Laparoendoscopic Single-site Surgery in Urology: Worldwide Multi-institutional Analysis of 1076 Cases

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Abstract

Background: Laparoendoscopic single-site surgery (LESS) has gained popularity in urology over the last few years.

Objective: To report a large multi-institutional worldwide series of LESS in urology.

Design, setting, and participants: Consecutive cases of LESS done between August 2007 and November 2010 at 18 participating institutions were included in this retrospective analysis.

Intervention: Each group performed a variety of LESS procedures according to its own protocols, entry criteria, and techniques.

Measurements: Demographic data, main perioperative outcome parameters, and information related to the surgical technique were gathered and analyzed. Conversions to reduced-port laparoscopy, conventional laparoscopy, or open surgery were evaluated, as were intraoperative and postoperative complications.

Results and limitations: Overall, 1076 patients were included in the analysis. The most common procedures were extirpative or ablative operations in the upper urinary tract. The da Vinci robot was used to operate on 143 patients (13%). A single-port technique was most commonly used and the umbilicus represented the most common access site. Overall, operative time was 160 ± 93 min and estimated blood loss was 148 ± 234 ml. Skin incision length at closure was 3.5 ± 1.5 cm. Mean hospital stay was 3.6 ± 2.7 d with a visual
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 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 last few years, many standard laparoscopic operations in urology have been successfully performed using LESS. However, the actual role of LESS in the field of minimally invasive urologic surgery remains to be determined [5,6].

Evidence supporting LESS has been limited to small case series or case-control studies from selected centers [5]. One multi-institutional study including >100 patients was recently reported [7]. Comparative studies have shown that LESS is at least comparable to standard laparoscopy [8,9]. Thus, more robust analyses of larger samples are desirable to corroborate positive findings from early series.

This study was initiated as a collaborative effort with the purpose of reporting the contemporary practice of LESS at institutions pioneering the development of this technique in urology. The aim was to provide an analytical overview of indications, techniques, and outcomes of urologic LESS in various hospital settings worldwide.

1. Introduction

Procedures were categorized as extirpative/ablative or reconstructive and as upper urinary tract or pelvic. Moreover, they were scored based on a Likert-type scale (1, slightly difficult; 5, extremely difficult) [10].

The following outcome parameters were analyzed: operative time, estimated blood loss, intraoperative adverse events, transfusions, length of stay, and visual analog pain score (VAS).

Relevant operative data related to the surgical procedure were recorded, including access technique (single-port or single-incision/single-site), access site (umbilical or extrarectal), approach (transperitoneal or retroperitoneal), use of articulating or prebent laparoscopic instruments, use of the da Vinci robot, type of single-port device, and use of ancillary needlescopic or minilaparoscopic ports [11].

Addition of one extra trocar was considered as conversion to reduced-port laparoscopy [12], whereas conversion from LESS to laparoscopic surgery was defined as unplanned installation of more than one trocar to complete the procedure. Conversion to open surgery was defined as an unplanned abdominal incision to perform the operation.

Postoperative complications were scored according to the standardized Clavien-Dindo system [13].

Two periods were arbitrarily defined: one including years 2007–2008 and the other including years 2009–2010. A comparative analysis between these periods was conducted.

2. Methods

2.1. Study design

Our cohort consisted of consecutive patients treated with LESS between August 2007 and December 2010 at 18 participating institutions. Groups at medical centers worldwide with reported experience in urologic LESS were identified by searching available literature and invited to participate in the study. Each group performed the procedures according to its own protocols, entry criteria, and techniques. All patients consented specifically for LESS. Raw data without any identifier were retrospectively collected and gathered into a standardized datasheet, which was specifically built for study purpose.

2.2. Outcomes

Demographic data included age, gender, race, body mass index (BMI), past history of previous abdominal/pelvic surgery, American Society of Anesthesiologists (ASA) score, comorbidities, and indication for LESS.

Conclusions: This study provides a global view of the evolution of LESS in the field of minimally invasive urologic surgery. A broad range of procedures have been effectively performed, primarily in the academic setting, within diverse health care systems around the world. Since LESS is performed by experienced laparoscopic surgeons, the risk of complications remains low when stringent patient-selection criteria are applied.

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There was a significant increase in the number of cases per month during 2009–2010; the rate of some procedures (ie, pyeloplasty, donor nephrectomy, simple prostatectomy, cryoablation, and sacrocolpopexy) was lower, whereas some other procedures were performed more frequently (ie, radical nephrectomy, partial nephrectomy, renal cyst decortication, adrenalectomy, varicocelectomy, and ureterolithotomy). There was a significant increase in use of the da Vinci robot over time (Table 2 and Fig. 1).

A single-port technique was chosen in 77% of cases and the umbilicus was the predominant site of access (71% of cases). In cases in which a single-port platform was used, 46% involved a homemade device and 54% used a commercially available device. Among these, Triport/Quadport (Advanced Surgical Concepts, Bray, Co. Wicklow, Ireland) was used in 29% of cases, SILSPort (Covidien, Dublin, Ireland) in 8%, Gelport/Gelpoint (Applied Medical, Rancho Santa Margarita, CA, USA) in 7%, and XOne/Endocone (Karl Storz GmbH & Co. KG, Tuttingen, Germany) and Uni-X (Pnavel Systems, Brooklyn, NY, USA) in 5%. When a single-incision technique was chosen, a variable combination of multiple trocars or multichannel port with trocars was used. Articulating instruments were used in 73% of cases.

### Table 1 – Demographic data: cumulative analysis

| Patients, no.                          | 1076 |
|----------------------------------------|------|
| Mean age, yr                           | 52.1 ± 16.9 |
| Male/female                            | 559/517 |
| Race, no. (%)                          | -    |
| Asian                                  | 506 (47) |
| Caucasian                              | 483 (45) |
| African American                       | 34 (3.2) |
| Others                                 | 51 (4.8) |
| BMI, kg/m²                              | 25 ± 4.2 |
| ASA score                              | 1.7 ± 0.7 |
| Past medical and surgical history, no. (%) |       |
| Previous abdominal or pelvic surgery  | 283 (26.3) |
| Renal insufficiency                    | 59 (5.4) |
| Hypertension                           | 368 (34.2) |
| Diabetes                               | 111 (10.3) |
| Most frequent indication for LESS, no. (%) |       |
| Renal tumor or mass                    | 417 (38.7) |
| Renal cyst                             | 117 (10.9) |
| Nonfunctioning kidney                  | 111 (10.3) |
| Upper tract obstruction                | 98 (8.4) |
| Adrenal mass/tumor/cyst                | 56 (5.2) |
| Urinary stone                          | 53 (4.9) |
| Living donor                           | 46 (4.3) |
| Varicocele                             | 45 (4.2) |
| BPH                                    | 42 (3.9) |
| Prostate cancer                        | 25 (2.3) |
| Vaginal prolapse                       | 13 (1.2) |
| Bladder cancer                         | 5 (0.4) |
| Number of procedures                   | 612 |
| BPH = benign prostatic hyperplasia; ASA = American Society of Anesthesiologists; BMI = body mass index; C6 = converted to open surgery; C244 = comparing the two study periods. |  |

### 3.3. Perioperative outcomes

Overall operative time was 160 ± 93 min and estimated blood loss was 148 ± 234 ml. Skin incision length at closure was 3.5 ± 1.5 cm. Mean hospital stay was 3.6 ± 2.7 d with a pain VAS at discharge of 1.5 ± 1.4. Perioperative outcomes for the most commonly performed procedures are presented in Table 3.

### 3.4. Complications and conversions

An additional port was used in 23% of cases. In 34% of these, a 2- to 3-mm extra port was used, whereas in the remaining 66% of cases, an extra 5- to 12-mm additional port was required.

The overall conversion rate was 20.8%, with 15.8% of cases converting to reduced-port laparoscopy, 4% to conventional laparoscopy or robotic surgery, and 1% to open surgery. Reasons for conversion were difficult dissection (37% of converted cases), failure to progress (21%), bleeding (25%), difficult suturing (11%), difficult retraction (3%), and difficult access (3%).

The intraoperative complication rate was 3.3%, with need for conversion to open surgery occurring in three cases and laparoscopy in five cases (Table 4).

Postoperative complications were encountered in 9.5% of cases, most being low grade according to Dindo-Clavien [13] (Table 5). The overall transfusion rate was 6.1%.

There was no difference in terms of conversion to laparoscopic or open surgery and in complication rates when comparing the two study periods. Use of additional instruments or ports, needlescopic or minilaparoscopic, or standard (reduced-port laparoscopy) approach occurred more frequently during the 2009–2010 period (Table 2).

### 4. Discussion

The first two large series of urologic LESS were published in 2009 [14,15]. Since then, other early single-center experiences have been reported, as have early comparative studies, albeit limited by small numbers, nonrandomized design, and lack of standardization in the assessment of postoperative outcomes [5]. Overall, these series suggested that LESS was not inferior to conventional laparoscopy in terms of perioperative outcomes, and revealed an encouraging trend toward less postoperative pain and better cosmesis.

Recently, two prospective trials comparing LESS versus laparoscopy have been reported. Tugcu et al compared LESS simple nephrectomy and conventional laparoscopic simple nephrectomy [16]. Time to return to normal activities was reduced in the LESS group and all patients undergoing LESS were very pleased with cosmetic outcome. Kurien et al conducted a randomized comparison of clinical outcomes following standard laparoscopic and LESS donor nephrectomies [17]. LESS donor nephrectomy gave early pain relief with shorter hospital stay and comparable graft function than standard laparoscopy.

Although they represent the highest level of evidence currently available in medicine, randomized controlled trial
results are not linearly generalizable. Even if more prone to be biased, real-life-practice studies might enjoy higher external validity [18].

The present analysis provides an overview of practice patterns and surgical techniques and outcomes in urologic LESS worldwide. The use of a central reporting system allowed standardized reporting from different institutions embracing this technique in a variety of settings and health care systems.

As a general principle, all eligible laparoscopic-surgery patients may be considered for LESS. On the other hand, although performed by experienced laparoscopic surgeons, patient selection with LESS is more rigorous than with conventional laparoscopy and the threshold for conversion is low [11]. Disease features, as well as patients’ features, are to be considered.

When looking at the overall population of our study, patients were relatively young, nonobese, and of low surgical risk. Almost one fourth of cases patients elected LESS, even if they had had previous abdominal or pelvic surgery.

### Table 2 – Temporal trends in urologic laparoendoscopic single-site surgery (LESS) surgery

| Procedure                  | Overall (n = 1076) | Period 2007–2008 (n = 234) | Period 2009–2010 (n = 842) | p value |
|----------------------------|--------------------|----------------------------|----------------------------|---------|
| Mean cases per mo, no.     | 27.3 ± 14.5        | 13.9 ± 5.1                 | 37.1 ± 11.4                | <0.001  |
| High-score procedures, %   | 24                 | 33.3                       | 21.5                       | <0.001  |
| Robotic LESS procedures, % | 13                 | 5.5                        | 15.4                       | <0.001  |
| Type of procedures, no.    |                    |                            |                            |         |

### Table 3 – Outcomes for most commonly performed urologic laparoendoscopic single-site surgery procedures

| Procedure                  | Cases, no. | ORT, min | EBL, ml | WIT, min | LOS, d | VAS       |
|----------------------------|------------|----------|---------|----------|--------|-----------|
| Radical nephrectomy        | 210        | 158 ± 47.5 | 168.3 ± 217.6 | –        | 4.1 ± 2.6 | 1.5 ± 1.1 |
| Simple nephrectomy         | 130**      | 160.7 ± 71.5 | 165.9 ± 331.9 | –        | 3.7 ± 2.6 | 2 ± 1.4   |
| Partial nephrectomy        | 127        | 208.3 ± 165.3 | 276.9 ± 294.3 | 18.4 ± 15.5 | 1.6 ± 1.7 | 1 ± 0.2   |
| Renal cyst decortication    | 115        | 90.9 ± 35.5 | 29.5 ± 41.5 | –        | 2.6 ± 1.2 | 1.2 ± 1    |
| Pyeloplasty                | 89         | 223.7 ± 72.4 | 69.7 ± 70    | –        | 3.8 ± 4   | 1.9 ± 1.5  |
| Adrenalectomy              | 55         | 153.5 ± 65.1 | 123 ± 118.6  | –        | 3.6 ± 1.5 | 1.9 ± 1.5  |
| Donor nephrectomy          | 51         | 175.2 ± 53  | 118.3 ± 96  | 5.1 ± 1.8 | 2.5 ± 1.1 | 1.4 ± 1.6  |
| Ureterolithotomy           | 51         | 138 ± 62  | 63.8 ± 60.3 | –        | 3.2 ± 1.6 | 1.8 ± 1.5  |

### Notes

- ORT = operative room time; EBL = estimated blood loss; WIT = warm ischemia time; LOS = length of stay; VAS = visual analog score at discharge.
- **Including four bilateral cases.
- Including one bilateral case.
- Including one bilateral case and seven cases with a renal vein thrombus.
- Including one case done in conjunction with a simple nephrectomy and one case done with a varicocelectomy.
tract surgery was performed much more frequently. One might argue that the adoption of nephron-sparing techniques might be slowed by LESS, similar to what has happened with standard laparoscopy [19]. However, it should be emphasized that, whenever feasible, nephron-sparing surgery should be the main treatment option for patients with renal masses, regardless of the surgical approach.

Not surprisingly, extirpative or ablative procedures were more commonly performed than reconstructive ones. This

Table 4 – Intraoperative complications

|                        | Cases, no. (%) | Case requiring conversion to open surgery, no. | Cases requiring conversion to laparoscopy, no. | Comment |
|------------------------|---------------|-----------------------------------------------|-----------------------------------------------|---------|
| Vascular injury        | 19 (1.7)      | 3                                             | 4                                             | Including injury to IVC (two cases), renal vein (two cases), adrenal vein (two cases), portal vein (one case) |
| Bowel injury           | 6 (0.5)       | –                                             | –                                             | Including minor serosal tears (five cases) |
| Splenic injury         | 2 (0.2)       | –                                             | –                                             | Including one minor and major injury |
| Diaphragmatic injury   | 2 (0.2)       | –                                             | –                                             | Minor injuries |
| Others                 | 7 (0.6)       | –                                             | –                                             | Including bleeding during transvesical enucleation of prostate (three cases), minor liver injury (one case), rectal injury (one case), ureteral injury (one case), pleural injury (one case) |
| Total                  | 36 (3.3)      | 3 (0.3)                                       | 5 (0.4)                                       | –       |

IVC = inferior vena cava.

Table 5 – Postoperative complications according to Dindo-Clavien [13]

| Grade | Cases, no. | Overall cohort, % |
|-------|------------|-------------------|
| 1     | 36         | 3.3               |
| 2     | 41         | 3.8               |
| 3a    | 14         | 1.3               |
| 3b    | 7          | 0.6               |
| 4a    | 5          | 0.4               |
| Total | 103        | 9.5               |
can be related to the recognized unfavorable ergonomics with LESS. A solid laparoscopic background is desirable before embarking in LESS. Peculiar features of this technique (ie, crossing or collision of instruments, lack of triangulation, and in-line vision) represent additional challenges for the surgeon compared with standard laparoscopy. These tasks become even more demanding reconstructive procedures when suturing is needed. An effective strategy can be the use of needlescopic or minilaparoscopic instruments in the nondominant hand to aid in triangulation. These are introduced through a small puncture requiring no formal closure and their use is still regarded as part of LESS [11].

To overcome current constraints, da Vinci robotic technology has been applied to LESS. Some robotic features are likely to be effective in pursuing this aim [20]. In 2008, Kaouk et al reported the first successful series of single-port robotic procedures in humans and noted an improved facility for intracorporal dissecting and suturing due to robotic instrument articulation [21]. Encouraging outcomes for robotic LESS have been reported by the same group [22–24]. Overall, robotic LESS represented 13% of this entire series, with an expected increase in the period 2009–2010.

Although addition of the da Vinci system to LESS has improved limitations experienced with conventional LESS, we are still in the infancy of robotic single-site surgery [20]. Currently available robotic platforms remain bulky, as they have not been specifically designed for LESS. Robotic innovations are in development [20,25]. As robotic surgery has aided the spread of laparoscopy, it is likely that robotics will play a major role in the development of LESS.

According to current endorsed nomenclature [3,4,11], LESS access can be obtained either by performing a single skin and fascial incision, through which a single multichannel access platform is placed (single port) or by placing several low-profile ports through separate fascial incisions (single site).

Several access devices have been developed for single-port surgery to allow simultaneous use of multiple instruments and their clinical application has been shown [22,23,26,27]. Each device presents specific features aiming to facilitate LESS. However, the ideal platform is yet to be defined [28].

In the present series, a single-port access was used most commonly, and the umbilicus was the most frequently chosen access site. All commercially available ports have been adopted and among them, the TriPort (R-port)/Quadport has been more frequently used. This platform was among the first to appear on the market; thus, it is likely that the use of one port over others has been dictated in each center primarily by availability. Interestingly, in one third of the procedures, homemade single-port devices were used.

Access was preferably through the umbilicus, which can obviously offer the desirable cosmetic outcome of a virtually scarless surgery. The choice of an extrumbilical site can be related to the approach (eg, tip of the 12th rib for retroperitoneal access) or specific indications, such as adrenalectomy (parapectal or subscolal site), donor nephrectomy (Pfannenstiel incision), or simple prostatectomy (above pubic symphysis). Bucher et al recently assessed the perception and preference of women regarding conventional laparoscopy, umbilical LESS, and transvaginal natural orifice transluminal endoscopic surgery (NOTES). An anonymous questionnaire was given to female medical and paramedical staff, patients, and the general population. With similar operative risk, 87% preferred LESS, 4% preferred NOTES, and 8% preferred laparoscopy [29].

With the increasing number of centers performing LESS, there was an expected increase in the number of cases per month; however, the rate of more advanced procedures significantly declined. This can be explained by the fact that centers starting LESS in the period 2009–2010 have opted for less challenging procedures in their early experience. An exception can be represented by adrenalectomy, almost exclusively performed by LESS in the 2009–2010 period. Because of the anatomical topography of the adrenal gland, the distance from the entry port to the target organ in a transumbilical LESS approach is suboptimal and this ultimately translates into a more demanding procedure. A retroperitoneal approach has been proposed [30] or a subcostal incision [31], which is cosmetically less appealing. A Pfannenstiel incision might represent an option when performing a donor nephrectomy [32].

In general, as for conventional laparoscopy, both transperitoneal and retroperitoneal routes have been described for LESS with variable strategies in terms of patient positioning, incision site, and port placement. Experience with retroperitoneal urologic LESS remains limited [30,33]. The retroperitoneal approach can limit working space, which, in LESS, can be even more problematic. In the present series, a transperitoneal approach was used most often. Several reports have described the use of fixed-shaft bent, as well as actively articulating, instruments to facilitate single-port surgery [2,5]. Although these instruments are helpful in resolving the problems of triangulation, the lack of sufficient strength to provide robust retraction and dissection persists. The use of articulating or prepent instruments was adopted by the majority of surgeons in our series.

When considering main perioperative outcomes, it can be grossly estimated that some of the most commonly performed LESS procedures (eg, radical or partial nephrectomy, pyeloplasty, adrenalectomy, and renal cyst decortication) compare favorably with reported series of their laparoscopic counterparts [34–38]. Some concerns remain for some other procedures, such as donor nephrectomy, where the warm ischemia times tend to be longer than in mature laparoscopic series [39], or ureterolithotomy and simple nephrectomy, where operating time tends to be longer [40,41].

It has been wisely stated that sensitivity to the potential for complications is critical and the threshold for conversion must be appropriately low [5–11]. Irwin et al first reported a study looking at complications and rates of conversion from LESS to conventional laparoscopy during upper tract urologic procedures [7]. Overall, 125 patients were included
in the analysis. Conversion to conventional laparoscopy was necessary in 5.6% of cases and complications occurred in 15.2% of patients undergoing LESS surgery.

The overall conversion rate in our series was 20.8% (15.8%, reduced-port laparoscopy; 4%, conventional laparoscopy or robot-assisted surgery; and 1%, open surgery). In 21% of cases, surgeons decided to convert because limitations of LESS prevented them from progressing or, more specifically, to proceed with suturing (11%); to have adequate counter traction (3%); or to gain adequate access (3%). In 25% of cases, conversion to laparoscopy or open surgery was made necessary by safe management of complications.

Overall, the intraoperative complication rate in our series was 3.3%. Most complications were managed conservatively, with conversions to open or laparoscopic surgery occurring only in 0.7% of cases. Postoperative complications were detected in 9.5% of cases, with most being low grade. When comparing these figures to reported rates of complications for urologic laparoscopy [42–44], there seems to be no significant difference, suggesting a duplication of outcomes, even if LESS can be still considered in its infancy and improvements are likely.

The strength of the present study is represented by the large number of patients, which probably mimics what is seen in real-life practice. Nevertheless, some limitations of this project are to be recognized. First, it represents a retrospective analysis. Centers were asked by and agreed to provide their raw data to a principal investigator who collected them into a purpose-built datasheet. Thus, even if data had been prospectively collected by each center, biases related to the retrospective design remain. For the same reason, the analysis was necessarily limited to variables that were available and of sufficient quality to allow a reliable assessment. Second, almost all invited centers had separately reported part of these data in the past 3 yr. Third, as no control group has been considered in the current analysis, the actual benefits of LESS compared to standard laparoscopy and the recently rediscovered scarless options, such as mini-laparoscopy, remain to be definitively proven [45]. As with any new surgical technique, LESS requires further clinical validation. Data from longer clinical follow-up are awaited. Prospective comparative studies are beginning to appear [16,17] or are under way.

5. Conclusions

This study reports the largest multi-institutional experience with urologic LESS to date. It provides a real-life-practice picture of what has been done so far in this field worldwide. Despite unsolved challenges, LESS can be regarded as an emerging trend in minimally invasive urologic surgery and it has significantly evolved, becoming a widely applicable technique in a relatively short time. Outcomes demonstrate that a broad range of procedures can be effectively and safely done by applying different LESS techniques in a variety of hospital settings. Undeniably, a solid laparoscopic surgical background and stringent patient-selection criteria are critical for successful LESS. Application of robotic technology may further facilitate LESS.

Author contributions: Riccardo Autorino had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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