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LESSons in minimally invasive urology

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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 (LESS) surgery 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. Technological developments in instrumentation, access and optics devices are overcoming some of the challenges that are raised when operating through a single site. Further advances in the technique have included the incorporation of robotics (R-LESS), which exploit the ergonomic benefits of *ex vivo* robotic platforms in an attempt to further improve the implementation of LESS procedures. In the future, urologists may be able to benefit from *in vivo* micro-robots that will allow the manipulation of tissue from internal repositionable platforms. The use of magnetic anchoring and guidance systems (MAGS) might allow the external manoeuvring of intra-corporeal instruments to reduce clashing and facilitate triangulation. However, the final promise in minimally invasive surgery is natural orifice transluminal endoscopic surgery (NOTES), with its scarless technique. It remains to be seen whether NOTES, LESS, or any of these future developments will prove their clinical utility over standard laparoscopic methods.

What's known on the subject? and What does the study add?

Laparoscopic surgery has evolved in an effort to reduce the complications associated with large incisions during 'open-access' surgery, leading to improvements in blood loss, recovery time, hospital stay, cosmesis, scar pain and hernia formation. LaparoEndoscopic Single-Site (LESS) surgery represents an extension to the minimally invasive principle, using only one small incision to provide access for all of the operating instruments.

We review this novel approach which has been successfully demonstrated across many urological sub-specialities. More experimental modifications to the minimally invasive technique are being developed, including Robotic-LESS and access via natural orifices (Natural Orifice Transluminal Endoscopic Surgery, NOTES). It remains to be seen whether NOTES, LESS, or any of these future developments will prove their clinical superiority over standard laparoscopic methods.

KEYWORDS

laparoendoscopic single-site surgery, LESS, single site, minimally invasive surgery, natural orifice translumental endoscopic surgery, robotics

INTRODUCTION

Ever since Clayman first reported laparoscopic nephrectomy in 1991 [1], urologists have been eager to expand their repertoire of minimally invasive operations in an effort to improve surgical outcomes. Many laparoscopic procedures deliver equivalent outcomes with less morbidity than their open counterparts. An extension of the rationale behind minimally invasive surgery has led to single-incision and even scarless operations, in an attempt to overcome the morbidity associated with port placement, namely scarring, bleeding, infection, damage to internal viscera, hernia formation and poor cosmesis. This mini-review will describe the current status of, and future developments for, single-site surgery in urology.

TERMINOLOGY

A multitude of terms have been used in the literature to describe single-site procedures, including one-port umbilical surgery (OPUS), single-port incision laparoscopic surgery (SILS), single-port laparoscopic surgery (SPLS) and single-port access surgery (SPA). In an effort to achieve consistency in these descriptions, a consortium of surgeons of various disciplines met in 2008 and formulated the term LESS – LaparoEndoscopic Single-Site surgery – to be the all-inclusive term [2].

Natural orifice transluminal endoscopic surgery – NOTES – should be considered as a separate entity from LESS surgery. Here, deliberate incisions of the gastro-intestinal (stomach or rectum) and/or genito-urinary (vagina or bladder) tract are made in order to perform intra-abdominal surgery endoscopically. Modifications of the technique, which exploit additional transumbilical instruments, are sometimes referred to as hybrid NOTES, in contrast to pure NOTES procedures. Confusingly, embryonic NOTES (E-NOTES) has been used to describe laparo-endoscopic procedures that utilize the umbilicus as a point of entry, and should be considered under the umbrella term of LESS surgery.

LESS INSTRUMENTATION

ACCESS DEVICES

Access can be obtained through the use of conventional low-profile laparoscopic trocars

inserted into a single incision site, or, much more commonly, through specially designed multi-channel ports in which a single trocar can accommodate several instruments simultaneously via multiple channels, without leakage of pneumo-peritoneum. One of the most common multi-channel ports in use is the Triport™ (ASC, Dublin/Olympus, NY) – a recent development of the R-Port (ASC/Olympus) access device. The TriPort requires an incision of 1–2.5 cm, and can accommodate one 12-mm and two 5-mm instruments. In comparison, the QuadPort™ (ASC/Olympus) facilitates a 5-mm, a 15-mm and two 10-mm ports. In both of these ports a removable cap allows specimens to be obtained during the operation, without the need to withdraw and replace the entire port. Applied Medical's GelPort™ is inserted through a skin incision of 2–7 cm, and allows the insertion of three conventional ports of various shapes and sizes. The larger extra-corporeal profile allows for greater port spacing, easier assistant access, and the ability to mobilize the ports to anywhere on the GelCap [3]. Whilst GelPort has the facility to accept instruments directly *without* ports, insufflation can lead to expansion of the device, pushing instruments outwards and destabilizing the fulcrum to some extent.

Although the cost of these ports is not insignificant, they serve to reduce clutter and competition for space around the incision site, and may offer cost savings in terms of operation duration [4].

INSTRUMENTS

LESS surgery offers various technical challenges owing to the restrictions of operating around a single site. In an effort to overcome the loss of triangulation, pre-bent and articulating instruments have been developed for use in conjunction with conventional instruments. Although pre-bent instruments require less crossing, they can be difficult to manipulate because of unfamiliar fixed angles and more restricted degrees of freedom; articulating instruments offer more degrees of freedom of movement but can sometimes lack the tensile strength to pull back tissues sufficiently, and are more expensive. Laparoscopic cameras with flexible tips have also been developed, which can replicate triangulation and reduce instrument sword-fighting (for example, the Olympus Endoeye).

CASE SERIES

Rane and colleagues were the first to report a single-site experience in urology, describing radical nephrectomy and transperitoneal uretero-lithotomy using an R-Port access device [5]. Although no complications occurred, the lack of triangulation made the procedures difficult and time-consuming. In an attempt to overcome this, Raman *et al.* described the use of articulating graspers in porcine nephrectomies before employing the technique in three clinical cases [6]. Following this, the first LESS transumbilical pyeloplasty was described, using the R-Port as well as 5-mm fixed-bent grasping forceps for tissue retraction [7]. An additional extra-umbilical 2-mm needlescopic port was used to insert a needlescopic grasper in order to retract and assist in triangulation for suturing. The same group was the first to document a LESS live-donor nephrectomy, demonstrating quality kidney retrieval without intra-operative complications and immediate allograft function upon transplantation [8]. Continuing their efforts, the group went on to demonstrate the feasibility of transumbilical single-port (R-Port) laparoscopic partial nephrectomy in five patients [9]. Again, an additional 2-mm Veress needle was used to aid in tissue retraction and sutured renal reconstruction, together with curved and articulating instruments when necessary. A 5-cm segment of Penrose drain with sutures at each end was used for liver retraction, although one patient with an enlarged liver required a 5-mm subxiphoid port for additional assistance. Tumour excision occurred under warm ischaemia and resulted in negative surgical margins in all five cases.

The first LESS simple prostatectomy for benign prostatic hypertrophy (BPH) has been described, using an intra-peritoneal R-Port. The authors repeated early sentiments regarding difficulties with instrument crowding, which contributed to a longer operating time than with the standard laparoscopic technique [10]. Suprapubic single-port transvesical enucleation of the prostate (STEP) – another LESS treatment for BPH – requires insertion of the R-Port directly into the bladder, establishing a pneumo-vesicum and removing the need for urethral instrumentation or irrigation fluids [11]. There are some technical difficulties in infravesical enucleation with the R-Port in place, and thus, when necessary, a finger was introduced to ease separation of the prostatic adenomas.

In a series of three STEP procedures, technical feasibility was demonstrated, and all patients were spontaneously voiding by postoperative day four, having achieved full continence [11]. Single-port umbilical laparoscopic radical prostatectomy has also been reported for patients with prostate cancer, using curved and articulating graspers to retract and optimize surgical exposure [12]. Extra-corporeal knot-tying was also employed to overcome the spatial constraints within the pelvis. In these first four patients, the 1.8-cm umbilical incision was extended up to 3 cm to extirpate the prostate. The mean operating time was 4.75 h, and there were no intra-operative complications; however, one patient developed a recto-urethral fistula. At 18 weeks of follow-up, three patients used one or no pads for continence daily, two patients had positive margins noted at the site of extracapsular extension, and all patients had an undetectable prostate-specific antigen level [12].

The range of urological procedures amenable to LESS was further expanded with the first report of advanced laparoscopic reconstruction through a single intra-umbilical port [13]. Two bilateral simultaneous pyelo-plasties, one laparoscopic ileal ureter and one psoas-hitch uretero-neocystotomy were successfully performed without complications or the need for any extra-umbilical incisions.

A retroperitoneal approach can offer urologists more direct access to the retroperitoneal organs. The feasibility and efficacy of retroperitoneal LESS has been demonstrated by a Korean group, using a novel homemade single-port device consisting of an Alexis Wound retractor (Applied Medical, CA) and a latex surgical glove [14]. This device provided a larger distance between neighbouring instruments, allowing greater movement; however, retained smoke within the glove had to be regularly released in order to avoid blurring the surgical field. Furthermore, a smaller working space and instrument collision are some of the additional challenges posed by the retroperitoneal approach [14], which may account for its limited uptake in current clinical practice.

Two of the largest groups performing LESS have amalgamated their own initial reports into separate case series, each describing 100 consecutive patients undergoing a range of

urological LESS procedures [15,16]. Both studies demonstrated the safety, feasibility and shortened convalescence for a variety of urological indications, but conceded the existence of a generous learning curve with this technique, as well as a need for prospective comparisons with standard laparoscopy in order to detect subtle differences in morbidity and cosmetic satisfaction [15].

COMPARATIVE STUDIES

In order to compare LESS with standard laparoscopy, matched case control studies have been performed. Whilst these are retrospective and subject to selection and confounding biases, no prospective or randomized controlled studies currently exist in the literature.

The first compared LESS ($n = 11$) with laparoscopic ($n = 22$) radical nephrectomy and found similar operation durations, complication rates, lengths of hospital stay, and analgesic use; cosmesis was the only benefit in the LESS group [17]. A similar comparative study, however, found lower postoperative pain and shorter hospital stays in the LESS group [18]. In a study investigating live-donor nephrectomies, 18 LESS and 17 standard laparoscopic procedures were compared, and a decrease in the number of days off work, oral pain medications after discharge, and days to full convalescence was found for the LESS cohort [19]. With an average of 6 min warm ischaemic time in the LESS cohort, postoperative allograft function was comparable between the two groups. Raman and colleagues went on to compare 14 LESS pyeloplasties with a historical cohort of 21 patients who underwent standard laparoscopic surgery [20]. They found no benefit in analgesic use or length of stay for LESS; however, this study recorded postoperative narcotic use as a measure of pain intensity, rather than using a visual analogue scale.

ROBOTIC-LESS

In an attempt to overcome some of the technical challenges of LESS, robotic-assisted devices are now being used to implement single-site procedures. The first description of Robotic-LESS (R-LESS) was a radical prostatectomy performed in fresh cadavers by the Cleveland Clinic [21]. Following the initial success of transvesical simple prostatectomy [11], Desai and colleagues used the DaVinci S (Intuitive Surgical, CA) to perform a cadaveric R-LESS radical prostatectomy. The telescope, two standard 8-mm robotic instruments, and a patient-side assistant instrument were inserted through the QuadPort's channels, which was itself placed within the bladder wall. Kaouk and colleagues went on to describe the first live human series of R-LESS, performing a radical prostatectomy, dismembered pyeloplasty, and radical nephrectomy using the R-Port and an additional robotic port through the same umbilical incision [22]. Although initial operating times were long and clashing occurred between the robotics arms and the camera, the authors postulated that the learning curve for R-LESS would still be shorter than that for non-robotic LESS, in part owing to the benefits of robotics with regard to suturing.

A recent retrospective review of 18 R-LESS procedures performed at the Cleveland clinic for various upper and pelvic tract operations (including nephro-uretectomy and partial nephrectomies) has revealed encouraging results [23], with procedures benefitting from the use of the GelPort access device during their most recent cases [3]. The R-LESS setup has been further improved by crossing the robotic instruments [24], using 5-mm paediatric-sized instruments, and setting the DaVinci to 'fine-tuning' mode to reduce external collisions of the robotic arms [25].

The robotic platform thus continues to provide a unique opportunity for surgeons to realize the full potential of LESS, making even delicate reconstructive suturing possible via a single site. This could be further refined in the future with lower-profile robotic systems and greater intra-corporeal flexibility.

FUTURE DEVELOPMENTS

NOTES

Scarless surgery – NOTES – represents the final step in minimally invasive surgery. Transvaginal nephrectomies in the porcine model were first described by Gettman *et al.* in 2002 [26], but the technique is yet to gain clinical acceptance owing to a number of significant limitations: parallel instrument placement becomes even more problematic in the depths of an internal orifice, as a result of confinement at the point of entry and by the surrounding viscera; suboptimal exposure and unfamiliar anatomical orientation are further difficulties when operating via natural orifices. Haber *et al.* recently demonstrated the feasibility of NOTES transvaginal nephrectomy in five farm pigs, without the use of any transabdominal assistance [27]. A video-gastroscope and flexible instruments were used together with an articulated endo-GIA stapler (US Surgical, CO), which was inserted via a separate vaginal incision for tissue retraction and renal hilar transection. Despite their initial success, the authors highlighted the need for more suitable instrumentation for use through the gastroscope. Attempts have therefore been made to develop more advanced endoscopes, such as the TransPort (USGI Medical, CA) – a 20-mm flexible endoscope that can be locked into position to create a rigid multi-tasking platform and that allows the independent movement of instruments inserted through its four working channels (two 4 mm, one 6 mm (for optics) and one 7 mm) [28].

Five years after the first human NOTES procedure (a transgastric liver biopsy), Kaouk *et al.* reported the first human pure NOTES urological procedure – a transvaginal nephrectomy in a 58-year-old woman [29]. A multi-channel single-port device was placed across a 3-cm colpotomy, which facilitated the entry of a deflecting laparoscope, articulating graspers and scissors, without any additional transabdominal ports or 2-mm instruments. The operating time of 420 min demonstrated the technical difficulty of dissection with this platform, but its successful completion, with a blood loss of 50 ml and the absence of any peri-operative complications, served as a definitive proof of concept.

MAGS

In single-site surgery, where instrument use is at a premium, delegating any surgical function to trocar-less devices proves invaluable. In 2007, Park *et al.* described a magnetic anchoring and guidance system (MAGS) platform, introduced via a 12-mm entry point [30]. Through the use of extra-corporeal magnets, MAGS was shown to manoeuvre intra-corporeal instruments, retract organs, and securely anchor a camera in a porcine model. Two years later this was

transferred to the clinical setting, where a MAGS camera was used in place of a conventional laparoscope to perform a human LESS nephrectomy [31]. Lens 'smudging and fogging' did occur on two occasions, which required irrigation and cleaning with a swab under laparoscopic guidance. Nevertheless, there was a significant reduction in instrument collisions, and, with stronger magnetic fields and an increased selection of MAGS-compatible instruments, this technology has the ability to further improve the triangulation and ergonomics of minimally invasive surgery in the future [31].

IN VIVO ROBOTICS

Whilst the use of *ex vivo* robotic platforms continues to further the development of LESS and NOTES, engineers are now also looking towards *in vivo* micro-robots. As an example, Lehman and colleagues [32] used an *in vivo* robot to perform a cholecystectomy in a porcine model. The *in vivo* system allowed the surgeon operating from a console to manipulate tissue from an internal repositionable platform, but still required a laparoscope to be inserted for visualization. Furthermore, the *in vivo* robot is still relatively bulky, requiring a large transabdominal incision; attempts to miniaturize these devices and increase their range of actions offer promise for this field in the future.

CONCLUSION

Great efforts are being made to advance minimally invasive surgery, with LESS representing the most clinically relevant development at the present time. What was once an experimental procedure is fast becoming a recognized alternative in many tertiary centres. The learning curve is steep, and surgeons need to critically appraise their techniques in order to achieve potential improvements in port-related morbidity and convalescence.

CONFLICT OF INTEREST

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