. For the entire cohort, the mean patient age was 40.4 years (range, 25—59 years), mean body mass index was 23.9 kg/m^2 (range 19.1—26.9 kg/m^2). The installation of homemade single ports was successful in all patients. For the unique double-layered design, significant air leakage was not encountered after needle penetration or after prolonged surgery.

The mean operative time was 213 $\pm$ 69 minutes, the estimated blood loss ranged from minimal to 50 mL, and the mean hospital stay was 4.4 $\pm$ 4 days. There were no intraoperative or postoperative complications. The median follow-up period was 5.5 months (range, 3.75—7.5 months). For ureteropelvic junction obstruction, an anterior crossing vessel was indentified in a 35-year-old female. Improvement of hydronephrosis was identified in all patients by intravenous urography, serial renal ultrasonography, or CT scan.

Discussion

Laparoendoscopic single site surgery is a novel technique, modified from conventional laparoscopy, in which the whole procedure is performed via a single skin incision. Therefore, it follows the same surgical principles of conventional laparoscopy. The only difference is that the

Table 1 Demographic data and surgical indications for the LESS procedures.

Procedure	No. of patients	Age (y)	Sex	BMI (kg/cm^2)	Indication or diagnosis
Pyeloureterostomy	1	25	F	19.1	Complete duplicated ectopic ureter with hydronephrosis
Dismembered pyeloplasty	2	35 and 44	F/M	22.8 and 26.7	Ureteropelvic junction obstruction (crossing vessel in 1 patient and high insertion in 1 patient)
Ureteroneocystostomy	1	59	F	24	Distal ureteral stricture because of previous hysterectomy
Ureteroplasty	1	39	F	26.9	Bifid blind ending ureter with recurrent APN

APN = acute pyelonephritis; BMI = body mass index; LESS = laparoendoscopic single-site.

Table 2 The detailed laparoscopic instruments and consumables used in the LESS procedure.

Instruments	Diameter (mm)	Length (cm)	Additional expenses in comparison to conventional LPS (US dollars)
30° endoscope	5	29	Reusable
Dissecting forceps	5	36	Reusable
Grasping forceps	5	36	Reusable
Scissors	5	36	Reusable
Dissecting electrode	5	36	Reusable
Needle holder	5	33	Reusable
Suction and irrigation cannula	5	36	Reusable
Alexis wound retractor	XSml	N.A.	78
5 mm trocars	5	N.A.	No greater expense than conventional laparoscopy

LESS = laparoendoscopic single-site; LPS = laparoscopy; N.A. = not applicable; XSml = extra small.

nature of a single incision precludes the ergonomic principle of laparoscopic triangulation. Therefore, the in-line suturing by using a conventional laparoscopic needle holder presents an extreme challenge for LESS reconstructive procedures.[11] Commercial articulating needle holders (Cambridge Endoscopic devices (Framingham, MA); Novare Surgical Systems (Cupertino, Calif)) offer a solution for the LESS reconstruction procedure.[3] An ancillary 2-mm or 3-mm needle port can otherwise offer a primary solution for LESS reconstructive procedures. The drawbacks of the aforementioned solutions are the inherent learning curve because of the counter-intuitive manipulation of crossing manipulation and additional parietal trauma due to the ancillary instrument. Performing LESS reconstructive procedure with conventional straight instruments seems to be a more reasonable and intuitive way, and conventional facilities are always ready for use worldwide. However, the technique has never been detailed anywhere in the medical literature.

According to our previously described ergonomic and geometric principles, most upper urinary tract reconstruction could be successfully completed in pre-existing facilities and with conventional laparoscopic instruments without an ancillary port or surgical conversion. No patient had postoperative complications. The operating time was longer than that of conventional laparoscopic reconstruction procedures reported in the medical literature, but the increased time may be related to the time needed to create the custom-make single port or related to inferior procedure efficiency because of the extremely limited triangulation. Based on our experience, conventional laparoscopic instruments could be safely and successfully used in LESS urinary tract reconstructions.

Prior to initiating the LESS procedure, several challenges should be addressed such as the loss of instrument triangulation and the crowding of instruments. Various commercial articulating instruments offer solutions to the aforementioned problems. However, crossing manipulation of these articulating instruments is counter-intuitive and therefore results in another learning curve that needs to be overcome.[2] Based on our ergonomic principles, LESS surgery could be performed safely with reasonable efficiency, although the operative time of LESS surgery is a little longer than that of conventional laparoscopy.

Several techniques may help improve the procedure's efficiency. First, because of the restraint of instrument angles, the surgeon can tent up the tissues or vessels to be dissected by taking the grasper to hold and pull durable tissues some distance away from the exact range of interest. Other instruments can then be used to complete the dissection, to control vessels, or to transect tissues/vessels. Second, the assistant holding the telescope needs to move the camera focus to the tissues that the nondominant hand grasper is going to hold. Let it grasp the tissue in position. The assistant then swiftly shifts the scope back to the exact range of interest for the dominant-hand instrument to execute its planned dissection. Third, to avoid unnecessary damage to the tissues, especially when the tissue is not under the direct visualization of the monitor screen, the assistant instruments responsible for tissue holding cannot be moved too vigorously. Fourth, it is very important to maintain instrument triangulation for successful intracorporeal suturing and knotting. The range of movement is extremely limited under such circumstances, however, intracorporeal suturing and knotting are feasible.

The only drawback of the LESS surgery is the procedural efficiency is not as good as that of conventional laparoscopy with normal triangulation.

The LESS reconstructive technique represents an ideal procedure for its minimal and nearly invisible scar because specimen retrieval is not necessary. However, reconstructive LESS surgery is still in its early stages of technique and technology development. The reconstructive LESS surgery is a complicated and extremely difficult procedure even for surgeons who are experienced in conventional laparoscopic reconstructive or LESS procedures. An early series indicated that reconstructive LESS surgery may be associated with a higher complication rate.[18] Therefore, we only recommend our technique to surgeons who are experienced in conventional laparoscopic reconstructive procedures. In conclusion, based on our ergonomic principles and suturing/knotting techniques, conventional laparoscopic instrument is feasible and safe for LESS urinary reconstructive procedures. The outcome advantages of reconstructive LESS surgery are still under investigation; however, in experienced hands, reconstructive LESS

surgery could be successfully performed for most indications with acceptable clinical outcomes.

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