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REVIEW ARTICLE

Minilaparoscopy and laparoendoscopic single-site surgery: mini- and single-scar in urology

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Abstract

Purpose: To review the development of laparoscopic single-site surgery (LESS) and minilaparoscopy (ML), with particular attention to the urological field, focusing on nomenclature, history and outcomes. **Methods**: A literature search was conducted on laparoendoscopic single-site surgery, minilaparoscopy, needlescopy and microlaparoscopy. The most relevant papers were selected over the last 30 years. **Results**: 830 manuscripts were found about LESS, 251 in urology, two CRTs and nine match-case controls. 258 papers were about ML and 55 in urology. ML is the main topic (169 papers), followed by needlescopy (58) and microlaparoscopy (32). The most significant articles are four non-randomized match-case control studies. **Conclusions**: Over the last few years, many urological laparoscopic operations have been successfully performed by LESS. However, the actual role of LESS remains to be determined with controversial data about postoperative pain control and almost no results on cosmesis. We are facing second-generation ML with superior performance granted by new endoscopes and most effective instruments. ML has demonstrated in almost all urologic indications to be feasible, safe and able to improve cosmetic and postoperative pain control. Anyway, CRTs are still lacking and only studies from other discipline can corroborate this trend.

Key words: *laparoendoscopic single-site surgery, minilaparoscopy, needlescopy, microlaparoscopy*

Introduction

In recent years surgeons have undertaken new routes to further reduce trauma and been chasing a new concept, the pursuit of cosmetic appearance (Figure 1A).

The shift from classic "multi-wound" laparoscopic surgery to "single-wound" laparo-endoscopic single-site surgery (LESS) and to "scarless" natural orifice translumenal endoscopic surgery (NOTES) has been driven by this tendency towards a minimally invasive approach (1).

Although these techniques have progressively reduced invasiveness, they increase the complexity of the procedure. Both LESS and NOTES present lack of triangulation, need to manage instruments in a parallel fashion, difficulty to manipulate and dissect tissues, risk of postoperative hernia and absence of specific tools. In spite of worldwide experiments with LESS in all urological fields, it is still not easy to perform. NOTES has been performed only in experimental environments because safety and superiority over classic procedures have not yet been confirmed.

Interestingly, other authors have tried to decrease invasiveness by preserving the classic tenets of laparoscopy, i.e. triangulation. Some examples are small strategic laparoscopic incision placement (SLIP), which hides the incisions in strategic less visible areas, and single-incision triangulated umbilical surgery (SITUS), where three trocars are placed through an enlarged umbilical incision (2)

Moreover, the technological improvement has encouraged the rediscovery of miniaturized laparoscopic instruments. Already in 1977, the application in emergency laparoscopy of the "mini and micro-wound" offered by mini-laparoscopy (ML) (instruments of 3-mm) and needlescopy (NS) (2-mm)

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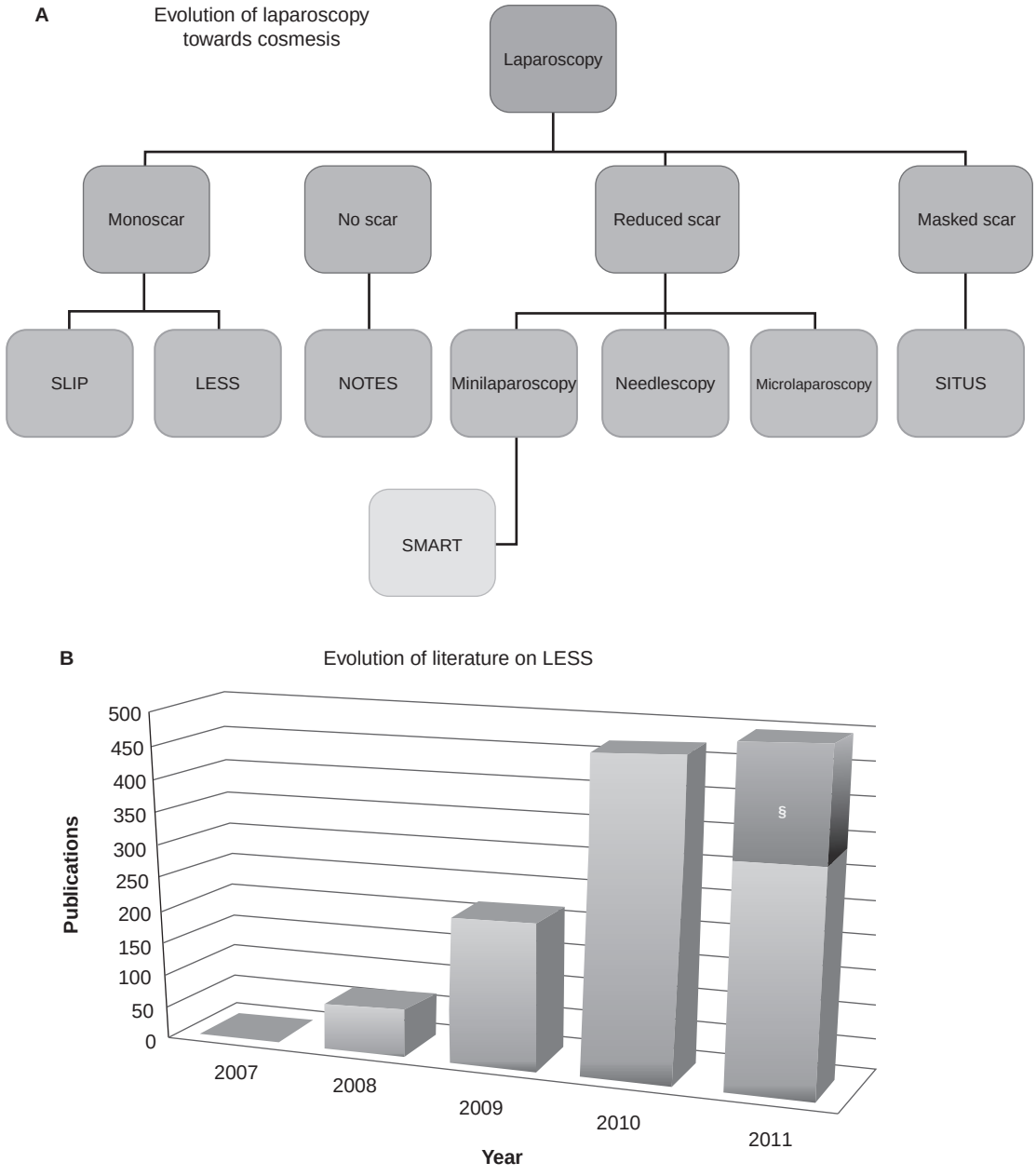

Figure 1. (A) Evolution of laparoscopy towards cosmetic improvements. (B) Publications on LESS from 2007 to august 2011. §: Prevision of publication (2011).

seemed to be promising (2). This refinement of laparoscopy could further reduce its invasiveness with the use of 3.5- and 2.5-mm instead of 6- and 13-mm ports. After an initial extensive use in gynecology, ML has been widely applied in general surgery and now this is the discipline that offers most clinical randomized trials (CRT) in the literature. ML could offer assistance to LESS and NOTES and even to normal laparoscopy.

The purpose of this work is to retrace the route of LESS and ML, giving special attention to urological clinical applications.

Material and methods

A comprehensive electronic English literature search was conducted in order to retrieve articles related to laparoendoscopic single-site surgery (LESS), minilaparoscopy (ML), needlescopy (NS) and microlaparoscopy (mL) from January 1977 to August 2011. PubMed, Medline and Ovid databases were used. We retrieved data combining surgical subject heading (MeSH) search terms and related articles function. Keyword searches included: laparoendoscopic single-site surgery, single-port surgery, single-incision

laparoscopy, minilaparoscopy, needlescopy and microlaparoscopy. Selection criteria were based on the journal, authorship and/or content. Case reports were reported only when adding new important information, demonstrating steps forward in target achieved and new advances in technical progress. Because of the lack of CRT in urology, several studies dealing with general surgery and gynaecology were used in ML to retrieve results regarding cosmetic appearance, post-operative pain control and benefits analysis.

In this paper two separate sections are discussed: LESS and ML.

Results

Eight-hundred and thirty manuscripts were found about LESS. Four-hundred and eighty four are related to general surgery, 80 to gynaecology, and 15 to thoracic surgery (Figure 1B). The first work among 251 papers in urology was published in 2007 (1), two CRTs and nine match-case control studies.

Two-hundred and fifty-eight papers were about ML, 14 reviews, 126 in general surgery, 86 in gynaecology, 55 in urology, 31 in thoracic surgery. ML was the main topic in 169 papers, needlescopy in 58 and microlaparoscopy in 32. No CRTs were available in urology and the most significant articles were four prospective non-randomized match-case controls.

Laparo-Endoscopic Single-site Surgery (LESS)

Definition and nomenclature

Several terms have been used to refer to this variance of laparoscopy. A consensus statement in 2010 agreed on the use of laparoendoscopic single-site surgery (1).

LESS represents any minimally invasive surgical procedures

- performed through a single entry port,
- applicable to multiple locations (abdomen, pelvis, thorax),
- utilizing laparoscopic, endoscopic or robotic instrumentation,
- transumbilical or extraumbilical access.

Single-port and single-site identify LESS performed by introducing a multi-trocar access platform through a single cutaneous/skin incision and several trocars through a separate fascial incision, respectively. Any procedures performed with an additional port should be referred to as Hybrid-LESS (1).

Instrumentation

Several multichannel devices are available on the market (Figure 2A–G), alternatively a small diameter head trocar with separate fascial incision could be used. The main targets pursued in construction of the former are to grant the maintenance of pneumoperitoneum, to allow easy interchange and movement of the instruments, ensuring the cleanliness of optics, allowing a smooth evacuation of gases/ fumes.

Standard laparoscopic instrumentation may be used; however, the result is often a clash of instruments outside of the patient, due to the obliged parallel work. In order to ensure a certain degree of triangulation, multiple measures have been proposed, including tools of different lengths and a 30° 5 mm telescope with built-in light optics. Recently, more options have become available with different advantages and disadvantages (Table I). Articulated (Figure 2H–I) and bent (Figure 2L) instruments allow for intracorporeal triangulation. Bent instrumentation is more cost-effective because it is reusable. However, the restriction on the degrees of freedom might result in a steeper learning curve than with articulating instruments. Dedicated new instruments have been built trying to promote ergonomics, increase freedom of movement, and reduce costs through reusable instruments. Newer articulating tools are able to mimic the hand movement reaching 360° of freedom; however, even here some trouble could be encountered by a non-expert laparoscopist.

History, evolution and clinical application

The true LESS, pioneered by gynaecologists in the 1960s, was anticipated by Hirano who performed a retroperitoneoscopic adrenalectomy in 2005 (1). In urology, the first work was presented by Rane et al. (abstract form, 2007 World Congress of Endourology). In this century, Raman et al. reported the first multi-trocar LESS nephrectomy on a porcine model, followed by three human nephrectomies (1).To date, many groups have contributed to demonstrate the feasibility of almost all procedures with a cumulative clinical experience of more than 2000 cases. Few single centres have reported more than 100 case studies (3–5). Recently, a worldwide multiinstitutional analysis allowed to report 1076 cases (6). Most procedures were extirpative/ ablative (84%) and performed in the upper urinary tract (86%), with a transperitoneal (92%) transumbilical (71%) single-port (77%) access. The daVinci robot was used in 143 cases (13%). In the biennium 2009/ 2010 the trend has stabilized on certain procedures such as radical nephrectomy, partial nephrectomy,

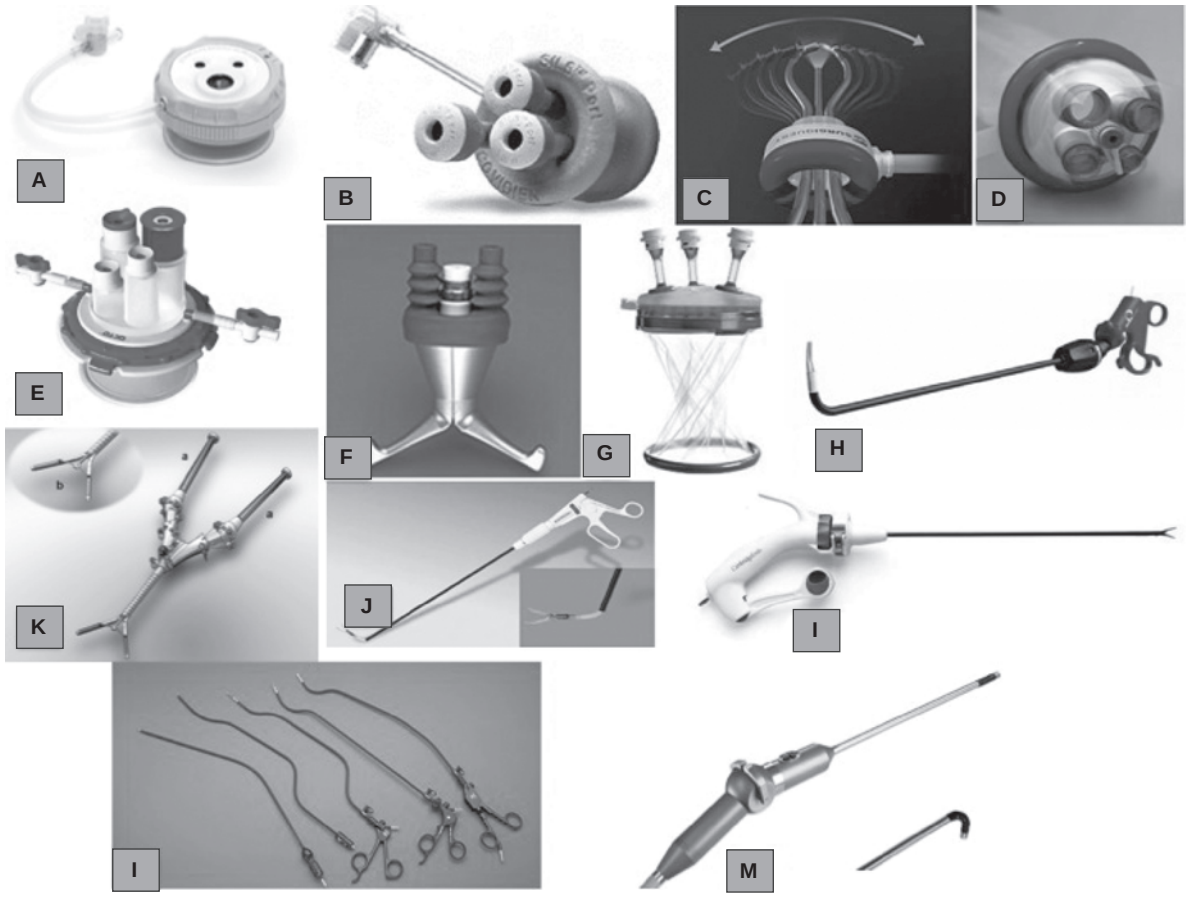

Figure 2. Specialized instruments for LESS (A-M), (A) Single Site Laparoscopy Access System (SSL) (Ethicon Endosurgery, Cincinnati, OH, USA); (B) Sils Port (Covidien, Mansfield, MA, USA); (C) Airseal (SurgiQuest, Orange, CT, USA); (D) Quadport (Olympus Medical, Orangeburg, NY, USA); (E) OCTO Port (DalimSurgNet, Seoul, South Korea) ; (F) X-cone (Karl Storz, Tuttlingen, Germany); (G) GelPOINT (Applied Medical, Rancho Santa Margarita, CA, USA); (H) Real Hand (Novare Surgical Systems, Cupertino, CA, USA); (I) Cambridge Laparo-angle (Cambridge Endo, Framingham, MA,USA); (J) Roticulator (Tyco Healthcare, Pleasanton, CA, USA), (K) SPIDER surgical system (TransEnterix, Durham, NC, USA); (L) S-Portal series (Karl Storz, Tuttlingen, Germany), (M) Ideal Eyes HD (Stryker, San José, CA, USA).

renal cyst decortication, adrenalectomy, varicocelectomy, and ureterolithotomy.

Comparison of LESS versus conventional laparoscopy has been completed in 11 series (7–17) (Table II) about adrenalectomy, simple and radical nephrectomy, renal mass cryoablation, donor nephrectomy, pyeloplasty and sacrocoplopexys; two of these are CRTs and nine are case matched control studies. Perioperative data and outcomes were comparable with few cases of conversion (reduced port laparoscopy/laparoscopy). Results were controversial about postoperative pain control and length of hospital stay. There were no differences in estimated blood loss (EBL) and Hb loss ratio and complication. Just one study reports cosmetic evaluation with no different results. Overall, the quality of evidence remains low because most are retrospective studies, thus susceptible to bias and based on limited samples. Thus, further comparative analyses are still needed.

Drawbacks of LESS

What does LESS need to be competitive with conventional laparoscopy? There are three main problems:

- *Triangulation:* Instrument triangulation allows proper tissue retraction. Placing several parallel instruments makes triangulation more difficult.
- *Retraction:* The lack of additional assistant trocars limits correct exposition of structures.
- *Instrument crowding:* The parallel and close proximity of instruments results in their crowding. Clashing of instruments could be avoided by using bent, articulated and different length instruments (i.e. obese and pediatric equipment). Moreover, recently developed laparoscopes (i.e. Endo-Eye, Olympus, Hamburg, Germany) offer a streamlined profile compared to the standard laparoscopic light cable entering the lens at 90°.

Table I. Instruments used in LESS: port-multitrocar devices; pre-bent and articulating instruments; telescope.

	Device *manufacturer*	Description	Comments
Port-Mutitrocar device	**TriPort™ and Quadport ™** *Olympus Medical, Orangeburg, NY*	Multi-instrument access port lodgeable in a single incision. Single plastic disk connected to a plastic ring by a clear plastic sheet. The plastic disk holds 3 or 4 (10/12-mm and 5-mm) working ports and the insufflation port. When the sheath is tightened, the plastic ring inside fits snugly against the inner aspect of abdominal wall	Easy and safe introduction; incision ranging from 12 – 25 mm; it offers reduced clutter; frequent need to clean camera; easy valve leakage because of usury of gel elastomer
	SILS port™ *Covidien, Mansfield, MA, USA*	A multiple access port. Unique flexible foam plug. It holds 3 interchangeable trocars (5 mm or 10/12 mm) and the insufflation port	Interchangeable trocars, easy set-up, no valve leakage. After lubrication, it could be inserted through a muscle-splitting incision
	Airseal™ *SurgiQuest, Inc. (Orange, CT, USA)*	Single large trocar. Provide insufflation system preventing air leakage by creating an air vortex. No physical seal	Can easily lodge multiple instruments
	X-Cone™ *Karl Storz, (Tuttingen, Germany)*	Two metallic conic parts are kept together by a plastic cap. Four working channels up to 12,5 mm. Requires Hasson introduction	Requires Hasson technique. Reusable. Offers high instrument mobility, stable instrument guidance. Allocates instrument up to 12.5 mm
	Gelpoint™ *Applied medical (Rancho Santa Margarita, Ca, USA)*	Smaller version of the previous Gelport™ (available for hand-assisted procedure), Hasson introduction, provided with insufflation port	Larger profile, port site selection is not fixed; provides adequate spacing and flexibility of port placement allowing improved triangulation
	OCTO™ Port *DalimSurgNet (Seoul, South Korea)*	Allocates up to four instruments. Self wound retractor. Soft Silicon cover. Detachable Port cap with separate smoke evacuation channel	Various Port Mix; good protection of incision infection; easy removal
	Single Site Laparoscopy Access System (SSL)™ *Ethicon Endo-Surgery, Inc. (Cincinnati, OH, USA)*	Low profile; variable size retractor (2–4 cm) and 360° seal able to rotate. No trocars. Two 5 mm and one 15 mm seal	Easy insertion and placement of retractor. Accommodate a wide range of instruments. No need of trocars, eliminates possible interference of cannulas. The rotating removable cap allows for a quick reorientation without instrument exchange and an easy extraction of large specimen
	SPIDER surgical system™ *TransEnterix (Durham, North Carolina, USA)*	4 working channels (2 flexible tubes for instrument delivery laterally located and 2 rigid channels, superiorly and inferiorly to accommodate an endoscope or one of the shelf rigid surgical instruments	It eliminates the awkward crossed arms movement: true right and left instrument manipulation; allows a single surgeon to operate; multiple degrees of freedom
Pre-Bent Instruments	**S-Portal series™** *Karl Storz, (Tuttingen, Germany)* **HiQLS hand instrument™** *Olympus Medical, (Orangeburg, NY, USA)*	Rigid instrument pre-shaped with a double bent	Reduces the crashing outside of the patient; allows to reach a certain level of triangulation; cost-effective because reusable; few degrees of freedom, useful to retract more than to active movement; requires training
	Pnavel Endoscopic™ *Pnavel system Inc (Morganville, NJ, USA)*	Bent laparoscopic grasper	Need of crossing hands

Table I. (*Continued*).

	Device *manufacturer*	Description	Comments
Articulating instrument	**Roticulator**™ *Tyco healthcare, (Pleasanton, CA, USA)*	Laparoscopic grasper and scissors	Deflection not manœuvrable with one hand; they transfer a weak force; articulating only in one plane
	Autonomy laparoangle™ *Cambridge Endo, (Framingham, MA, USA)*	Flexible endoshears, needle drivers and scissors. They can move 360° and be locked in the desirable position	Movement and deflexion obtained in an easy and intuitive way; large and bulky handles; significant learning curve
	RealHand™ *Novare Surgical systems, (Cupertino, CA, USA)*	Flexible grasper, needle holder scissors. The handle is connected to the tips through several cables	Reticulation on 360° mimics hand movement
	SILS Stitch Articulating Suturing devices instruments™ *Covidien, (Mansfield, MA, USA)*	Toggle-activated needle-passing technology. Distal shaft articulation, tip rotation	Different degree of freedom; longer shaft length ideal to avoid clashing outside of patient
Telescope	**EndoEye camera system LS**™ *Olympus Medical, (Orangeburg, NY, USA)*	HD, 5-mm, 30° digital scope	Lower profile, 30° allows working in different plane, reducing instrument clashing
	EndoEye camera system LFT VP™ *Olympus Medical, (Orangeburg, NY, USA)*	HD, 5–10-mm flexible laparoscope, high definition; deflectable tip (100° angulation). Integrated light cable and CCD on the tip	Integration of light cable and camera offers lower profile, reducing instrument clashing
	Endo CAMeleon™ *Karl Storz, (Tuttingen, Germany)*	10-mm; variable direction of view. Provides a viewing angle that can be adjusted continuously between 0 and 12° ; Extra long version (42 cm working length) available	
	Ideal Eyes HD™ *Stryker (San Jose, CA, USA)*	5 mm articulating laparoscope, an angled handle and friction-assist control level allows fixing the articulating tip with great precision; 15° handle bend for proper horizon orientation	

Table II. Comparison of LESS versus conventional laparoscopy: two CRTs and nine match-pair case controls.

	Author (year) study type, (level of evidence)	Access/ trocar/ instrument	Cases	Conversion	OP time (min)	Analgesic	Other results	Complications
Adrenalectomy	Jeong BC (7) (2009) Match case –control (2b)	2-cm umbilical incision; Home made Single port (4 trocars fixed through the fingers of a $6^{1/2}$ surgical glove; fixed to outer ring of wound retractor). Endo-Eye laparoscope, Roticulator instruments; Ultracision	9 LESS	1 (11.1%)	169	Number of days of intravenous (IV) painkiller 0.9 days	Comparable results regarding EBL, and LHS.	1 (11.1%): serosa tearing of small bowel (conservative management)
			17 Lap	1 (5.9%)	144,5 (p = 0.287)	1.9 days (p = 0.047)		1 (5.9%): postoperative bleeding (4 units of concentrated blood transfusion)
Retroperitoneoscopic adrenalectomy	Walz MK (8) (2010); Retrospective Comparison (2b)	2 cm single Access, 2 port, 5-mm 30° endoscope, 5 mm-Bipolar scissors (LigaSure_, Covidian, Neustadt, Germany)	47 LESS	5 to lap	56 ± 28 (20–155)	56% no analgesic		8.5 %, temporary lesions of the subcostal nerve was also noticed
			47 Lap	0	40 ± 12 (20–90)	26% no analgesic		6.4 % temporary lesions of the subcostal nerve was also noticed
	Shi TP, (9) (2011); Retrospective Matched pair comparison (1:2) (2b)	2,5–3 cm single-access, Triport (Olympus), 2 Conventional Instrument (Ultracision (Ethicon)	19 LESS	0	55 (38–120)	No difference in VAPS	No difference in time to resume oral intake, ambulation, LHS and convalescence days	2 (10.5%) angina and contralateral atelectasis
			38 Lap	0	41.5 (25–110)			3 (7.9%) subcutaneous emphysema and one case of radiating shoulder pain occurred
Simple and radical nephrectomy	Raman JD, (10) (2010); retrospective case control study (2b)	Single incision, 3 3 separate fascial incision 5–12 mm (reusable trocars). Hybrid-technique for right procedure (3-mm subxyphoid trocar. Realhand articulating graspers and endoshears	11 LESS	0	122	mMeq (mg) 8 (1–54) vs 15 (0–49) (p = 0.6)	EBL: 20 (10–600) vs 100 (20–520) (p = 0.001); no difference in Hb change and Length of hospital stay, intiating oral intake or regular diet. No blod transufusions	0
			22 Lap	0	125 (p = 0.78)			0
Simple nephrectomy	Raybourn JH 3rd (11) (2010); retrospective case control study (2b)	2-cm periumbilical Single incision, Triport (Olympus). 5-mm 0° HD Laparoscope (Olympus), Autonomy Laparo-Angle Hook (Cambridge Endo), United Stated Sugical (Covidien)	11 LESS (1 Radical)	0	151 (45–290)	mMeq 364 mg	No differences in length of stay (2.3 vs 2.1); EBL (51 vs 68)	2 (20%) 1 port site bruising; 1 Postoperative pyrexia
			10 Lap	0	165 90–220 (p = 0.63)	231 mg (p = 0.55)		1 (10%) delayed return of bowel function
	Tugcu V (12) (2010); Prospective Clinical randomized trial (2b)	Transumbilical 2-cm single incision, SILS Port, 5-mm 30° Laparooscope; Cambridge Endoscopic Flexible devices; liver retraction through stay sutures, specimen morcellation	14 LESS	0	117.5	VAS: significant better for LESS they of op, pod1, pod2, pod3. mMeq significant lower in pod1 and pod 2 for LESS	No difference in EBL, Hospitalisation. Faster return to normal activities for LESS (10.7 vs 13.5 day)	0
			13 Lap	0	114.0 (p = 0.52)			0

Table II. (*Continued*).

	Author (year) study type, (level of evidence)	Access/ trocar/ instrument	Cases	Conversion	OP time (min)	Analgesic	Other results	Complications
Sacrocolpopexys	White WM (13) (2009), Retrospective matched-case control study (2b)	1.8 cm periumbilical incision, Multichannel Single Port Uni-X or Pnavel; 5-mm flexible Laparoscope (Olympus); articulating Cambridge endoscopic devices	10 LESS	0	162	VAPS Score 0.7/10	No differences in length of hospital stay (p = 0.908) and EBL (0.051)	0
			10 Lap	0	151	2.1/10		0
			10 Robotic	0	150 (p = 0.349)	1.4/10 (p = 0.2)		0
Pyeloplasty	Tracy CR (14) (2009), Retrospective matched-case control study (1:2) (2b)	Single 2.5-cm umbilical incision. 5-mm adiacent trocars. Hybrid technique on right side (3-mm subxyphoid port for liver retraction); Articulating graspers and endoshears (Real Hand). 45° 5-mm rigid laparoscope. Endo Stitch device from case 1st to case 7th to perform anastomosis	15 LESS	1 (2 additional port)	202	mMeq 34 mg	EBL (35 vs 85 ml) in favour of LESS (p = 0.02); No difference of Length of Stay (77 vs 74)	5 Clavien I/II: 2 (14.3%); IIIa/IIIb: 3 (21.4%)
			28 Lap)	0	257 (p = 0.01)	38 mg (p = 0.93)		6 Clavien I/II 4 (14.3%); Clavien IIIa/IIIb: 2 (10%)
Kidney cryoablation	White WM (15) (2009); Retrospective matched pair control study (2b)	Single port retroperitoneal	5 LESS	0	174	/	Not difference in EBL (75 vs 100) and hospital stay length: (33 vs 44)	0
			5 Lap	0	120 (p = 0.001)	/		0
Donor nephrectomy	Canes (16) (2010); Retrospective matched pair control study. (2b)	2–2.5-cm vertical intraumbilical incision and single access multichannel (Tri-Port). Needlescopic (2-mm) hybrid procedure. Curved (Novar surgical system) and articulating (Cambridge Endo) where used	18 LESS	1 (1 additional 5-mm port)	269	mMeq 100 mg vs 97 mg (p = 0.9); VASP: 1,4 vs 2.7 (p = 0.2); Oral medication at discharge faster for LESS (6 vs 20 d; p = 0.01)	No difference in EBL (108 vs 141) and Serum craetinine at 3 months (1.3 vs 1.5 mg/dl; p = 0.6), LHS: (3.5 vs 3 d; p = 0.2) WIT longer in LESS (6.1 vs 3.1 min; p < 0.0001); Return to work faster in LESS (18 vs 46, p = 0.0009). Patient reportet scar satisfaction better in LESS 9.5 vs 7.7; p = 0.003)	2 (11%); 1 corneal abrasion; 1 allograft thrombosis
			17 Lap		239 (p = 0.3)			0
	Kurien (17) (2011); Prospective randomized comparative study (1b)	Single umbilical "Z" incision; multichannel TriPort or QuadPort; 10-mm 30 or 5-mm EndoEye telescope. Hybrid procedure (3-mm forceps) in all cases	18 LESS	2 conversions to multiple port laparoscopy	172.2	VAS: advantage of LESS at 60–72 and 96 postopereative hours	No difference in EBL (84 vs 92.4; p = 0.16); Hb drop (0.68 vs 0.87; p = 0.21), Body image score, comesis score, total ischemia before revascularisation and mean e GFR. Longer WIT fro LESS (7.15 vs 5.11; p = < 0.0001). Faster discharge for LESS (3.92 vs 4.56; p = 0.003)	Intraop 4 (16%): 2 minor splenic capsule tear; 1 diaphragmatic tear; 1 small renal upper pole tear. Postop 4 (16%): 3 Clavien I; 1 Clavien II.
			17 Lap	0	175.8 (p = 0.38)			Intraop 2 (8%); Bladder injury; Minor splenic capsule tear. Postop 5 (20%): 4 Clavien I; 1 Clavien II

LESS = Laparoendoscopic single-site surgery; Lap = Classic laparoscopic; mMeq = Mean morphine equivalent; LHS = Length of hospital stay; EBL = Estimate blood loss; VAPS = Visual analogue pain score; WIT = Warm ischemia time.

Level of Evidence: 1a Evidence obtained from meta-analysis of randomized trials, 1b Evidence obtained from at least one randomized trial, 2a Evidence obtained from at least one well-designed controlled study without randomization, 2b Evidence obtained from at least one other type of well-designed quasi-experimental study, 3 Evidence obtained from well-designed non-experimental studies, such as comparative studies, correlation studies and case reports, 4 Evidence obtained from expert committee reports or opinions or clinical experience of respected authorities.

Robotic daVinci LESS

In order to face the limitations initially encountered by LESS, a robotic system seems intuitively to provide an effective solution.

Table III resumes first experiences performed with the widespread daVinci surgical system (Intuitive Surgical, Sunnyvale, CA, USA) (18-24). Robotic LESS could offer major capability for intracorporeal dissecting and suturing due to instrument articulation and stability. Clashing of the daVinci arms represents the primary technical difficulty. Only the introduction of new robots with a small footprint, capable of supporting 3–5-mm trocars and equipped with more flexible and articulate instruments will allow to better exploit its potential.

Evolution of daVinci LESS

Joseph et al. (25) first suggested the "chopstick" technique: Reallocate the remote center of the port at the level of the abdominal wall in order to cross the daVinci instruments and by inverting the instrument controls. The VeSPA (Intuitive Surgical, Ca, USA) is based on the same principle: Specific curved cannulae and instruments and multiport tailored on the daVinci system (26). The system offers a certain triangulation but the instruments are lacking the endowrist technology.

LESS and new robots

New tools should perform more autonomous tasks in a less invasive way at lower costs and dimension. The cameras used in robotic surgery are fixed and limited to only four degrees of freedom (DoF). Some micro-robots provide an unparalleled view of the surgical field and recently new prototypes have been tested on canine prostatectomy and nephrectomy. The pan and tilt micro-robot and the crawler are some examples and the six-DoF remote-controlled miniature robot is capable of applying significant force throughout its workspace with two "arms" (1).

Cosmetics

To date a validated survey for patient reporting of scar satisfaction after abdominal surgery does not exist. Literature and plastic surgeons describe several ways to objectify the results of wound healing. Interesting is the recent study from Park et al. (27), which tries to assess the cosmetic outcomes in patients undergoing kidney surgery, comparing LESS, laparoscopic and open approach. The survey used was based on three main components: Body image questionnaire, photo-series questionnaire and questions querying future surgical approach preference. The patients with LESS provide a higher liking over other approaches with better scar outcomes, even if the prevailing demographic LESS profile was a younger and thinner candidate and mostly operated for benign indications.

Kurien et al. (17) in a CRT did not show any cosmetic advantages in transumbilical LESS donor nephrectomy as compared to classic laparoscopy.

Complications

Irwin et al. (28) analysed the complication/conversion rate of 125 upper tract procedures from a multicentric experience (NOTES Woking Group). Only 5,6% of cases required the addition of ancillary ports (2–5) and just 0.8% needed to control bleeding; there was no need for open conversion. The overall complication rate was 15.2%; however, the frequency was much higher (27,1%) in reconstructive procedures than in those for extirpative/ablative indications (7,8%). Moreover, the former were mainly attributed to the need of a more complex and difficult technique in absence of perfect instruments and by lack of triangulation. Urine leak (2 on 35 pt - 5.7%) and obstruction in pyeloplasty (3 on 35 pt - 8.6%) were higher than in classical laparoscopy (<1% and 3.5–4.8%). Bleeding after partial nephrectomy was higher than in classic laparoscopy.

Reduced port surgery

Definition and nomenclature

Minilaparoscopy (ML, 3-mm). ML-instruments measure 3-mm in size (Figure 3A–B), and trocars 3,5-mm. There has been little or no consensus as to what the appropriate technical definition or terminology should be, nor has it yet been clearly determined how many miniature instruments are required to qualify a ML procedure (2). ML procedures should meet the following criteria:

- For diagnostic/reconstructive procedures, 3-mm instruments should be used exclusively.
- For extirpative procedures requiring specimen extraction, one 10-/12-mm and one 6-mm port are allowed, while all remaining access should be 3.5-mm.
- In retroperitoneoscopic cases the use of a 10-/12-mm port is not necessary to develop the space. As described by Pini and Rassweiler (29), a home-made 5-mm trocar firmly bonded to a two-finger glove is enough to perform an effective dissection (Figure 3C–D).

Table III. Robotic assisted LESS experiences in urology with the daVinci System.

Author/Year	Procedure	Technique	Details
Kaouk et al., 2009 (18)	Radical Prostatectomy (1) Pyelopalsty (1), Radical nephrectomy (1)	Human, Quadport (Olympus) and auxillary port along a single-incision	No complications
Barret et al., 2009 (19)	Radical Prostatectomy	Cadaver, Hybrid-Single-Incision transumbilical LESS, additional 5 mm in right lower abdomen	No copmlications
	Radical Prostatectomy (1)	Human, Pure-Single-incision, 4 trocars	-
Kaouk et al., 2009 (20)	Partial Nephrectomy (2)	Human, Triport (Olympus), pediatric 5-mm instrument and 30° lens, without renal clamping	Surgical margin negative, no complication
Stein et al., 2010 (21)	Radical Nephrectomy (1), Partial Nephrectomy (1), Pyeloplasty (2)	Gelport, Pure-LESS	No complications
Desai et al., 2010 (22)	Transvesical enucleation of the prostate (1)	Human, Quadport (Olympus)	-
Jeon et al., 2010 (23)	Simple (1), Radical (1), Partial nephrectomy (11), Nephroureterectomy (3)	Homemadetrocar, Small Alexis Wound Retractor + Surgical gloves, 30° upward optic	Bowel injury - serosal Teasing (1), Warm Ischemia time: 30.7 min 30–44), Surgical margin negative, 1 open conversion (Bleeding)
White et al., 2010 (24)	Radical Prostatectomy/20) with Iliac Lymphnode Dissection (12)	Human, SILSPort (Covidien)	Nerve sparing procedure (3); positive margins 23.5% Conversion to RALP (1), Additional port (2), 2 weeks urethral catheter for anastomotic leakage (29%); Complications: Clavien II: Lung Embolism (1) and Blood Transfusion (1); Clavien 4: Urosepsis and intensive care hosptalisation (1)

RALP = Robot assist laparoscopic prostatectomy.

Needlescopy (NS, 2-mm). NS-instruments and scopes present an external diameter of 2 mm (2). As such, 2-mm rigid endoscopes, ports, and instruments for NS surgery are currently available. Trocars have an outer diameter comparable to a 14-gauge angiocatheter needle and require only a minute skin puncture for insertion. Earlier reserved for diagnostic purposes only, NS is now being explored for definitive therapeutic procedures as well.

Microlaparoscopy (mL, <2-mm). The term "microlparoscopy" (mL) usually refers to endoscopes that are 2-mm in diameter (2). The initial smaller endoscopes were utilized for visually guided access strategies rather than for purposeful laparoscopy itself (30). However, the fiberoptics of these small laparoscopes had very poor resolution, illumination, and optical clarity. The first account of mL was published in 1993.

Obese patients are unsuitable for mL; the short instrument is likely to end up in the extraperitoneal space, and the low insufflation pressures can be insufficient to lift the weight of the abdomen and provide a good view. Patients with multiple adhesions from previous surgery are also less suitable. Further developments in optics and small instruments could increase the indications for mL.

ML-hybrid procedure. When a procedure does not fully meet the criteria previously described, e.g. the use of a 6-mm instead of a 3,5-mm port.

ML-assistance. In daily practice, an adjunctive port is often required, particularly to retract tissue, to offer assistance during a running suture, etc. The literature offers multiple examples where ML offers assistance during a new fascinating technique such as LESS, NOTES, SLIP and SITUS.

Recently Nicolay et al. (31) described the effectiveness of a NS-assisted laparoscopic nephrectomy versus LESS approach on pigs, showing that the restoration of triangulation enables shorter operative times, increased surgeon comfort, improved technical ease, and lower costs while maintaining the scarless cosmesis of the traditional LESS protocol.

Clinical application

Transperitoneal access in ML. The navel can usually accommodate a 10-, 12-mm trocar without worsening

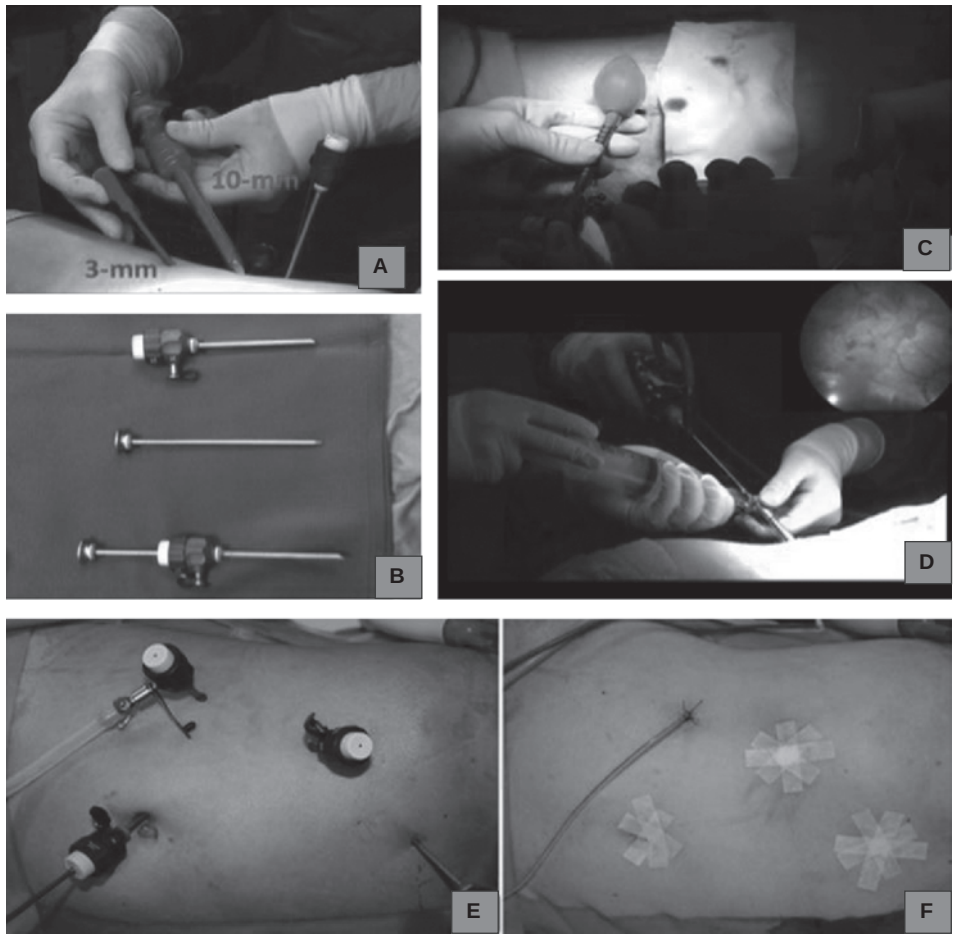

Figure 3. (A,B) Minilaparoscopic (3.5-mm) and classic trocar. (C,D) Retroperitoneal dissection with a 5-mm home-made trocar. The use of a 10-/12-mm port is not necessary and a home-made 5-mm trocar firmly bonded to a two-finger glove is enough to perform an effective dissection. (E,F) Transperitonealfour4-trocar approach for minilaparoscopic pyeloplasty. 4 × 3.5-mm Trocars.

the final cosmetic result. In extirpative procedures it is a prerequisite to retrieve the specimen through the port at the end of the procedure. Moreover, it allows the interchange of instruments: Clips-applier and Endo-GIA-stapler can be easily allocated, while a smaller endoscope (2- or 3-mm) is a temporary shift in the other working ports.

Retroperitoneal access in ML. Already in 1997, Soble assessed the feasibility of NS-retroperitoneoscopy. However, the lack of a miniaturized balloon-dissector/trocar necessitated placement of a primary 10-mm port (32). In 2002, Gaur illustrated a "mini-version" of his previously described retroperitoneoscopic access through a 5-mm trocar (33). By using this approach Pini and Rassweiler described the small-access retroperitoneoscopic technique (SMART) approach for pyeloplasty, aiming to offer adults the benefits of ML, thus preserving all advantages of standard retroperitoneoscopy (29).

Reconstructive indications (Table IVa). Among reconstructive indications few experiences have been reported in ureteral reimplantations (34) and orchiopexys (32–35). Pyeloplasty (29,36–38) (Figure 3E–F) and inguinal hernioplasty (39–42) are most extensively studied reporting a total experience of 1700 cases with the former and 46 with the latter. ML-pyeloplasty results supported by two matched-pair comparisons with classic laparoscopy show superior cosmetic results but no difference in pain control. ML-hernioplasty supported by three non-randomized case control studies with open and laparoscopic approach shows lower recurrence rate and less postoperative pain.

Extirpative surgery (Table IVb). In extirpative surgery, after a few cases series in hydrocelectomy (43) and more extended series in varicocelectomy with more than 170 cases (44,45), adrenalectomy is the most frequent NS-surgery operation because of the

Table IV. Minilaparoscopic clinical experience in (a) reconstructive and (b) extirpative urologic indications.

Procedure	Author, year	Instruments/ approach	Indication/ population	Type of study/ level and grade of Evidence	Procedure/ patients/ follow up	Conclusion
A						
Ureteral reimplantation	Tsai et al., 2008 (34)	ML TP (3-mm scope, 2 × 3-mm Instruments)	Congenital Vesicoureteral reflux	Case series Retrospective (3b)	14 (9 Pediatric)	safe technique with a better cosmetic results
Orchiopexis/ Orchiectomy/ excision testicular remnant	Soble and Gill, 1998 (32) Gilll et al., 2000 (35)	NS TP (2-mm scope, 2 × 3-mm instruments, + 10-mm in Orchiectomy in Adults	Cryptorchidism	Case series Retrospective (3b)	12 (10 - 2 Adult)	
Pyeloplasty	Tan, 2001 (36)	ML TP (5-mm scope, 2 × 3-mm Instruments)	Congenital UPJO	Case series Retrospective (3b)	18 (Pediatric)	reduced postoperative pain and results in a "spectacular postoperative cosmetic appearance
	Munteanu, (37) 2007	ML TP (5-mm scope, 2–3 × 3-mm instruments	UPJO and Pyelolithotomy (1 case)	Case report Retrospective (3c)	2 (Adult)	
	Turial, 2008 (38)	NS TP (2,4-mm Scope, 2–3 × 3-mm instruments)	Congenital UPJO	Case Reports (3c)	2 (Pediatric)	
	Porpiglia, 2011 (In Press)	ML TP (3-mm Scope, 2–3 × 3-mm instrment	UPJO	Prospective non-randomized Match-pair controll (2b)	12 vs 12 classic laparoscopy (Adult)	Better cosmetic results, comparative
	Pini and Rassweiler, 2011 (29)	ML RP (3-, 5-mm scope, 2–3 × 3-mm instruments	UPJO	Prospective non randomized Match-pair controll (2b)	12 vs 12 classic retroperitoneoscopy (Adult)	Better cosmetic results, Earlier drain removal Effective in experience hand
Inguinal hernioplasty	Lau and Lee 2002 (39)	NS TEP (10-mm Scope, 2 × 2-mm Instruments,)	Congenital Inguinal hernia	Prospective non-randomized match-case controll (2b)	30 vs 30 classic laparoscopy	Lower postoperative pain upon coughing on pod 1 In 2002 was not available a bipolar forcep
	Tsai et al. 2010 (40)	ML TAPP (3-mm Scope and 2 × 3-mm Instruments)	Congenital Inguinal hernia	Prospective non-ramdomized comparative cinical trial, (2b)	109 vs 65 open Herniorrapphy (pediatrics)	ML was superior to open prevention of contralateral hernia (0% vs 9,7%)occurrence and overall satisfaction
	Lin et al. 2011(41)	ML TP (3-mm scope and 2 × 2-mm instruments)	Congenital Inguinal hernia	Retrospective non-ramdomized match-case control, (2b)	24 (17 bilateral) vs 31 (9 bilateral) open HErniorraphy Pediatrics	Decrease Longer operative time in monolateral repair
	Turial et al., 2011 (42)	mL + NS TP (1.7–2-mm scope + 2 × 2-mm instruments)		Prospective pilot feasibility study, (2b)	140 100 pediatrics	All procedures were completed microlaparoscopically Hernia recurrence was observed in 2 patients
B						

Table IV. (*Continued*).

Procedure	Author, year	Instruments/ approach	Indication/ population	Type of study/ level and grade of Evidence	Procedure/ patients/ follow up	Conclusion
Hydrocelectomy	Ho et al. 2010 (43)	ML TP (3-mm Scope, 2 × 3-mm instruments	Clinical Hydrocele	Case series (3,B)	22 (21 pediatric)	
Varicocelectomy	Sánchez de Badajoz, Jiménez Garrido (44), 2002	ML TP (3-mm scope umbilical, 2 × 3-mm Instruments)	Scrotal symptomos and/or Infertiilty	Case Series		Microlaparoscopic technique not only reduces surgical aggression, but also the risk of complications is less and it does not increase operative difficulty or operation time
	Chung et al. (45), 2011	NS TP (3-mm Scope, 2 × 2-mm insruments	Scrotal symptomos and/or Infertiilty	Case series	153 (87 Adults)	5-year Follow-up ML approach can preserve spermatic arteries and lymphatic channels without leading to a high varicocele persistence or recurrence
Adrenalectomy	Gnagner et al. 1998 (31)	NS TP	/	Case report	1	
	Gill et al. (46),1998	NS TP (10-mm transumbilical scope, 3 × 2-mm, 5–10-mm clip applier, 10-mm Endo-GIA		Retrospective Match-case controll, (2a,B)	15 vs 21 (Classic laparoscopic) (adults)	
	Mamazza et al. (2) 2001	NS TP		Retrospective Match case non-randomized controll, (2a,B)	3 (Adults)	No significant difference in conversion rates, morbidity,or mortality
	Chueh et al. 2002 (47)	"Clip-less" NS TP, (10-mm transumbilical scope, 2–3 × 2-mm)		Retrospective non-randomized match-case controll, (2a,B)	12 vs 20 classic laproscopy (Adults)	lower mean analgesic requirement, lower mean pain and scar scores and more rapid convalescence Similar blood loss, time to oral intake hospital stay were noted in the 2 groups. longer operative time A 2 mm. port was converted to a 10 mm (inability to retract liver)

Table IV. (*Continued*).

Procedure	Author, year	Instruments/ approach	Indication/ population	Type of study/ level and grade of Evidence	Procedure/ patients/ follow up	Conclusion
	Liao et al. 2006 (48)	"Partial Adrenalectomy" NS TP (10-mm transumbilical scope, 3 × 2-mm)	Aldosterone-producing adenomas	Case series	10 (Adult)	
		NS TP	Pheocromocitoma	Case reports	1 (Adult)	
		NS TP	Tumor less tha 5-mm Benign adrenal pathologies (57 aldosterone-producing adenomas, 23 Cushing's adenomas, 12 pheochromocytomas, and 20 incidentalomas) 1 Leiomyosarcoma	Case series	112 (Adults)	Conversion and transfusion rate was 4.5% and 0.9% and. The NS-instruments are ideal for most adrenal tumor less than 5-mm

ML = Minilaparoscopy; NS = Needlescopy; mL = microlaparoscopy; TP = Transperitoneal; RP = Retroperitoneal; TEP = totally extraperitoneal inguinal hernioplasty; pod = Post operative day. Level of Evidence: 1a Evidence obtained from meta-analysis of randomized trials, 1b Evidence obtained from at least one randomized trial, 2a Evidence obtained from at least one well-designed controlled study without randomization, 2b Evidence obtained from at least one other type of well-designed quasi-experimental study, 3 Evidence obtained from well-designed non-experimental studies, such as comparative studies, correlation studies and case reports, 4 Evidence obtained from expert committee reports or opinions or clinical experience of respected authorities.

relatively small calibre of the vessel and of the gland and the fact that there is no need for excessive traction (30,46-48). A 10-mm transumbilical laparoscope the replacement with a 5-, 10-mm clips applier or a 12-mm endo-GIA vascular stapler, while a 2-mm endoscope can be lodged in the other NS port. Three papers provide a retrospective comparison with classic laparoscopy showing shorter surgical time, less blood loss and shorter hospital stays but the authors agreed that a prior experience with conventional laparoscopy is essential before embarking on NS surgery. The conversion and transfusion rates were 4.5% and 0.9%, respectively, and the authors concluded that the NS-instruments are ideal for most adrenal tumors < 5-mm, also pheocromocytomas. The description of the "clipless" procedure, characterized by the total control of the vessel with bipolar instrument, is also interesting. This series (12 patients) showed longer operative time (46 minutes) justified by the absence of hemostasis control systems.

Minilaparoscopic assisted natural orifice surgery (Ma-Nos). NOTES is currently under clinical investigation because it still presents a number of barriers (1) and only few experiences on humans have been performed. Progression to clinical application has been possible by adoption of the new hybrid surgery approach and the transvaginal route is the only way that has earned its validation in this scenario thanks to the easiness of access/closure and the possibility of retrieval large specimens.

ML-assisted natural orifice surgery (MA-NOS) provides a solution restoring the trocar triangulation over the pure-NOTES approach and solving some disadvantages of the pure ML-technique such as obtaining a rapid insufflation/forceful irrigation or extraction of large specimens. Porpiglia et al. (49) reported a cases series with hybrid transvaginal-NOTES nephrectomy by further reducing invasiveness with the use of 3.5-mm ports instead of the 5- and 12-mm abdominal laparoscopic ports. The transvaginal port provided CO_2 insufflation, an adeguate suction/irrigation, use of ENDO-GIA and Hem-o-lock, necessary preconditions to perform a radical nephrectomy. The authors report an operative time (120 min) comparable to standard laparoscopic techniques. During kidney and pedicle dissection the transvaginal assistance port is essential to overcome the technical limitations of ML.

Advantages of ML

The placement of a ML or NS port results only in a skin needle puncture, and its closure is secured by the

application of a single steri-strip or Dermabond (Ethicon, Somerville, NJ, USA) adhesive tissue without need for any sutures.

Another advantage is the extreme precision and firmness provided by ML-needleholders during reconstruction. This concept is corroborated by the lack of difference regarding operative time in some studies (29), even if other older studies show opposite results (32).

ML-instruments even allow the straightening of the needle prior to retrieval from the trocar. This example shows that the applied force required is not affected by the calibre of the instruments, even if they are superior over NS-instruments in stability, tissue handling and grasping ability.

The use of ML also has the potential to reduce the risk for trocar-site herniation and to decrease the incidence of wound complications primarily by minimizing the consequences of wound infection.

Gill (32) suggested that the delicate 2-mm NS instruments, because of their extremely small diameter, have significant potential to cause "inadvertent" injury to the bowel and viscera. However, other authors have analyzed complications of mL, revealing that the seriousness of the complication is directly dependent on the size of the perforation (2). Using smaller-diameter trocars and instruments reduces trocar-related injuries to both abdominal wall vessels and intraabdominal organs.

Drawbacks of ML

- The quality of laparoscopic vision provided by the 3-mm scope is inferior in terms of image resolution, clarity and light transmitting capacity, in comparison to a 10-mm laparoscope. To improve vision the camera zoom must be set to maximum, and this can impair the definition of the image. Moreover, the image is adequate when the operative field is clean, however, in case of bleeding, the illumination-induced light absorption causes a substantial decrease in image quality.
- ML-clips or Hem-o-lok applicators are unavailable, and this is a clear limitation, in particular when an extirpative procedure is planned. Although the use of bipolar can compensate the lack of a proficient mechanism of coagulation, Platt et al. (2) showed in animal experiments the efficacy and the feasibility of the ML-argon coagulator.
- NS-instruments are extremely delicate and fragile and the functional capability and tensile rigidity of the current 2-mm instrumentation are limited.
- The suction-irrigation cannula, due to its small diameter, has poor flow characteristics and, in some cases, fails to maintain a clear surgical field. The evacuation of smoke can also be compromised by the small-caliber ports, especially when an instrument is inserted.
- Additionally, previous laparoscopic experience is required.

Surgical stress response

Yoder (50) compared the surgical stress responses (cortisol and glucose production) after hand-assisted laparoscopic (HALS) (Hand-assisted device 7-cm, 12-, 12-mm), standard (12-, 5-, 5-mm) and ML (10-, 5-, 2-mm) nephrectomy in a canine model. Even though HALS was faster than other procedures it was associated with a greater operative stress response during the first two hours. The stress differences among the techniques were insignificant by four hours postoperatively.

By analysing the electroconductivity of representative dermatomes Schmidt et al. (51) found that NS provides less sympathetic activity.However, no more differences over laparoscopic cholecystectomy where evaluable at one hour after the operation and visual analogue scale (VAS) presented no difference. This finding can suggest that intraoperative drug administration for analgesia during NS can be reduced as long as the operation time is not prolonged.

Cosmesis

The evaluation of postoperative cosmesis is challenged by the absence of reliable objective scales, potential observer bias, and variation in patients' expectations.

However, in randomized trials comparing NS and conventional laparoscopy in general surgery, both patients and blinded observers scored ML-wounds significantly better with regard to cosmetic appearance (2,52-54).

Although the clinical relevance of differential scarring after small incisions can be questionable, even a small cosmetic benefit may be psychologically important, especially to relatively young women (29).

Pain

Decreased incisional pain is a well-established benefit of laparoscopic surgery, and several investigators in non-urologic CRTs have demonstrated that using smaller incisions significantly reduces postoperative pain scores and analgesic requirements (2,55). However, the direct link between further reduction in the size of access incisions and decreased pain has not been consistently confirmed (2,56). Possible

explanations of divergent findings include a multifactorial etiology of postoperative pain, multimodal analgesic regimens that may theoretically overcome the effect attributable to the smaller accesses, and concomitant use of 10- or 12-mm ports in extirpative procedures.

Learning curve

Previous clinical trials suggested that a steep learning curve exists for NS and that operative time can be longer than that for laparoscopic procedures (57). However, other studies, even performing high-complexity procedures (58), substantiate this claim. We believe that learning curves and operative times are more strongly influenced by the surgeon's background in advanced laparoscopy than by accustomation to smaller instruments. Therefore, progression to NS technique should be undertaken in a stepwise manner, only after acquisition of extensive experience with conventional laparoscopic procedures.

Financial analysis

As introduced by DeQuattro (59) mL-tubal ligation under local anesthesia offers the potential for cost savings (total cost savings for the 29 cases were $16,211) when performed in an outpatient setting by reducing operating time and recovery.

Hobart (60) tried to elucidate the costs of NS-adrenalectomy. NS showed a 18.1% increase in intraoperative and a 63.4% decrease in postoperative charge. Overall NS resulted in a 17.9% decrease in total hospital costs compared to open procedures.

Carvahlo (2) showed in his 1000 series of NS-clipless-cholecystectomy that it entails a considerable reduction in cost, and, as it does not use the 3-mm laparoscope or disposable materials, it is possible to perform the procedure on a larger number of patients. Similar analyses were provided by Chou SH (2).

Recently Nicolay et al. (31) evaluated whether the addition of a single 2-mm subcostal port could restore triangulation while not jeopardizing recovery or cosmetic outcome in the porcine model in comparison with LESS. At the same time they found that the former had significantly lower disposable equipment costs ($363 vs $1696) in comparison withLESS.

Conclusion

Even if ML is older, LESS has been more extensively studied and several comparisons with standard laparoscopy have been performed. Data about postoperative pain and cosmetic results are still lacking in order to confirm what is just a trend. LESS is feasible but challenging. The rate of intra- and postoperative complications and conversion rate remain respectively higher in the former and equal the latter compared to the historical rate of classic laparoscopy. New robots will better define the role of LESS, which nowadays is still a procedure for expert and well-trained surgeons.

The advantage of reduced-size laparoscopic instruments can be insignificant when compared to the progress gained by laparoscopy over the open technique. ML, NS and mL, fruit of the last generation technology, grant an equal effectiveness as classic instruments, even if there is a lack of basic tools such as clips-applier or haemostasis source.

While trocar positions remain in the original setting of classic laparoscopy, the surgeon benefits from the experience already gained. This results in an easier adaptation without establishing a completely new technique as compared to LESS and NOTES. To date, ML offers better cosmetic results and reduced postoperative pain even if no clinical randomized trials are available in urology.

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