

Review Article

Current Status of Laparoendoscopic Single-Site Surgery in Urologic Surgery

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Since the introduction of laparoscopic surgery, the promise of lower postoperative morbidity and improved cosmesis has been achieved. Laparoendoscopic single-site surgery (LESS) potentially takes this further. Following the first human urological LESS report in 2007, numerous case series have emerged, as well as comparative studies comparing LESS with standard laparoscopy. However, comparative series between conventional laparoscopy and LESS for different procedures suggest a non-inferiority of LESS over standard laparoscopy, but the only objective benefit remains an improved cosmetic outcome. Challenging ergonomics, instrument clashing, lack of true triangulation, and in-line vision are the main concerns with LESS surgery. Various new instruments have been designed, but only experienced laparoscopists and well-selected patients are pivotal for a successful LESS procedure. Robotic-assisted LESS procedures have been performed. The available robotic platform remains bulky, but development of instrumentation and application of robotic technology are expected to define the actual role of these techniques in minimally invasive urologic surgery.

Key Words: Laparoscopy; Minimally invasive surgical procedures; Robotics

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INTRODUCTION

Laparoendoscopic single-site surgery (LESS) has been proposed as an evolutionary step beyond standard laparoscopy and has been increasingly adopted by urologists worldwide since its introduction [1,2]. Conceptually, it is driven by the hypothesis that minimization of the skin incision to gain access to the abdominal or pelvic cavities may benefit patients in terms of port-related complications, recovery time, pain, and cosmesis [3,4].

Over the past few years, many standard laparoscopic operations in urology have been successfully performed with the use of LESS. However, the actual role of LESS in the field of minimally invasive urologic surgery remains to be determined [5,6].

The purpose of this review was to update the current status of LESS in urologic surgery.

BASIC PRINCIPLES AND TERMINOLOGY

The first LESS Consortium for Assessment and Research was organized in Cleveland, Ohio, in July 2008 [3]. Subsequently, other organizations included their recommendations, making the term "LESS" broader by encompassing the following concepts: 1) a single entry port; 2) applicability to multiple locations (abdomen, pelvis, thorax); 3) laparoscopic, endoscopic, or robotic surgery; 4) umbilical or extraumbilical access; 5) intra- and transluminal (percutaneous single-port access) approaches [2,3,6].

LESS access can be obtained either by making a single skin and fascial incision in which a single multi-channel access platform is placed (single-port) or by placing several low-profile ports through separate fascial incisions (single-site). The access point can be umbilical or extraumbilical.

LESS: CURRENTLY AVAILABLE TOOLS FOR UROLOGIC APPLICATIONS

Despite evolving from the concepts and techniques of standard laparoscopy, LESS defies some basic laparoscopic principles, including instrument and external port spacing to decrease clashing. New laparoscopic access devices, optics, and instrumentation specifically designed for successfully facilitating LESS have been developed in the past few years [5,7-9] (Table 1).

ACCESS DEVICES

Multichannel ports can be used during LESS as one approach to access. These devices allow for the insertion of instruments and a camera and involve a single fascial incision.

The TriPort port (Olympus Co., Tokyo, Japan), previously known as R-port, is the first multi-instrument port designed specifically for LESS [10]. The SILS port (Covidien, Mansfield, MA, USA) is a foam port that expands after insertion to prevent air leakage. The GelPOINT port (Applied Medical Resources Co., Rancho Santa Margarita, CA, USA) is similar to the already available GelPort port but with a smaller diameter. The AirSeal port (SurgiQuest, Orange, CT, USA) maintains pneumoperitoneum by creating an air vortex [11].

Alternatively, LESS access can be obtained with the use of several low-profile, small-diameter head trocars (such as AnchorPort trocars [SurgiQuest], Peditport trocars [Covidien], and Hunt trocars [Apple Medical Resources Co.]) with separate fascial stab incisions (single site). These devices can be clustered within a single incision or through three separate stab incisions clustered within the umbilical ring.

Initial clinical experience with LESS nephrectomy using a homemade single-port device has also been reported [12,13]. In those reports, an Alexis wound retractor was inserted at the umbilicus, and a surgical glove was installed over the outer ring of the wound retractor. About 3 to 4 fingers of the glove were cut, and one 10-mm and two or three 5-mm trocars were placed. The fingers of the glove were secured to the end of the trocars with a rubber band and fixed to the outer ring of the wound retractor. The device provided adequate range of motion and enough flexibility in port placement for LESS.

INSTRUMENTS

When instruments are inserted in parallel through the same site, clashing and decreased maneuverability represent major limitations. Articulating instruments have been developed to allow the surgeon's hands to be positioned apart from each other while maintaining the tips of the instruments still focused on the same point inside the abdomen. A combination of conventional and flexible (articulating) instruments provides improved intra-

operative ergonomics [7-9]. Traditional rigid, straight instruments have also been used for LESS. Branco et al. [14] evaluated LESS urologic surgery with the use of conventional laparoscopic instruments and ports, claiming that articulating instruments might not be strictly necessary.

Pre-bent instruments have been introduced with the aim of minimizing instrument clashing outside the port, providing triangulation in the operative field and better force application at instrument tip during dissection [15]. These instruments are also cost-effective, because they are reusable compared with the single-use disposable flexible instruments. Stolzenburg et al. [16] recently performed a comparative evaluation in a dry and animal laboratory of conventional, flexible, and pre-bent instruments in an attempt to elucidate instrument effectiveness and maneuverability. Pre-bent instruments proved to be less time-consuming and provided better maneuverability.

With the rise of LESS and natural orifice transluminal endoscopic surgery (NOTES), needlescopic instruments have also been re-discovered, because they can be introduced through a small puncture that requires no formal closure, thus pursuing the philosophy of scarless surgery.

OPTICS

A key problem with conventional laparoscopes is that they have a large extracorporeal profile, with a light cable exiting at 90°. This configuration leads to clashing of instruments and the camera during LESS. Thus, the ideal telescope for LESS should remove the light cord and camera head from the operative field. Low-profile camera systems have been introduced for this purpose [7-9].

Articulating laparoscopes, such as the EndoEYE (Olympus, Tokyo, Japan) or the IDEAL EYES (Stryker, Kalamazoo, MI, USA), represent additional tools for the single-port armamentarium. One issue with articulating scopes is the plastic casing that covers the flexible part of the tip, which tends to degrade over time. The camera chip in the 10-mm EndoCAMEleon (Karl Storz, Tuttlingen, Germany) scope rotates within the tip, thus eliminating the need for the plastic casing while still giving surgeons the multidirectional view they need to operate. Moreover, 5-mm, 308, extra-long telescopes have been developed and marketed for LESS. The extra length removes the camera head and light cord from the operative field.

PATIENT SELECTION

All eligible laparoscopic surgery patients may be considered for LESS depending on the surgeons' LESS experience. When starting LESS, patient selection criteria are expected to be stringent. Disease features (i.e., locally advanced disease requires more extensive dissection and abnormal anatomy requires extensive suturing) and characteristics of the patients (i.e., body habitus, body mass index, comorbidity score, previous surgery or radiation, and personal preferences for better cosmetic outcome) should be

TABLE 1. Laparoendoscopic single-site surgery toolbox: access devices, instruments, and optics

Product	Company	Features
Access devices		
Triport™	Olympus	Allows three instruments through one small (10-25 mm) incision. Consists of a boot containing one 12-mm and two 5-mm gel valves. Two Luer connectors for insufflation and smoke evacuation. Introducer to aid placement.
SILS™ port	Covidien	Foam port inserted through a 2-cm fascial incision. Expands once inserted to prevent air leakage. Small holes within the foam accommodate 5-mm or 12-mm trocars.
Gelpoint™	Applied	Similar to the already available GelPort™, but smaller, without perforations in the gel cap with an insufflation port on the side of the device, and a suture attached to the wound protection apparatus to allow for easier removal.
Airseal™	Surgiquest	No physical seal. It maintains pneumoperitoneum by creating an air vortex. Multiple instruments to fit through one large opening in the trocar.
X-Cone™	Karl Storz	Metallic conical structure, to which a plastic cap is attached. Four instrument ports and an insufflation port are available. Open Hassan technique for insertion. Reusable.
Endocone™	Karl Storz	Allowing ergonomic placement of the vales for multiple telescope and instrument access. Rigid seal cap. Reusable.
SSL access system	Ethicon	Low-profile seal cap including two 5-mm seals and one 15-mm seal. 360° reticulation mimicking hand's movement. Significant learning curve.
Octo™ port	DalimSurg	Consists of inferior base plate that sits under the skin edge in the peritoneum, external disc with self-retractor, transparent silicone cover with three/ four channels.
SPIDER™	Transenterix	Composed of two primary assemblies, platform access device, stabilizer with a bed clamp. Includes an insertion trocar, covered by a retractable sheath and nose cone. Four working channels.
Articulating instruments		
Real hand™	Novare surgical	High Dexterity technology: 5-mm hand instruments in which the handle is connected to the tips by several cables, allowing for 360° reticulation mimicking hands's movement. Significant learning curve.
Autonomy Laparo-Angle™	Cambridge-Endo	Can move in 360° plane and be locked into position. Large bulky handle remains suboptimal.
Rotulator™	Covidien	Already used in laparoscopy. Limited degree of freedom, as articulation is in one plane only.
SILS™ Stitch	Covidien	Toggle-activated needle-passing technology already available for conventional laparoscopy with the additional features of distal shaft articulation needle jaw tip rotation and additional shaft length.
SILS™ hand instruments	Covidien	Ability to articulate in a near hemispherical space, allowing access to surgical site from different angles. Allows handle to be moved off-axis. Ability to lock instrument shaft in a chosen position. Enables the jaw to be closed in any number of orientations. Different shaft lengths allow instrument handle staggering which can reduce handle clashing.
Pre-bent instruments		
S-portal™ series	Karl Storz	Pre-shaped, rigid instruments, with different profiles. Reusable. Fewer degrees of freedom.
HIQ LS hand instruments	Olympus	
Optics		
EndoEYE™ LS	Olympus	High definition, 5-mm, 30° digital scope. Can be bent by as much as 90°; Integrated light and camera; CCD chip on the tip.
EndoEYE™ LTE VP	Olympus	High definition, 5-10-mm, 0° digital scope. Deflectable tip (100° angulation). Integrated light and CCD chip on the tip.
Ideal Eyes™	Stryker	10-mm; Friction assist brake; Integrated light cable; Over 100° of flexion in all directions.
Endo CAMEleon™	Karl Storz	10-mm laparoscope with variable direction (between 0° and 120°) of view camera by means of a chip rotating within the tip.

considered. A low threshold for conversion to standard laparoscopy or even open surgery must be adopted.

CLINICAL STATUS

Currently, the feasibility and safety of major urological extirpative, ablative, and reconstructive procedures has been reported worldwide [3,5,7,17-38] (Table 2). However, longer clinical follow-up remains to be determined for each LESS procedure.

ROBOTIC LESS

Robotic manipulation of instrumentation to address the current constraints and limitations of LESS has also been tested. The first successful series of single-port robotic procedures in humans, including radical prostatectomy, dismembered pyeloplasty, and radical nephrectomy, were reported by Kaouk et al. [39]. A robotic 12-mm scope and a 5-mm grasper were introduced through a multichannel single port (R-Port), whereas an additional 5- or 8-mm robotic port was introduced through the same umbilical incision (2 cm) alongside the multichannel port to facilitate entry of robotic instruments. Predictably, the robotic instrument articulation allowed the surgeon to perform a less challenging operative maneuvering.

Further expanding the application of robotics to LESS, Kaouk and Goel [40] reported an initial experience with single-port robotic partial nephrectomy in two patients. Moreover, Han et al. [41] have recently reported their cumulative experience with robot-assisted LESS partial nephrectomy to treat 14 cases of renal cell carcinoma (mean

tumor size, 3.2 cm). Stein et al. [42] used a GelPort (Applied Medical Resources Co.) as an access platform for robotic LESS. Four LESS procedures were successfully performed, including two pyeloplasties, one radical nephrectomy, and one partial nephrectomy. In addition, adequate trocar spacing and flexibility of placement allowed the surgical assistant to actively assist the surgeon during the LESS. The surgical technique and reported early outcomes of robotic LESS radical prostatectomy have also been more recently described [28].

LESS VS CONVENTIONAL LAPAROSCOPY

Comparative series between conventional laparoscopy and LESS have recently become available (Table 3).

Raman et al. [43] were the first to report a case-control study comparing LESS with conventional laparoscopy. They compared 11 LESS procedures with 22 laparoscopic nephrectomies. According to the authors, the superiority of LESS over standard laparoscopic nephrectomy was "limited" to a mere subjective cosmetic advantage, even if this advantage was not specifically measured or quantified.

Considering that in this study, half of the LESS patients had a nephrectomy for malignancy, necessitating extension of the initial umbilical incision for specimen extraction, the investigators speculated that this may have blunted the potential benefit of LESS. Therefore, they addressed a reconstructive procedure, such as pyeloplasty. Fourteen patients undergoing LESS pyeloplasty were matched 2:1 with regard to age and side of surgery to a previous cohort of 28 patients who underwent laparoscopic pyeloplasty [44]. Suturing was aided through a 5-mm instrument placed in the eventual drain site. Interestingly, median operative times and median estimated blood loss (EBL) were significantly lower in patients undergoing LESS. The authors claimed that the 50-ml difference in blood loss was not likely to be clinically significant and was probably related to the inevitable inaccuracies in intraoperative measurement. Regarding the operating room time, they partially attributed the difference to the fact that 75% of control patients underwent cystoscopy with retrograde stent placement, which requires repositioning of the patient and additional equipment compared to the antegrade stent placement performed in all LESS cases. In addition, more patients in the laparoscopy cohort had previous endoscopic management of their ureteropelvic junction, which may have made dissection more difficult.

Jeong et al. [45] recently described the first study comparing LESS with laparoscopy in the treatment of benign adrenal adenoma. Nine patients undergoing LESS adrenalectomy were compared with 17 matched patients undergoing conventional laparoscopic adrenalectomy. Postoperative pain, as measured by the mean number of days of intravenous patient-controlled anesthesia use, was significantly lower in the LESS group. LESS adrenalectomy was comparable to the conventional laparoscopic approach in terms of perioperative parameters. The authors claimed

TABLE 2. Urologic laparoendoscopic single-site surgery procedures: what has been done so far

Procedure [reference]
Kidney, adrenal & ureteral surgery
Simple nephrectomy [1,12,14,17]
Radical nephrectomy [18]
Living donor nephrectomy [21-23]
Cyst decortications [31-33,37]
Partial nephrectomy [19,26]
Nephroureterectomy [31-33]
Cryoablation [20]
Adrenalectomy [25,26]
Partial adrenalectomy [36]
Pyeloplasty [31,32]
Ureterolithotomy [35,37]
Ileal ureter [24,32]
Ureteral reimplantation [24,32]
Pelvic surgery
Simple prostatectomy [29,32]
Radical prostatectomy [27,28,31]
Radical cystectomy [30,31]
Bladder diverticulectomy [34]
Sacral colpopexy [31]

TABLE 3. Laparoendoscopic single-site surgery versus laparoscopy: reported outcomes from case-control comparative series

Ref.	Level of evidence	Procedure	LESS access	No. of cases	Conversion no.	Median OT (min)	Median EBL (ml)	Median length of hospital stay (h)	Analgesics	Complication rate (%)
[43]	3	Simple and radical nephrectomy	Single incision	11 LESS	0	122	20	49	8 ^a	0
				22 Laparoscopic	0	125	100	53	15 ^a	0
						NS	0.001	NS	NS	NS
[44]	3	Pyeloplasty ^b	Single incision ^c	15 LESS	1 ^d	202	35	77	34 ^a	33
				28 Laparoscopic	0	257	85	74	38 ^a	21
						<0.001	0.002	NS	NS	NS
[45]		Adrenalectomy	Single port	9 LESS	1	169.2	177.8	77	0.9 ^e	11
				17 Laparoscopic	1	144.5	204.7	84	1.9 ^e	6
						NS	NS	NS	0.047	NS
[46]		Simple nephrectomy	Single port ^f	11 LESS	0	151	51	32	364 ^g	20
				10 Laparoscopic	0	165	68	26	231 ^g	10
						NS	NS	NS	NS	NS
[47]		Sacrocolpopexy ^b	Single port	10 LESS	0	162	47	36	NR	0
				10 Laparoscopic	0	151	65	38		0
				10 Robotic	0	150	87	38		0
							NS	NS	NS	NS
[48]		Kidney cryoablation ^b	Single-port	5 LESS	0	174	75	33	NR	0
			Retroperitoneal	5 Laparoscopic	0	120	100	43		0
						<0.001	NS	NS	NS	NS

LESS, laparoendoscopic single-site surgery; OT, operative time; EBL, estimated blood loss; NS, not significant; NR, not reported; IV, intravenous.

^a:Morphine equivalents (mg), ^b:Mean values expressed, ^c:Additional 5-mm trocar systematically used, ^d:Excluded from the analysis, ^e:No. of days of IV patient-controlled anesthesia use, ^f:Additional 5-mm trocar in one case. ^g:mg (drug not specified).

a higher cosmetic outcome, even if this outcome was not specifically measured.

Raybourn et al. [46] matched a total of 11 patients undergoing LESS simple nephrectomy with a group of 10 patients who previously underwent simple laparoscopic nephrectomy. All LESS procedures were completed with no intraoperative complications. Postoperative complications included fever and port site bruising in two patients. No difference was detected in the analgesia requirement between matched groups. The authors claimed an obvious cosmetic advantage, even if it was not specifically quantified.

White et al. [47] performed a retrospective cohort study to determine the efficacy and safety of LESS abdominal sacral colpopexy for the treatment of female pelvic organ prolapse. Despite a limited postoperative follow-up, the procedure appeared to be comparable to the laparoscopic and robotic approaches in terms of efficacy but with superior cosmesis.

The same group from the Cleveland Clinic retrospectively compared single-port retroperitoneal cryoablation with standard retroperitoneoscopy [48]. Subjective evaluation by the patients of postoperative pain was significantly in favor of the LESS approach, but the amount of analgesics used in each group was not reported, partially mitigating the clinical significance of this finding.

Two retrospective matched-pair comparisons of LESS to standard laparoscopic live-donor nephrectomy were recently reported [49,50] (Table 4). Canes et al. [49] performed the LESS procedure through an intra-umbilical multichannel port, using a 5-mm rigid laparoscope with integrated camera head, with standard and curved/articulating instruments. The kidney was extracted through a slightly extended umbilical incision. Mean warm ischemia time was significantly longer in the LESS group, even if allograft function was comparable between groups at 3 months. Patients undergoing LESS donor nephrectomy had similar in-hospital analgesic requirements and mean visual analogue scale (VAS) scores at discharge, but their convalescence, as assessed by considering days on oral pain medication, days off work, and days to full physical recovery, was faster.

Andonian et al. [50] compared their LESS Pfannenstiel donor nephrectomy with a series of standard laparoscopic donor nephrectomy procedures. In the LESS group, there were no conversions to laparoscopy or open surgery. The laparoscopic group included more right-sided patients and more venous anomalies. No significant difference was found between the groups in terms of operative time, warm ischemia time, EBL, length of hospital stay, or total morphine equivalents. A patient in the laparoscopic group developed a wound infection. There were no perioperative

TABLE 4. Laparoendoscopic single-site surgery versus laparoscopy living donor nephrectomy: comparative outcomes

	Canes et al. [49]		Andonian et al. [50]	
	LESS	Laparoscopy	LESS	Laparoscopy
Cases (n)	17	17	6	6
Age (yr)	40	43	46	28
BMI (kg/m ²)	25	25.6	28	25
Allograft volume (C ^a)	169	177	175	146
Side (n)				
Right	0	0	1	3
Left	17	17	5	3
Complex anatomy (n)	5	4	1	1
OR time (min)	240	222	142	117
Warm ischemia time (min)	6 ^b	3 ^b	5	5
EBL (ml)	50	100	100	150
Length of hospital stay (d)	3	3	2	2
Complications, n (Clavien grade)	2 (I; IIIb)	0	0	1 (I)
Morphine equivalent (mg)	97	98	83	42
VAS at discharge	3.5	1	0	2
Days on oral pills	4 ^b	14 ^b	N/A	N/A
Days to return to work	14 ^b	49 ^b		
Days to 100% recovery	26 ^b	60 ^b		

LESS, laparoendoscopic single-site surgery; BMI, body mass index; OR, operating room; EBL, estimated blood loss; VAS, visual analogue scale; N/A, not assessed.

^a:For continuous variables, values expressed as median, ^b:Statistically significant difference (p < 0.06).

complications in the LESS group. Postoperative VAS scores were lower in the LESS group but did not reach statistical significance.

So far, all comparative studies have been limited by small numbers, their nonrandomized design, their retrospective nature, and the lack of standardization in the assessment of postoperative outcomes. Overall, these series have shown a noninferiority of LESS over conventional laparoscopy in terms of perioperative outcomes, with an encouraging trend toward less postoperative pain and better cosmesis.

FUTURE OF UROLOGIC LESS

LESS as a new surgical technique requires clinical validation. Not only feasibility, longer clinical follow-up, and safety results are sought after, but advocates of LESS should also assess cosmetic outcome by using a standardized and validated patient and surgeon’s scar assessment tool, such as the Patient and Observer Scar Assessment Scale [51].

Historically, poor instrument ergonomics, crossing or collision of instruments, lack of triangulation, and depth perception have created limitations for universal acceptance of conventional laparoscopic surgery and similarly for acceptance of LESS. Undeniably, the use of specific instrumentation available for LESS and a solid laparoscopic surgical background are critical for successful LESS. Even with the robotic-assisted LESS system (Fig. 1), the lack of

	LESS	R-LESS
Scope (vision)	2D:HD:unstable	3D:HD:stable
Instruments	Straight:articulating	Articulating
Triangulation	Lacking (crossed hand or chopstick surgery)	Lacking (chopstick surgery)
Range of motion	Limited	Enhanced (endowrist technology)
Collision	Significant	Significant
Dissection	Challenging	Limited at steep angles
Suturing	Extremely challenging	Accurate
Key assistant's role	Camera manoeuvring	Managing collisions
Learning curve	Steep	Reduced

FIG. 1. Stepping forward: from laparoendoscopic single-site surgery (LESS) to R-LESS (Robotic-LESS) (modified from Rane and Autorino. *Curr Opin Urol* 2011;21:71-7, with permission of Wolters Kluwer) [52]. 2D, 2 dimensions; HD, high definition.

instruments, lack of full range of motion, and bulky platforms pose challenges for the robotic-assisted LESS [52]. Ongoing new developments in this area (VeSPA-robot instruments) may surpass our expectations [53].

Whether patients would prefer LESS to laparoscopy remains to be determined. Bucher et al. [54] sent a questionnaire describing laparoscopy, LESS, and NOTES to medical and paramedical staff, surgical patients, and the general population. Given similar operative risk, 90% of the participants preferred a scarless approach to laparoscopy, and this preference was significantly higher among the younger participants.

Although "cure" and safety remain the main concern, it seems that the concept and perception of scarless surgery is universally favorable due to the promise of improved cosmetic outcome and quicker recovery [55]. As conventional laparoscopic surgery challenged open surgery, LESS examines conventional laparoscopy and tackles the need for multiple entry sites, faster patient recovery, and possible better cosmetic outcome.

CONCLUSIONS

LESS has proved to be immediately applicable in the clinical field, being safe and feasible in the hands of experienced laparoscopic surgeons in well-selected patients. Despite promising early outcomes, the benefits of LESS are not obvious at present, with the only claimed advantage being cosmetic.

Prospective randomized studies are largely awaited to define the benefits of this technique for patients as well as to elucidate the cost-effectiveness of the approach. Refinement of instruments and application of robotics are likely to improve intraoperative ergonomics, allowing easier training and facilitating the current steep learning curve.

CONFLICTS OF INTEREST

The authors have nothing to disclose.

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