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Surgery in Motion

Robotic Laparoendoscopic Single-Site Radical Nephrectomy: Surgical Technique and Comparative Outcomes

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Abstract

Background: Recent reports have suggested that robotic laparoendoscopic single-site surgery (R-LESS) is feasible, yet comparative studies to conventional laparoscopy are lacking.
Objective: To report our early experience with R-LESS radical nephrectomy (RN).
Design, setting, and participants: A retrospective review of R-LESS RN data was performed between May 2008 and November 2010. A total of 10 procedures were performed and subsequently matched to 10 conventional laparoscopic RN procedures (controls). The control group was matched with respect to patient age, body mass index (BMI), American Society of Anesthesiologists score, surgical indication, and tumor size.
Surgical procedure: R-LESS RN was performed using methods outlined in the manuscript and supplemental video material. All patients underwent R-LESS RN by a single surgeon. Single-port access was achieved via two commercially available multichannel ports, and robotic trocars were inserted either through separate fascial stabs or through the port, depending on the type used. The da Vinci S and da Vinci-Si Surgical Systems (Intuitive Surgical, Sunnyvale, CA, USA) with pediatric and standard instruments were used.
Measurements: Preoperative, perioperative, pathologic, and functional outcomes data were analyzed.
Results and limitations: The mean patient age was 64.0 yr of age for both groups, and BMI was 29.2 kg/m^2. There was no difference between R-LESS and conventional laparoscopy cases in median operative time, estimated blood loss, visual analogue scale, or complication rate. The R-LESS group had a lower median narcotic requirement during hospital admission (25.3 morphine equivalents vs 37.5 morphine equivalents; $p = 0.049$) and a shorter length of stay (2.5 d vs 3.0 d; $p = 0.03$). Study limitations include the small sample size, short follow-up period, and all the inherent biases introduced by a retrospective study design.
Conclusions: R-LESS RN offers comparable perioperative outcomes to conventional laparoscopic RN. Prospective comparison is needed to definitively establish the position of R-LESS in minimally invasive urologic surgery.

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1. Introduction

Laparoendoscopic single-site surgery (LESS) represents a progression in laparoscopic surgery and is being reported with increasing frequency [1–10]. Although no randomized data are available in the literature, it appears as though this technique may have promise compared to its conventional laparoscopic counterpart in terms of operative outcomes, postoperative pain, length of hospitalization, and patient-reported convalescence after certain procedures, including nephrectomy and pyeloplasty [11–15].

Unfortunately, LESS is challenging secondary to technical constraints encountered, including lack of triangulation, clashing of instruments, and limited operating space. In an attempt to overcome these limitations, the da Vinci Surgical System (Intuitive Surgical, Sunnyvale, CA, USA) has been applied to LESS and termed *robotic-laparoendoscopic single-site surgery* (R-LESS). Various procedures have been reported, including radical prostatectomy, pyeloplasty, partial nephrectomy (PN), and radical nephrectomy (RN) [16–23]. Herein, we report on our initial experience of R-LESS RN. Our aim is to demonstrate the feasibility of the procedure by describing the technique and analyzing early outcomes in comparison to the gold-standard technique of conventional laparoscopic RN.

2. Methods

2.1. Study design

Data were prospectively entered in an institutional review board–approved LESS database and retrospectively reviewed. A case-control study comparing a single surgeon's experience with 10 R-LESS RN procedures performed between May 2008 and November 2010 and 10 conventional laparoscopic RN procedures performed between August 2008 and June 2010 was completed. Demographic data were accrued, including patient age, body mass index (BMI), American Society of Anesthesiologists (ASA) score, gender, tumor size, and tumor sidedness. The control group was matched with respect to patient age, BMI, ASA score, surgical indication, and tumor size. The preoperative evaluation consisted of standard history and physical exam, basic laboratory blood

Table 1 – Description and evaluation of instrumentation used in robotic laparoendoscopic single-site radical nephrectomy

Instrument	Features	Advantages	Disadvantages
SILS port (Covidien)	Flexible platform; up to three individual ports and instruments	Easy exchange of different-sized ports; allows for instrument tunneling and increased triangulation	Difficult to use with large abdominal walls; requires tunneling of robotic trocars
GelPOINT port (Applied Medical)	Three components: GelSeal cap providing the PseudoAbdomen platform; Alexis wound retractor; self-retaining trocars	Larger outer working profile for enhanced triangulation; adapts to incision and abdominal wall thickness	Fragile; gas leakage during prolonged procedures; decreased working space
8-mm EndoWrist (Intuitive Surgical) monopolar shears	7 degrees of freedom 90 degrees of articulation Intuitive motion and finger-tip control Motion scaling and tremor reduction	Instrument articulation allows access to difficult operative angles	Larger profile; increased instrument clashing because of lack of deflection
8-mm EndoWrist permanent cautery hook	7 degrees of freedom 90 degrees of articulation Intuitive motion and finger-tip control Motion scaling and tremor reduction	Instrument articulation allows access to difficult operative angles	Larger profile; increased instrument clashing because of lack of deflection
8-mm EndoWrist Prograsp grasper	7 degrees of freedom 90 degrees of articulation Intuitive motion and finger-tip control Motion scaling and tremor reduction	Instrument articulation allows access to difficult operative angles	Larger profile; increased instrument clashing because of lack of deflection
8-mm EndoWrist Hem-o-lok (Teleflex Medical) homemade	7 degrees of freedom 90 degrees of articulation Intuitive motion and finger-tip control Motion scaling and tremor reduction	Instrument articulation allows access to difficult operative angles; can be applied by the operating surgeon	Time-consuming; extra large clip size is not available
5-mm EndoWrist Schertel grasper	Robust snake-wrist architecture Intuitive motion and finger-tip control Motion scaling and tremor reduction	Lower profile; triangulation is increased secondary to instrument deflection; functional in a tight working space	Lack of distal instrument tip articulation decreases overall range of motion; decreased grip strength
Robotically controlled Harmonic (Ethicon Endosurgery, Cincinnati, OH, USA) curved shears	Nonwristed instrument based on Ethicon Endosurgery Harmonic technology Simultaneously cuts and coagulates Motion scaling and tremor reduction	Can be applied by the operating surgeon; time efficient	Does not articulate; increased amount of instrument clashing
ENDO GIA stapler (Ethicon Endosurgery)	Ability to staple and transect between six rows of staples	Often requires a single application; time efficient	Must be applied by the bedside assistant; difficult to maneuver through the access device

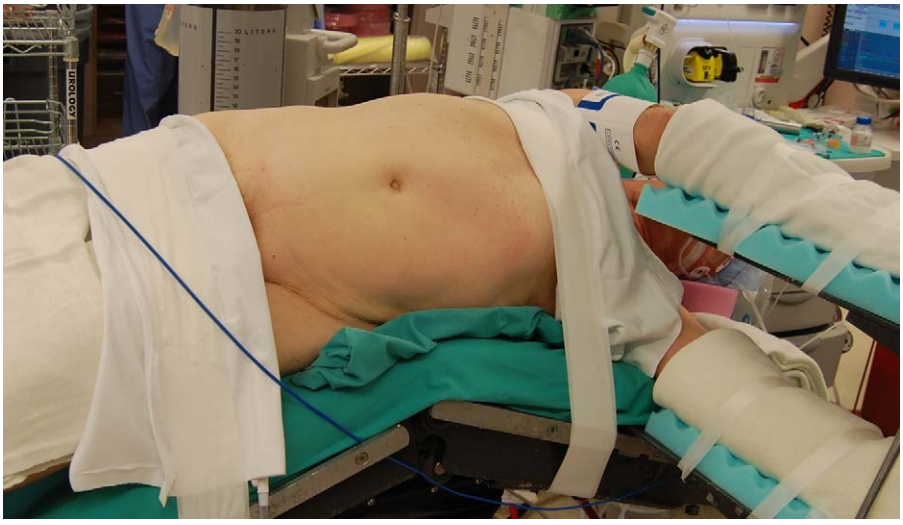

Fig. 1 – Depiction of patient positioning.

work, metastatic staging when required, and further cardiac/pulmonary workup when indicated.

The inclusion criteria for R-LESS RN were presumed malignant renal masses that were not amenable to PN; apart from the exclusion criteria, any patient with a renal mass fit for laparoscopic surgery was offered R-LESS RN. After comprehensive discussion, informed consent was obtained, and patients were counseled that additional incisions may be necessary as warranted during the surgical procedure. Exclusion criteria included previous renal surgery to the diseased kidney, advanced TNM clinical staging (≥T3), metastatic renal cell carcinoma (RCC), bulky lymphadenopathy, masses requiring cytoreduction, previous tyrosine kinase inhibitor treatment, and large upper-pole tumors that would require hepatic or splenic retraction. Additionally, patients with conventional contraindications to laparoscopic procedures, such as uncorrectable coagulopathy, intestinal obstruction, abdominal wall infection, massive hemoperitoneum or hemoretroperitoneum, generalized peritonitis or retroperitoneal abscess, and suspected malignant ascites, were excluded. No patients required pain relievers for preexisting conditions.

Perioperative data, intraoperative complications, length of stay (LOS), visual analog scale (VAS) scores, narcotic requirements, and postoperative complications were recorded. All surgical complications were classified as according to the Clavien classification [24]. Patients were followed at 1 wk after surgery for an incisional check and at 4 wk for kidney function analysis and blood pressure monitoring. They were then seen every 6 mo for 1 yr and annually thereafter for a physical exam and basic laboratory analysis, including complete blood counts, liver function tests, and imaging, if indicated.

2.2. Statistical analysis

SPSS (IBM Corp., Somers, NY, USA) was used to perform all statistical analyses. Statistical significance was set at $p \leq 0.5$. Descriptive analyses were performed to describe the characteristics of patient samples. Paired student t tests were used to compare the outcomes between the two groups.

2.3. Surgical technique

2.3.1. Instruments

Two single-port devices—the SILS port (Covidien, Mansfield, MA, USA) and the GelPort or GelPOINT port (Applied Medical, Rancho Santa Margarita, CA, USA)—were used equally based on surgeon discretion, and the da Vinci S or da Vinci Si Surgical System (in a three-arm approach) was employed. Additionally, the standard robotic scope with a 30° lens directed downward and either two 8-mm or one 8-mm and one pediatric 5-mm robotic trocars were used. Specific robotic instrumentation is listed in Table 1.

2.3.2. Patient positioning and port placement

The patient is positioned in the modified flank position at approximately 60 degrees, and the arms are supported with a double arm board. The table is flexed, positioned in slight Trendelenberg, and the patient is secured (Fig. 1).

The umbilicus is identified and an incision is made, intraumbilically, 2 cm above and 1 cm below the umbilicus. The abdomen is entered in the midline using an open technique. When the SILS port is to be used, the fascial incision is enlarged enough to accommodate two fingers. The robotic trocars are placed inside the skin incision at the apices of the incision. The trocars are tunneled into the abdomen atop two fingers and directed lateral to the midline. The SILS port is inserted with the premade trocars, and the abdomen is insufflated (Fig. 2).

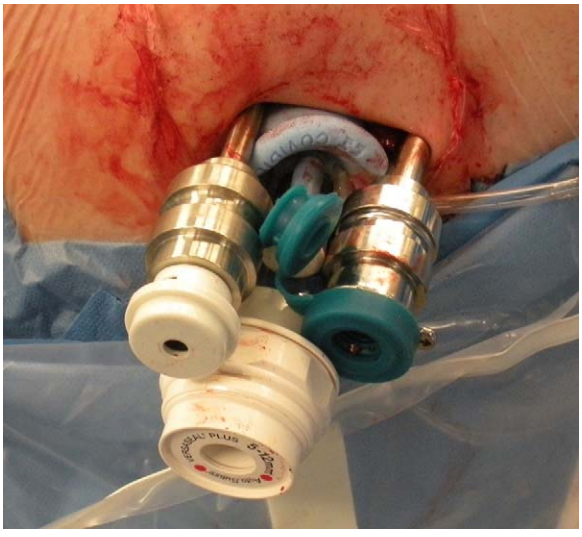

Fig. 2 – SILS port with 5-mm and 8-mm adjacently placed robotic cannulae.

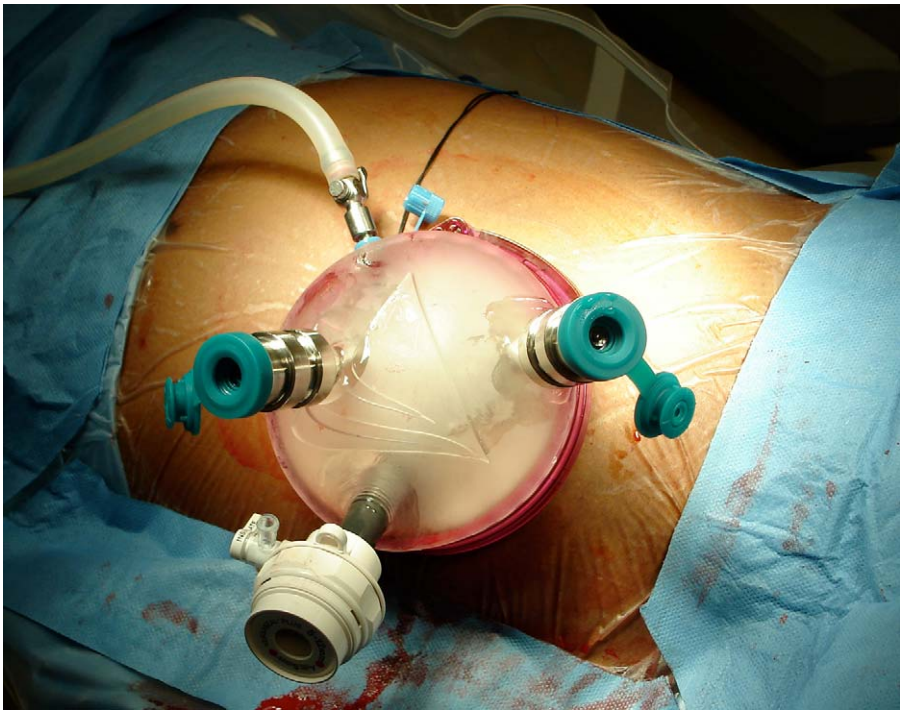

Fig. 3 – GelPOINT platform with trocar configuration.

When the GelPort or GelPOINT port is used, the fascial incision is enlarged, and the device is deployed in the standard fashion. The robotic trocars are inserted at the most cephalad and caudal aspects of the device, while the camera trocar is place at the most medial and central portion (Fig. 3).

Either the da Vinci S or da Vinci Si system (in a three-arm approach) is then positioned over the patient's shoulder, with the camera oriented in line with the kidney, and docked (Fig. 4). No modifications to the robotic system are needed, and the system is docked in the same fashion as traditional robotic renal procedures. The 12-mm robotic scope with a 30° lens directed downward is introduced, and either a 5-mm channel in the SILS port or an additional 12-mm port added through the GelPort or GelPOINT port remains free for assistance. We prefer to use the SILS port with the tunneled trocar configuration to fully optimize our range of motion. In addition, we have used both the da Vinci S and da Vinci Si systems and have not noticed a great deal of difference between the two; however, we prefer the da Vinci Si system, as it offers improved visualization.

Fig. 4 – Robot docked over the patient's shoulder.

2.3.3. *Colon mobilization*

Colon mobilization is performed using the 8-mm EndoWrist (Intuitive Surgical) monopolar shears in the right hand and an 8-mm EndoWrist Prograsp grasper in the left. Instruments are not intentionally crossed throughout the procedure. The bowel is mobilized medially, and dissection continues cephalad to mobilize the spleen or liver. Colon mobilization proceeds similarly to conventional laparoscopic nephrectomy, except that the assistant's suction retraction is more vital to the dissection.

2.3.4. *Ureteral identification*

The ureter and gonadal vein are identified, and dissection proceeds cephalad along the psoas muscle, with slight anterior elevation of the ureter to identify the renal hilum. The assistant provides counter-retraction with the suction device.

2.3.5. *Hilar dissection and control*

After the hilum is identified, it is dissected using either the 8-mm EndoWrist monopolar curved shears or the 8-mm EndoWrist permanent cautery hook. The 8-mm EndoWrist Hem-o-lok clip applier (Teleflex Medical, Research Triangle Park, NC, USA) is used to control the artery, and then the vein. If difficulty in mobilization of the renal hilum is encountered, an endovascular stapler is introduced through a vacant SILS port trocar site after the 5-mm trocar has been removed or directly through the GelPort/GelPOINT faceplate, and the artery and vein are controlled separately.

2.3.6. *Kidney mobilization*

The remaining attachments to the kidney are freed by a combination of blunt and sharp dissection. If the spleen or liver cannot be retracted adequately, an additional 5-mm trocar can be placed outside the initial incision, in a reduced port fashion, to allow for assistant retraction and

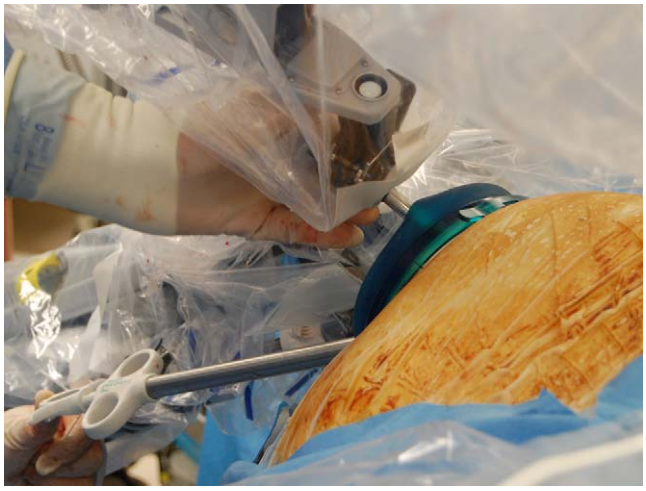

Fig. 5 – A 15-mm entrapment sac is inserted directly through the faceplate of the GelPort port.

completion of upper-pole mobility. Because we have avoided large upper-pole masses and have performed only one concomitant adrenalectomy, we have yet to add a trocar.

2.3.7. Kidney extraction and closure

A 15-mm entrapment sac is inserted through one of the premade trocar sites of the SILS port after the 5-mm trocars have been removed or directly through the faceplate of the GelPort or GelPOINT port (Fig. 5). The specimen is removed and, if needed, the skin incision is enlarged (Fig. 6). The fascia is closed with a large absorbable suture, and the umbilicus is reapproximated to the fascia with the same suture. The subcutaneous adipose tissue is closed with a 3-0 absorbable suture to reduce seroma formation, and the skin is sutured in a subcuticular fashion (Fig. 7). No drain is placed.

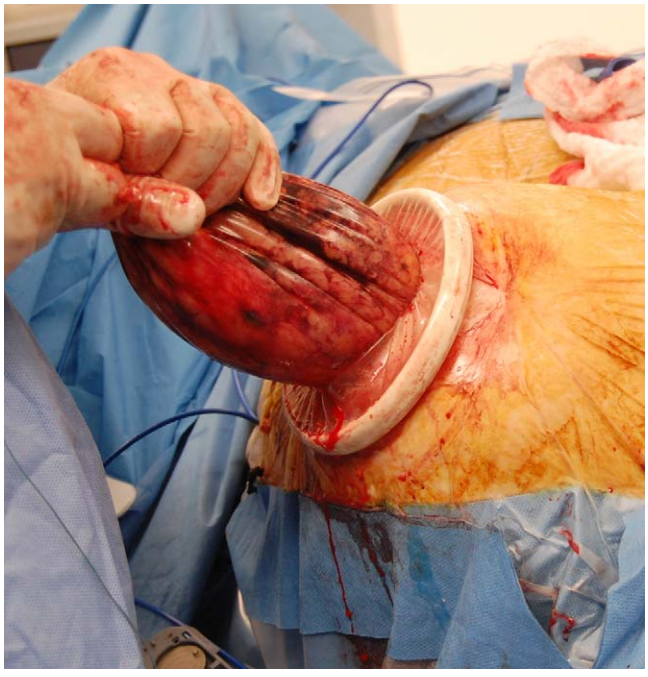

Fig. 6 – Extraction of radical nephrectomy specimen.

Fig. 7 – Postoperative incision closure, 6 cm in length.

2.3.8. Special considerations

If carbon dioxide leakage occurs, Vaseline gauze is packed around the trocars or single-port device. In addition, it is important to exchange instruments carefully when using the GelPort or GelPOINT port to prevent tearing of the wound retractor portion of the device. We have not encountered significant intraoperative hemorrhage, but we are prepared to convert to standard robotic surgery or open surgery, if needed. Another important indication for adding robotic trocars or converting to standard robotic surgery is failure to progress in the procedure. We have not had to convert to standard robotics, but we are cognizant of the possibility.

3. Results

3.1. Demographic data

From May 2008 to November 2010, a total of 10 R-LESS RN procedures were performed at our institution. Complete demographic data are listed in Table 2.

3.2. Operative data

The mean operative time was recorded from skin incision to skin closure. Ketorolac was not administered in either cohort. Operative and postoperative data are provided in Table 2.

3.3. Pathologic data

Nine of the patients in the R-LESS RN group had RCC—seven clear cell and two papillary—with a stage distribution of two T1a, two T1b, one T2, and four T3a tumors. One patient was found to have a benign papillary adenoma. In the conventional laparoscopic RN group, there were seven cases of RCC—five clear cell and two papillary—with a stage distribution of one T1a, one T1b, two T2, two T3a, and one T3b tumors. The additional three patients were found to have oncocytomas. Surgical margins were negative in each group. A single patient in each group was hemodialysis dependent and represented the two small renal masses that required nephrectomy (1.6 and 1.4 cm).

Table 2 – Comparison of patient demographic, perioperative, and postoperative outcomes data for patients undergoing radical nephrectomy by either robotic laparoendoscopic single-site surgery or conventional laparoscopy

	R-LESS	Conventional	*p* value
Patients, no.	10	10	–
Age, yr, median (range)	64 (57–77)	64.5 (61–74)	0.50
Gender, %			
Male	4	6	
Female	6	4	0.44
BMI, kg/m^2, median (range)	28.7 (26.3–33.3)	29.9 (26.0–35.5)	0.76
ASA score	3 (3–3)	3 (2–3)	0.34
Tumor size, cm, median (range)	4.8 (4.5–7.1)	7.6 (5.0–8.4)	0.29
Side, no.			
Right	5	6	
Left	5	4	0.67
Upper-pole tumor location	1	2	0.34
Operative time, min, median (range)	167.5 (150–210)	150 (150–173)	0.28
EBL, ml, median (range)	100 (50–100)	100 (81–150)	0.39
VAS, median (range)	2 (0–5)	0 (0–2)	0.54
Morphine equivalents, mg, median (range)	25.3 (11.0–38.3)	37.5 (33.4–51.3)	0.049
LOS, d, median (range)	2.5 (2–3)	3.0 (3–4)	0.03
Complications (Clavien grade)	1 (grade II)	1 (grade I)	1.0

R-LESS = robotic laparoendoscopic single-site surgery; BMI = body mass index; EBL = estimated blood loss; LOS = length of stay. Range represents the interquartile range (IQR).

3.4. *Complications and conversions*

No cases were converted to conventional laparoscopy or open surgery. In addition, no trocars or additional instruments were required outside of the single incision. Overall, there was a single complication in each group: a Clavien grade 2 conservatively managed skin infection in the R-LESS RN group and a Clavien grade 1 conservatively managed port-site hematoma in the conventional laparoscopic RN group.

4. Discussion

Two of the most significant advancements in minimally invasive urologic surgery since Dr Clayman's first laparoscopic nephrectomy [25] have been the introduction of the da Vinci Surgical System [26] and the development of LESS [3]. The da Vinci Surgical System continues to permeate throughout all laparoscopic procedures and allows for improved dexterity, increased visualization, tremor filtration, and an ergonomic setting to enhance surgeon comfort [27]. Conversely, LESS has gained enthusiasm largely for the promise of improved cosmesis at the expense of instrument triangulation, clashing, operating space, and surgeon comfort.

In an attempt to merge these two approaches and to maximize their benefits, our group introduced the da Vinci Surgical System to several urologic procedures [16,17,19,20,22]. Specific to R-LESS, the robotic platform reduces or eliminates instrument crossing and has superior ergonomics, and instrument tip articulation significantly facilitates suturing. Additionally, introduction of the robotically controlled 8-mm EndoWrist Hem-o-lok clip applier eliminates the need for bedside assistant application of clips or endovascular staplers, which is often difficult and time-consuming.

The current study aimed to describe in detail the technique of R-LESS RN and further compare this technique to conventional laparoscopic RN as performed by a single surgeon in a case-controlled fashion. In controlling for patient age, BMI, ASA score, surgical indication, and tumor size, we hoped to minimize the selection bias between surgical modalities. Our results did not demonstrate a statistically significant difference between the two groups in terms of operative time, estimated blood loss (EBL), VAS, or postoperative complications. However, there was a statistically significant reduction in the RLESS-RN group compared to the conventional laparoscopic RN group in terms of inpatient narcotic requirements and LOS. The skin incision measured 3–7 cm, depending on the specimen size, and was sometimes concealed within the umbilicus.

Perioperative complications occurred in two patients: a Clavien grade 2 (localized skin infection) in the R-LESS RN group and a Clavien grade 1 (port-site hematoma) in the conventional laparoscopic RN group. Both patients recovered uneventfully.

R-LESS RN appears feasible and may result in reduced inpatient narcotic requirements and hospital stay compared to conventional laparoscopic RN. The enthusiasm generated over these results must be tempered, though, as this was a small series and clinical significance must be confirmed with larger, prospective studies. Patient bias or author bias may potentially have played a role in the results, as neither party was blinded to the treatment modality. Additionally, these results are preliminary, and comparison should be regarded as highly limited by the methodology and small numbers included in this study. It must also be noted that our R-LESS technique utilized two separate single-port access devices, two separate methods of inserting the robotic trocars, and two different generations of robotic systems.

When the SILS port is used, the robotic trocars are placed through the muscle, while doing so is avoided using the GelPort or GelPOINT port. We surmise that when R-LESS RN is performed using a single incision through the linea alba

(GelPort or GelPOINT port), the postoperative pain may be reduced further. Unfortunately, we have found that the GelPort or GelPOINT devices do not allow for optimal robotic range of motion compared to the SILS port and the tunneled robotic trocars.

More importantly, we lack a robotic system dedicated to LESS, although modifications to the current system have been made and experimentally tested by Joseph et al. [28]. They determined that the ideal port arrangement for avoiding external instrument clashing requires a triangular port arrangement with 2-cm trocar distance and remote center at the abdominal wall. They termed this technique *chopstick surgery,* as this arrangement crosses the instruments at the abdominal wall, subsequently requiring reassignment of the right- and left-hand effector at the robotic console, and determined that doing so enhanced the functionality of the surgical robot. The ideal robotic system would be task specific, deployable through a single incision, possess articulating instruments, and have reduced external housings. Recently, task-specific instruments and accessories for R-LESS have been developed that allow for deployment of the da Vinci Surgical System via a small single incision through the linea alba while still affording an excellent range of motion [29]. This new system is promising, but its instruments do not contain articulated wrist motion and furthermore have not been cleared by the US Food and Drug Administration, so they have not been applied clinically.

There are a few limitations to the present study that should be mentioned. First and foremost, these results are preliminary and are primarily limited to interpolar renal masses that do not require significant hepatic or splenic retraction. Additionally, only one concomitant adrenalectomy was performed in the R-LESS RN group, restricting application of the results to patients not requiring adrenalectomy. Selection bias may have been introduced as a result of the retrospective nature of this analysis. Currently, this is unavoidable, as this approach is new and feasibility must first be established prior to embarking on a prospective comparative analysis. Because this paper was dedicated to the technical feasibility of R-LESS RN in a small, select group of patients with a mean follow-up of 10.5 mo, a reliable evaluation of oncologic outcomes was outside the scope of this manuscript and cannot be reliably concluded. Finally, this was a single surgeon with considerable LESS and robotic experience; therefore, these results may not be applicable to the general urologist.

5. Conclusions

R-LESS RN is technically feasible, with perioperative outcomes comparable to conventional laparoscopic RN. Although R-LESS RN may offer reduced analgesic use and a decreased hospital stay, prospective comparison is needed to definitively establish its position in minimally invasive urologic surgery.

Author contributions: Jihad H. Kaouk 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.

Study concept and design: White, Autorino.
Acquisition of data: White, Spana, Hillyer.
Analysis and interpretation of data: White, Autorino, Khanna, Spana.
Drafting of the manuscript: White, Autorino, Laydner.
Critical revision of the manuscript for important intellectual content: White, Autorino, Kaouk.
Statistical analysis: Kaouk.
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Supervision: Kaouk, Stein, Haber.
Other (specify): None.

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Appendix A. Supplementary data

The Surgery in Motion video accompanying this article can be found in the online version at doi:10.1016/j.eururo.2011.02.020 and via www.europeanurology.com.

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