Surg Endosc (2015) 29:1241–1249
DOI 10.1007/s00464-014-3807-0

DYNAMIC MANUSCRIPT

Endoscopic robot-assisted simple enucleation (ERASE) for clinical T1 renal masses: description of the technique and early postoperative results

Andrea Minervini · Agostino Tuccio · Lorenzo Masieri · Domenico Veneziano · Gianni Vittori · Giampaolo Siena · Mauro Gacci · Graziano Vignolini · Andrea Mari · Arcangelo Sebastianelli · Matteo Salvi · Sergio Serni · Marco Carini

Received: 18 January 2014 / Accepted: 23 July 2014 / Published online: 27 August 2014

Abstract

Background Simple enucleation (SE) has proven to be oncologically safe. We describe the surgical steps and report the results of the Endoscopic Robotic-Assisted Simple Enucleation (ERASE) technique.

Methods Data were gathered prospectively from 130 consecutive patients undergone ERASE for intracapsular kidney cancer, between 2010 and 2013. ERASE was performed using the 4S Da Vinci surgical system, (Intuitive Surgical, Sunnyvale, CA, USA) in a three-arm configuration. Patients' characteristics and surgical outcomes of ERASE in cT1 were analyzed and the results in cT1a tumors were compared to those of pure laparoscopic SE performed in the same institution in the same time period.

Results The mean (range) preoperative tumor size was 3.2 cm (0.8–10.0 cm), and clinical stage was T1a for 101 patients, T1b for 28, and T2a for 1. Median PADUA score was 8 (IQR 7–9). In 33.9 % of patients, ERASE was done without pedicle clamping. Mean (±SD) warm ischemia time (WIT) was 18 ± 6 min. According to Clavien system, 1 grade 1 (0.8 %), 5 grade 2 (3.1 %), 4 grade 3 (3.8 %), and 1 grade 4 (0.8 %) surgical complications occurred. Positive surgical margin (PSM) rate was 2.8 %. ERASE in cT1a tumors was associated with a significantly lower need for pedicle clamping, shorter WIT, and lower estimated blood loss (EBL) along with similar operative time and intra and postoperative complication rates but with a significantly lower incidence of urinary fistulas requiring stent insertion compared to laparoscopic SE. Also mean time to drainage removal and length of hospital stay (LOS) were significantly lower in for ERASE. The two groups had comparable PSM rate.

Conclusions ERASE has proven to be a feasible technique for the minimal invasive treatment of clinical stage T1 renal masses. The robotic approach can achieve surgical results superior to those of pure laparoscopy by reducing the need for clamping, WIT, EBL, and LOS.

Keywords Partial nephrectomy · Peritumoral capsule · Renal cell carcinoma · RAPN · Robotic partial nephrectomy · Simple enucleation

Partial nephrectomy (PN) with a minimal tumor-free surgical margin is considered the gold standard technique of NSS to minimize the risk of local recurrence [1, 2]. In this scenario, some studies have supported the oncological efficacy of the simple enucleation (SE) technique, defined as the blunt excision of the tumor without a visible margin, following the natural cleavage plane between the tumor capsule and healthy parenchyma. Prospective studies confirmed the SE safety from a pathological perspective [3] and large retrospective series showed its oncological equivalence to standard PN [4–6].

Data from the largest comparative study between open PN (OPN) and laparoscopic PN (LPN) found LPN to be a

Electronic supplementary material The online version of this article (doi:10.1007/s00464-014-3807-0) contains supplementary material, which is available to authorized users.

A. Minervini · A. Tuccio · L. Masieri · G. Vittori · G. Siena · M. Gacci · G. Vignolini · A. Mari · A. Sebastianelli · M. Salvi · S. Serni · M. Carini
Department of Oncology, Urologic Clinic I, University of Florence, Careggi Hospital, Florence, Italy

A. Minervini (✉)
Clinica Urologica I, Azienda Ospedaliera Careggi, Università di Firenze, San Luca Nuovo, Via Lungo Rio Freddo, 50139 Florence, Italy
e-mail: andreamine@libero.it

D. Veneziano
Ospedali Riuniti BMM, Reggio Calabria, Italy

technically feasible, safe, and effective option in selected patients with RCC who are candidates for a nephron-sparing procedure. However, although LPN has the advantages of the minimal invasiveness and it is able to duplicate the open technique with excellent results, it still remains a technically challenging procedure both for the extirpative and reconstructive phase [7–9].

First reported in 2004 by Gettman et al. robot-assisted partial nephrectomy (RAPN) using the da Vinci Surgical System (Intuitive Surgical, CA, USA) represents an alternative procedure to LPN and OPN for the treatment of intracapsular RCCs and has steadily gained acceptance between surgeons [10]. Early feasibility studies have demonstrated that RAPN provides equivalent oncological results to LPN with the further advantage of significantly lower intraoperative blood loss, reduced hospital stay, and WIT [11]. Recent studies have also shown that RAPN can be effectively utilized for the treatment of larger renal tumors that are over 4 cm in diameter and in cases of parahilar lesions [12–15]. Indeed, the 3D vision associated with the 'endowrist' technology allows for excellent vision of the operative field and the possibility of dissecting the tissue optimally by varying the degree of incidence with the target structures.

In this video we present our surgical technique for the treatment of clinically localized renal masses: the Endoscopic Robotic-Assisted Simple Enucleation (ERASE).

It represents the robotic translation of the SE technique, developed in our center over 25 years ago and become the standard of care for NSS either open and laparoscopically [5, 6, 16–18].

Materials and methods

After institutional review board approval was obtained, data were gathered prospectively from 130 consecutive patients who had ERASE and from 67 patients who had laparoscopic SE for intracapsular kidney cancer, between January 2010 and January 2013. Preoperative assessment included blood count, liver function test, serum creatinine, electrolytes. Abdominal CT scan with contrast medium and 3D reconstruction or angio-MRI were used to delineate the vascular anatomy, tumor size, spatial development, involvement of the collecting system, and relationship with the renal sinus. All patients were scored according to the PADUA nephrometric classification [19].

Surgical techniques

A detailed illustration of the surgical techniques for ERASE employed at our institutions can be found in the accompanying video material.

For the present series of ERASE we used the 4S Da Vinci robot, (Intuitive Surgical, Sunnyvale, CA, USA), always in a three-arm configuration with a 30° laparoscope. Laparoscopic SE was performed using a 2D full HD KARL STORZ 30° camera and HD monitor. The transperitoneal approach was always preferred, with the exception of tumors with posterior location, or previous complicated transperitoneal surgery.

Transperitoneal approach

For the transperitoneal approach, the patient was positioned in the flank position, elevated at approximately 70°. Pneumoperitoneum was created using a standard mini-open access. One 12-mm trocar for the camera plus two 8-mm ports for the robotic instruments (Hasson trocar and two 10-mm trocars for the laparoscopic procedure) were used, one in mid-clavicular line 3 cm below the costal margin, and another one, caudally and on the same line to obtain an optimal triangulation. According the complexity of the case and patients' configuration one or two additional trocars were inserted (Fig. 1).

The standard transperitoneal approach was then followed: the peritoneum is incised along the line of Told and the bowel medialized. Once the Gerota's fascia is incised, progressively all landmarks are identified. Subsequently, the kidney is totally freed from the fatty tissue to clearly delineate the limits of the tumor and to detect satellite lesions. In case of posterior tumors the kidney was rotated in order to perform comfortably the extirpative and reconstructive phase. According to the surgeon's preference warm ischemia was obtained with an en-bloc pedicle or a selective/superselective arterial bulldog-clamp.

Retroperitoneal approach

For the retroperitoneal approach, the patient was positioned in flank position, elevated at approximately 90°.

After the open access at the level of the mid-iliac crest, the finger tip is used to mobilize the peritoneum and to create the retroperitoneal space.

For ERASE, a 4-port technique is used, including one 12-mm trocar for the camera at the level of the first incision, two 8-mm trocars for the robotic arms: the first placed at the level of the lateral border of the peritoneal reflection, the second one at the lateral border of the paraspinal muscles and a 12-mm trocar for the assistant is placed on the anterior axillary line between the camera and one of the robotic arm (Fig. 1).

For the laparoscopic approach, again a 4-port technique is used, including three 10-mm trocars, the first placed at the level of the mid-iliac crest, the second one at the lateral border of the paraspinal muscles, and the third at the

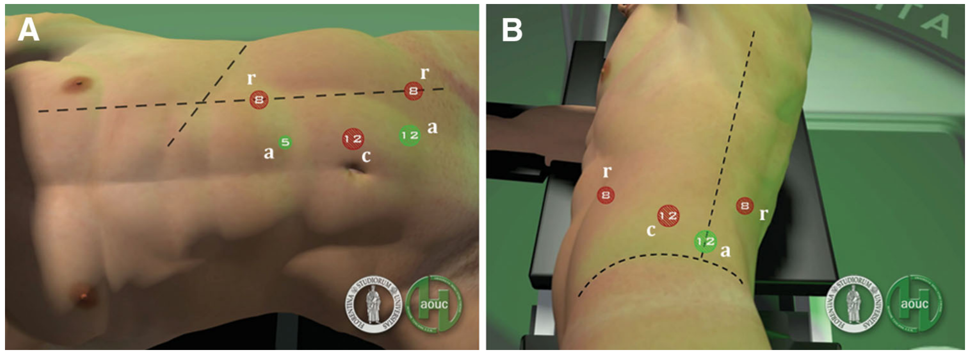

Fig. 1 Port configuration used during ERASE. **A** Transperitoneal approach port placement. **B** Retroperitoneal approach port placement. c = 12-mm port for the robotic scope; r = 8-mm ports for the robotic instruments; a = 12-mm and 5-mm port for the assistant

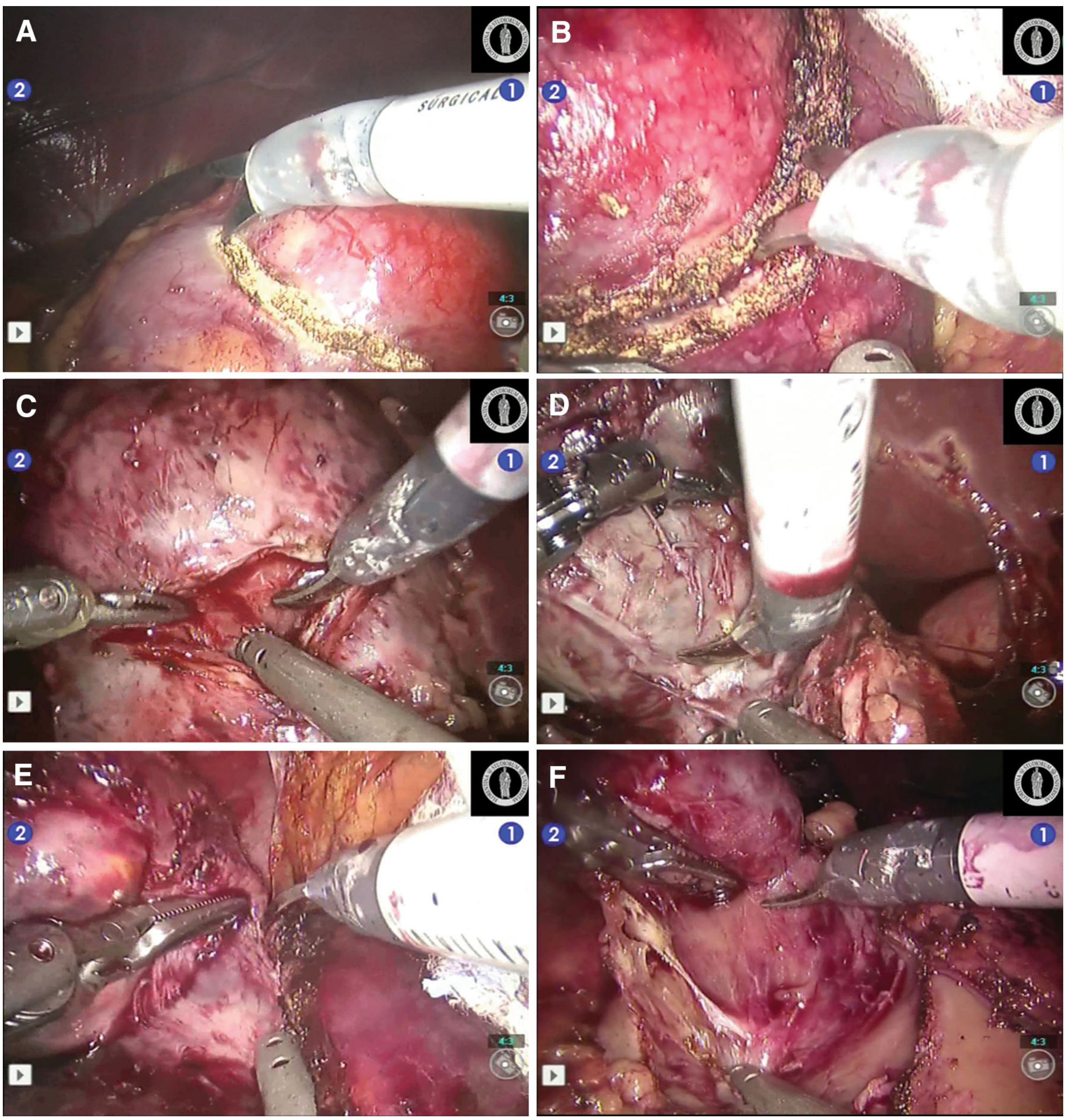

Fig. 2 Intraoperative views showing: Cautery marking (**A**) and incision of kidney parenchyma 1 or 2 mm away from the lesion (**B**). Widening of the space between healthy tissue and kidney tumor with monopolar scissors and bipolar dissector (**C**). The natural cleavage plane between kidney parenchyma and tumor capsule is followed by blunt dissection (**D**–**F**)

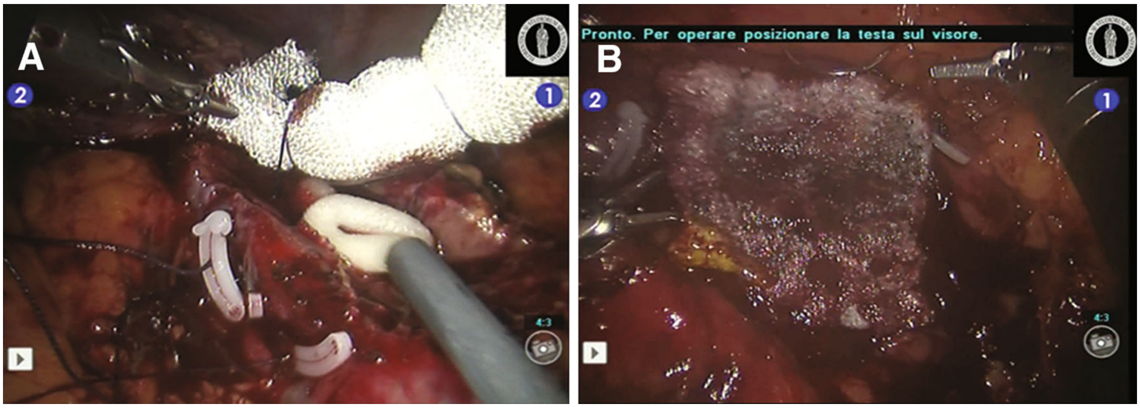

Fig. 3 A sliding clip approximation of the renal capsule defect over Floseal® and Tabotamp® bolster (**A**). Tachosil® apposition without the approximation of the renal capsule (**B**)

anterior axillary line at the lateral border of the peritoneal reflection. A 5-mm trocar is inserted at the tip of the 12th rib.

Intraoperative ultrasonography was used during this period only in case of completely endorenal masses.

Endoscopic Robotic-Assisted Simple Enucleation (ERASE) and laparoscopic SE

To prevent ischemic renal damage, all patients were hydrated and infused with mannitol a few minutes before arterial clamping to minimize intracellular swelling.

To obtain warm ischemia an en-bloc pedicle or a selective/superselective arterial bulldog-clamp is placed.

A clamp less technique was chosen based on the size, site, and growth pattern of the tumor and indications for surgery.

Once the tumor is isolated, its limits are clearly identified and the excision template is marked with cautery, 1–2 mm away from the lesion. The kidney is sharply incised toward the tumor margins and when the tumor capsule is visually identified, the tumor is enucleated by blunt dissection, with no visible rim of normal parenchyma around it (Fig. 2). The preferred instruments used during ERASE were monopolar scissors on the right and prograsp/Maryland grasper on the left. Suction was provided by the table assistant while the preferred instruments used by the first operator during laparoscopic SE were monopolar scissors and suction device. Hemostasis was then controlled either by a knot-tying suture repair (standard-LNSS) or by a sutureless technique (s-LNSS) according to the intraoperative findings.

Hemostasis was then controlled by one or two 2-0 monofilament running sutures on the parenchymal bed with the hemlock® placed on the kidney capsule at the beginning and at the end of the suture. Approximation of the renal capsule defect over Floseal® and Tabotamp® bolster was obtained with a sliding clip 2-0 Vicryl single suture. Alternatively, Tachosil® apposition was used without the approximation of the renal capsule, mainly in case of wide and not deep resection beds (Fig. 3).

When approaching small cortical lesions a sutureless hemostasis was done using a bipolar cauterization of the resection bed, followed by Floseal® or Tachosil ® apposition.

Table 1 Patient demographics and preoperative parameters

Age, year; mean (SD)	61.8 (11.3)
Sex, no. (%)	
Male	76 (58.5 %)
Female	54 (41.5 %)
BMI, median (IQR)	25.7 (23.4–28.3)
ASA score, no. (%)	
0–2	116 (89.2 %)
3	14 (10.8 %)
Charlson index, median (IQR)	1 (0–1)
Clinical diameter, cm, mean (SD)	3.2 (1.5)
Clinical T stage, no. (%)	
cT1a (≤4 cm)	101 (77.7)
cT1b (4–7 cm)	28 (21.5)
cT2a (7–10 cm)	1 (0.8)
PADUA score, median (IQR)	8 (7–9)
Padua scores ≥8, no. (%)	42 (32.3 %)
Padua scores ≥10, no. (%)	10 (7.7 %)
Indication, no. (%)	
Absolute/relative	9 (6.9 %)
Elective	121 (93.1 %)
Preoperative hemoglobin, g/dl, median (IQR)	14.1 (1.5)
Preoperative creatinine, mg/dl, median (IQR)	0.86 (0.30)

BMI body mass index, *ASA* American Society of Anesthesiologists class risk, *SD* standard deviation, *IQR* interquartile range

Table 2 Intraoperative outcomes

Clamping, no. (%)	86 (66.1 %)
Pedicle/renal artery	72 (83.7 %)
Arterial branch/es	14 (16.3 %)
No clamping, no. (%)	44 (33.9 %)
WIT of pedicle/renal artery clamping, min, mean (SD)	18 (6)
WIT >25 min, no. (%)	20 (15.4 %)
Estimated blood loss, ml, mean (SD)	119 (105)
Operating time, min, mean (SD)	158 (56)
Total intraoperative complications, no. (%)	1 (0.8 %)
Transfusion	1 (0.8 %)
Pleural damage	–
Spleen damage	–
Renal vein damage	–

WIT warm ischemia time, *SD* standard deviation

An early unclamping technique was always adopted in case of arterial occlusion with the bulldog-clamp. In such cases, the bulldog-clamp was removed always at the end of the medullar reconstructive phase.

Results

Patients and tumors characteristics in the ERASE group are summarized in Table 1.

The mean preoperative tumor size was 3.2 cm with a range between 0.8 and 10.0 cm, and clinical stage was T1a for 101 (77.7 %) patients, T1b for 28 (21.5 %), and T2a for 1 (0.8 %) patient. Median PADUA score resulted 8 (IQR 7–9), and it was ≥10 in 10 (7.7 %) patients. Indication was elective for 121 (93.1 %) patients, and relative/imperative for 9 (6.9 %).

Intraoperative data are reported in Table 2. In 44 patients (33.9 %), ERASE was done with no pedicle clamping. Clamping was used in 86 (66.1 %) patients, among them pedicle clamping was used in 72 (83.7 %), with a mean ± SD warm ischemia time (WIT) of 18 ± 6 min; while the selective clamping of the isolated arterial branch of the tumor was used in 14 (16.3 %) patients. Overall, 20 patients (15.4 %) had WIT >25 min. Mean (range) operative time (including the console time) resulted 158 ± 56 min, mean ± SD estimated blood loss (EBL) was 119 ± 105 cc. Intraoperative transfusion for bleeding was required in 1 patient (0.8 %) with low preoperative hemoglobin (9 mg/dl).

Postoperative results are summarized in Table 3. Overall, postoperative complications occurred in 16/130 patients (12.3 %); of these, 11 (8.5 %) were surgical and 5 (3.8 %) medical. Surgical complications included blood loss treated with transfusions in 5 (3.8 %) patients, with selective arterial embolization in 3 (2.3 %), and with reoperation to achieve hemostasis in 1 (0.8 %). Urinary fistula occurred in 1 patient (0.8 %) and was treated with bedrest and antibiotics, No patient needed ureteral stenting in this series. One patient underwent reoperation due to spleen rupture, and was treated with splenectomy. According to Clavien system, 1 surgical complication was grade 1 (0.8 %), 5 grade 2 (3.1 %), 4 grade 3 (3.8 %), and 1 grade 4 (0.8 %).

Table 3 Postoperative outcomes

LOS including day of surgery, d, median (IQR)	5 (5–6)
Overall postop complications, no. (%)	16 (12.3 %)
Medical complications, no. (%)	5 (3.85 %)
AF pharmacologically cardioverted	2 (1.5 %)
Pneumonia	1 (0.8 %)
Pleural effusion	1 (0.8 %)
Deep venous thrombosis	1 (0.8 %)
Surgical complications, no. (%)	11 (8.5 %)
Postop transfusions only [Cl.2]	5 (3.85 %)
Selective embolization [Cl.3a]	3 (2.3 %)
Reoperation [Cl.3b]	1 (0.8 %)
Spleen rupture [Cl.4]	1 (0.8 %)
Fistula without stenting [Cl.1]	1 (0.8 %)
Fistula with stenting [Cl.3a]	–
Acute renal failure, no. (%)	2 (1.5 %)
Delta hemoglobin, g/dl, mean (SD)	2.21 (1.81)
Delta creatinine, mg/dl, mean (SD)	0.06 (0.23)

LOS length of stay, *AF* atrial fibrillation, *Cl.* Clavien grade, *SD* standard deviation, *IQR* interquartile range

Table 4 Pathology

Benign tumors, no. (%)	23 (17.7 %)
Malignant tumors, no. (%)	107 (82.3 %)
Histotype of malignant tumors, no. (%)	
Clear cell RCC	68 (63.6 %)
Papillary RCC type 1	15 (14.0 %)
Papillary RCC type 2	6 (5.7 %)
Chromophobe RCC	17 (15.9 %)
Collecting duct RCC	1 (0.8 %)
Fuhrman grade in clear cell RCC, no. (%)	
Grade 1–2	59 (86.7 %)
Grade 3–4	9 (13.3 %)
Pathological T stage, no. (%)	
T1a	70 (65.4 %)
T1b	25 (23.4 %)
T2a	1 (0.9 %)
T3a	11 (10.3 %)
Pathological diameter, cm, mean (SD)	3.0 (1.5)
Positive surgical margins, no. (%)	3 (2.8 %)

RCC renal cell carcinoma, *SD* standard deviation

Table 5 Patient demographics and preoperative parameters of patients with cT1a tumors undergoing ERASE or laparoscopic SE

Preoperative data (cT1a group)	Laparoscopic SE	ERASE	*p*
Age, year; mean (SD)	59.3 (12.5)	62.9 (10.7)	0.06
Sex, no. (%)			0.89
Male	38 (60.3 %)	62 (58.5 %)	
Female	25 (39.7 %)	39 (38.6 %)	
BMI, median (IQR)	25.8 (23.2–28.1)	25.5 (23.2–28.1)	0.08
ASA score, no. (%)			0.12
0–2	60 (95.2 %)	91 (90.1 %)	
3	3 (4.8 %)	10 (9.9 %)	
Charlson index, median (IQR)	1 (0–1)	1 (0–1)	0.77
Clinical diameter, cm, mean (SD)	2.4 (0.9)	2.5 (0.8)	0.23
PADUA score, median (IQR)	7 (6–8)	7 (6–8)	0.83
Indication, no. (%)			
Absolute/relative	0	6 (5.5 %)	0.05
Elective	63 (100.0 %)	95 (94.5 %)	
Preoperative hemoglobin, g/dl, mean (SD)	14.6 (1.4)	14.1 (1.5)	0.12
Preoperative creatinine, mg/dl mean (SD)	0.8 (0.1)	0.8 (0.2)	0.58

BMI body mass index, *ASA* American Society of Anesthesiologists class risk, *SD* standard deviation, *IQR* interquartile range

Table 6 Intraoperative and postoperative outcomes of patients with cT1a tumors undergoing ERASE or laparoscopic SE

Intraoperative data (cT1a group)	Laparoscopic SE	ERASE	*p*
Clamping, no. (%)			0.01
Yes	52 (82.5 %)	64 (64.6 %)	
No	11 (17.5 %)	35 (35.4 %)	
WIT of pedicle/renal artery clamping, min. mean (SD)	20.3 (6.9)	17.3 (5.6)	0.02
Estimated blood loss, ml. Mean (SD)	170 (130.6)	111 (95.0)	<0.0001
Operating time, min	146.2 (45.3)	153.4 (50.1)	0.50
Total intraoperative complications, no. (%)	1 (1.6 %)	1 (1.0 %)	0.85
Days to drainage removal, mean (SD)	4.3 (2.8)	2.8 (1.3)	0.03
LOS including day of surgery, median (IQR)	6 (3-8)	5 (4-6)	0.05
Overall postop complications, no. (%)	5 (7.9 %)	9 (8.9 %)	0.01
Medical complications, no. (%)	0	2 (2.0 %)	0.81
Surgical complications, no. (%)	5 (7.9 %)	7 (6.9 %)	0.26
Urinary fistula treated with stenting, n. %	4 (6.3 %)	1 (1.0 %)	0.05
Selective embolization, n. %	0	2 (2.0 %)	0.52
Delta hemoglobin, g/dl	2.2 (1.3)	2.3 (1.9)	0.81
Delta creatinine, mg/dl	0.1 (0.2)	0.1 (0.2)	0.65
PSM rate	1.8 %	2.2 %	0.45

SD standard deviation, *IQR* interquartile range, *WIT* warm ischemia time, *LOS* length of stay, *PSM* positive surgical margin

At pathological assessment, benign tumors resulted in 23 (17.7 %) patients. Of the 107 confirmed malignant lesions, 68 were conventional clear cell carcinoma (63.6 %), 21 papillary (19.6 %), 17 chromophobe (15.9 %), and 1 collecting duct RCC. Mean ± SD pathological diameter was 3.0 ± 1.5 cm. Pathological stage was pT1a in 70 cases (65.4 %), pT1b in 25 (23.4 %), pT2a in 1 (0.9 %), and pT3a in 11 (10.3 %) cases. Fuhrman nuclear grade in clear cell RCC resulted 1–2 in 59 (86.7 %) patients, and 3–4 in 9 (13.3 %). Positive surgical margin (PSM) occurred in 3 patients (2.8 %) (Table 4).

At a mean (median, range) follow up of 24 months (25, 12–42), all patients were alive, one patient had distant relapse with stable disease under antiangiogenetic therapy. No local recurrences were observed.

In the same period, 67 SE were performed laparoscopically without the robotic assistance and of those 93 % were cT1a (63 cases). A sub analysis of cT1a tumors showed no statistically significant differences between the laparoscopic SE group and the ERASE group for age, gender, BMI, clinical diameter, nephrometric score, preoperative hemoglobin, and creatinine (Table 5). However, all the laparoscopic procedures were elective versus 94.5 % of ERASEs ($p = 0.05$) (Table 5). A comparison of intra and postoperative outcomes among laparoscopic SE and ERASE procedures is reported in Table 6. Overall, a clampless procedure was more frequently performed in case of ERASE than during laparoscopic SE (35.4 vs. 17.5 %; $p = 0.01$) and in case of pedicle clamping, median WIT was significantly shorter after ERASE than after laparoscopic SE (17.3 vs. 20.3 min.; $p = 0.02$) (Table 6). Median EBLs was significantly lower in the ERASE group than during laparoscopic SE (111 vs. 170 ml; $p < 0.0001$) (Table 6). Median operative time was comparable between the two groups (Table 6). Intraoperative complications rate was similar between the two groups (Table 6).

Concerning postoperative data, surgical complication rates were comparable between ERASE and laparoscopic SE (6.9 vs. 7.9 %) with a significantly higher incidence of urinary fistulas requiring stent insertion in the laparoscopic SE group (6.3 %) in comparison to the ERASE group

(1 %). Indeed, mean time to drainage removal ($p = 0.03$) and overall hospital stay ($p = 0.05$) were significantly lower in the ERASE group compared to the laparoscopic approach. Groups were comparable also in terms of PSMs rate.

Discussion

RAPN may overcome the technical limitations of LPN due to three-dimensional visualization associated with the EndoWrist® technology that allows for excellent vision of the operative field and the possibility of dissecting the tissue optimally by varying the degree of incidence with the target structures [10–15]. Moreover, we confirm at least in cT1a that RAPN can provide equivalent oncological results to LPN with the further advantage of significantly lower the need for clamping, WIT, EBL, and LOS [11, 20].

ERASE represents the transposition of open SE to robotic surgery and is becoming the standard technique of NSS in our institution.

SE as a conservative approach in the management of intracapsular renal masses has gained ever more acceptance among urologists [3–6, 16–18, 21, 22]. This technique consists in removing the tumor by blunt dissection, using the natural cleavage plane between the tumor and normal parenchyma, without a visible rim of healthy tissue around it.

SE technique provides excellent perioperative results and a low surgical complications rate. In a prospective series of 200 consecutive patients who had open SE, we reported a low rate of Clavien grade III surgical complications such as urinary fistula requiring JJ stent positioning, that was 0.5 %, and postoperative bleeding requiring superselective embolization of renal artery, that occurred in 2 % of cases [18]. These data compare favorably with the rates reported after standard PN in the best available evidence, that is 4.4 % for urinary fistula and 3.1 % for severe postoperative bleeding [23].

Possible explanation of this evidence might be that SE technique, resecting no renal parenchyma around the tumor, causes the slightest unnecessary deepening of the excision in healthy tissues, resulting in a lower theoretical risk of postoperative bleeding and laceration of the urinary collecting system that can cause the development of urinary fistulas.

In the present series, we recorded a relatively low rate of overall perioperative complications (13.1 %), with a 3.9 % of Clavien grade III–IV surgical postoperative complications, which are consistent with prior published robotic series [20, 24].

Some authors in the past have expressed skepticism about the risk of PSM during SE and the risk of local recurrence resulting from inadequate tumor excision or tumor multifocality closely related to the main tumor [25–27]. However, good oncologic, functional and perioperative outcomes were reported in some large, retrospective series of SE with long-term follow up and we confirm in the present series that ERASE in oncologically safe with no local recurrences at a short term follow up (mean 24, range 12–42 months) [4–6, 16–18].

Recently, a multicentric study conducted by the Surveillance and Treatment Update Renal Neoplasms (SATURN) project, promoted by the Italian Society of Urology that collected data of 1519 patients from 16 academic centers in Italy, showed no statistically difference in terms of progression-free survival, cancer specific survival estimates and local recurrence rate between patients treated with SE and standard PN for RCC. Interestingly, the reported PSM rates in the traditional PN group were significantly higher than those reported in the SE group [28].

In a prospective series of 164 patients with RCC who underwent open SE with no ablation of the tumor bed, we reported no PSM and a local recurrence rate at the enucleation site of 0.6 %, that is in perfect harmony with those reported in the literature after standard PN. This study demonstrates the oncological safety of SE without the presence of the tumor bed ablation bias [17].

A recent prospective study based on pathologic examination of the surgical specimen obtained after SE provided the pathologic rationale of SE. In this study we described that all RCCs suitable for NSS are surrounded by a continuous, not fenestrated fibrous pseudocapsule. This peritumoral pseudocapsule can be penetrated irrespective of tumor size, with a reported infiltration rate of 26.6 % on the parenchymal side, but the presence of a thin layer of parenchymal tissue, not macroscopically detectable, separates neoplastic cells from the enucleation bed and allows for negative surgical margins, also if no efforts are made to leave a rim of healthy kidney tissue around the neoplasm [3]. This microscopic layer of renal parenchyma make it possible to consider SE as a minimal PN [3, 21, 29]. Therefore, if the surgeon follows the natural cleavage plane between tumor pseudocapsule and kidney parenchyma by blunt dissection, thus performing a SE, there is a limited risk of PSM even with larger masses.

This data has been confirmed by our paper on prognostic role of pseudocapsule infiltration, in which emerges that neoplastic infiltration of pseudocapsule on the parenchymal side does not increase the risk of having a local or systemic recurrence [30].

The 3D vision and the EndoWrist® also help to decrease the PSM as they typically provide optimal dissection angles [10–15]. Moreover, a faster and precise removal step, without the need of repositioning the kidney to achieve an incidental angle, that is mandatory during LPN, allows the surgeon to perform a more ergonomic and 'intuitive' tumorectomy and to approach even more difficult cases, such as large, intraparenchymal or perihilar tumors [12–15]. In these latter cases, when the depth of the lesion or the proximity to important vascular structures makes the procedure more challenging, the adoption of the SE technique can be decisive, as the blunt dissection provides a clear dissection plane identification, helping the surgeon to discriminate the natural cleavage plane existing between the tumor and the renal parenchyma, and "to stay close" to the pseudocapsule allows the surgeon to avoid entering into the tumor.

The advent of the robotic platform has certainly changed and will change the conservative renal surgery. In fact, the RAPN has reduced the technical gap of traditional laparoscopy allowing to achieve surgical results superior to those of LPN, especially by reducing the WIT, EBL, and LOS as showed in the present series [11]. Furthermore, the robotic approach allowed to remove the lesions with a significantly lower need for clamping the renal pedicle in comparison to laparoscopic SE. In the present series, ERASE with no pedicle clamping was used in 33.9 % of patients, while arterial clamping or selective clamping of the isolated arterial branch were used in 66.1 % of patients, with a mean $\pm$ SD WIT of 18 $\pm$ 6 min.

The combination of robotic surgery with the SE, ERASE technique, might be considered a further evolution of the NSS, in which the maximum preservation of the renal parenchyma, less WIT, less incidental calyceal tearing or vascular injuries, together with the advantages of minimal invasiveness, were obtained.

The pursuit of natural cleavage plane existing between the tumor and the renal parenchyma might be difficult in smaller and exophytic lesions, so it should not be mandatory for the success of the procedure, but we believe that this technique could be very helpful in complex cases such as large tumors, hilar or centrally located lesions, in order to reduce the risk of damage to noble structures in the renal sinus.

Limitations of the present study include the relatively few patients enrolled, considering that robotic program has started in our institution since January 2010. Moreover, in the first part of the learning curve, many factors such as tumor size, nephrometric score, and surgeon experience might have influenced the decision to perform the procedure in open fashion. However, at our knowledge, this is the sole prospective series of patients, who had NSS performed by SE with the robotic approach.

Conclusions

In our experience, the ERASE has proved to be a feasible and oncologically safe technique for the minimal invasive treatment of clinical stage T1 renal masses. ERASE execution is not a priority even if, in complex cases, such as hilar or endophytic lesions, it leads to an unquestionable advantages compared to a standard RAPN allowing a greater preservation of adjacent structures. Overall, the ERASE is associated with a low risk of postoperative complications and as in the open SE does not imply an increased risk of PSM compared to standard PN. Finally, the robotic approach can achieve surgical results superior to those of pure laparoscopy by reducing the need for clamping, WIT, EBL, and LOS.

Disclosures Drs Andrea Minervini, Agostino Tuccio, Lorenzo Masieri, Domenico Veneziano, Gianni Vittori, Giampaolo Siena, Mauro Gacci, Graziano Vignolini, Andrea Mari, Arcangelo Sebastianelli, Matteo Salvi, Professor Sergio Serni, and Professor Marco Carini have no conflicts of interest or financial ties to disclose.

Funding No funding or other financial support was received.

References

1. Ljungberg B, Cowan NC, Hanbury DC et al (2010) EAU guidelines on renal cell carcinoma: the 2010 update. Eur Urol 58:398–406
2. Antonelli A, Cozzoli A, Nicolai M et al (2008) Nephron-sparing surgery versus radical nephrectomy in the treatment of intracapsular renal cell carcinoma up to 7 cm. Eur Urol 53:803–809
3. Minervini A, Di Cristofano C, Lapini A et al (2009) Histopathological analysis of peritumoral pseudocapsule and surgical margins status after tumor enucleation for renal cell carcinoma. Eur Urol 55:1410–1418
4. Kutikov A, Vanarsdalen KN, Gershman B et al (2008) Enucleation of renal cell carcinoma with ablation of the tumour base. BJU Int 102:688
5. Carini M, Minervini A, Lapini A et al (2006) Simple enucleation for the treatment of renal cell carcinoma between 4 and 7 cm in greatest dimension: progression and long-term survival. J Urol 175:2022
6. Carini M, Minervini A, Masieri L et al (2006) Simple enucleation for the treatment of pT1a renal cell carcinoma: our 20-year experience. Eur Urol 50:1263
7. Gill IS, Kavoussi LR, Lane BR et al (2007) Comparison of 1,800 laparoscopic and open partial nephrectomies for single renal tumors. J Urol 178:41–46
8. Lane BR, Gill IS (2010) 7-year oncological outcomes after laparoscopic and open partial nephrectomy. J Urol 183:473–479
9. Shikanov S, Lifshitz DA, Deklaj T et al (2010) Laparoscopic partial nephrectomy for technically challenging tumours. BJU Int 106:91–94
10. Gettman MT, Blute ML, Chow GK, Neururer R, Bartsch G, Peschel R (2004) Robotic-assisted laparoscopic partial nephrectomy: technique and initial clinical experience with DaVinci robotic system. Urology 64:914–918
11. Benway BM, Bhayani SB, Rogers CG et al (2009) Robotic partial nephrectomy versus laparoscopic partial nephrectomy for renal tumors: a multi-institutional comparison of over 200 procedures. J Urol 182:866–873

12. White MA, Haber GP, Autorino R et al (2011) Outcomes of robotic partial nephrectomy for renal masses with nephrometry score of ≥7. Urology 77:809–813
13. Dulabon LM, Kaouk JH, Haber GP et al (2011) Multi-institutional analysis of robotic partial nephrectomy for hilar versus nonhilar lesions in 446 consecutive cases. Eur Urol 59:325–330
14. Patel MN, Krane LS, Bhandari A et al (2010) Robotic partial nephrectomy for renal tumors larger than 4 cm. Eur Urol 57:310–316
15. Laydner H, Autorino R, Spana G et al (2012) Robot-assisted partial nephrectomy for sporadic ipsilateral multifocal renal tumours. BJU Int 109:274–280
16. Minervini A, Serni S, Tuccio A et al (2012) Simple enucleation versus radical nephrectomy in the treatment of pT1a and pT1b renal cell carcinoma. Ann Surg Oncol 19:694–700
17. Minervini A, Serni S, Tuccio A et al (2011) Local recurrence after tumour enucleation for renal cell carcinoma with no ablation of the tumour bed: results of a prospective single-centre study. BJU Int 107:1394–1399
18. Minervini A, Vittori G, Lapini A et al (2012) Morbidity of tumour enucleation for renal cell carcinoma (RCC): results of a singlecentre prospective study. BJU Int 109:372–377
19. Ficarra V, Novara G, Secco S et al (2009) Preoperative aspects and dimensions used for an anatomical (PADUA) classification of renal tumours in patients who are candidates for nephron-sparing surgery. Eur Urol 56:786–793
20. Khalifeh A, Autorino R, Eyraud R, et al. Three-year oncologic and renal functional outcomes after robot-assisted partial nephrectomy. Eur Urol 64(5):744–50. http://dx.doi.org/10.1016/j.eururo.2013.03.052
21. Ficarra V, Galfano A, Cavalleri S (2009) Is simple enucleation a minimal partial nephrectomy responding to the EAU Guidelines' recommendations? Eur Urol 55:1315–1318
22. Cambio AJ, Evans CP (2006) Management approaches to small renal tumors. BJU Int 97:456–460
23. Van Poppel H, Da Pozzo L, Albrecht W et al (2007) A prospective randomized EORTC intergroup phase 3 study comparing the complications of elective nephron-sparing surgery and radical nephrectomy for low-stage renal cell carcinoma. Eur Urol 51:1606–1615
24. Benway BM, Bhayani SB, Rogers CG et al (2010) Robot-assisted partial nephrectomy: an international experience. Eur Urol 57:815–820
25. Rosenthal CL, Kraft R, Zingg EJ (1984) Organ-preserving surgery in renal cell carcinoma: tumor enucleation versus partial kidney resection. Eur Urol 10:222–228
26. Blackley SK, Ladaga L, Woolfitt RA, Schellhammer PF (1988) Ex situ study of the effectiveness of enucleation in patients with renal cell carcinoma. J Urol 140:6–10
27. Touijer K, Jacqmin D, Kavoussi LR et al (2010) The expanding role of partial nephrectomy: a critical analysis of indications, results, and complications. Eur Urol 57:214–222
28. Minervini A, Ficarra V, Rocco F et al (2011) Simple enucleation is equivalent to traditional partial nephrectomy for renal cell carcinoma: results of a nonrandomized, retrospective, comparative study. J Urol 185:1604–1610
29. Minervini A, Serni S, Di Cristofano C, Carini M (2009) Rebuttal from authors re: Vincenzo Ficarra, Antonio Galfano and Stefano Cavalleri. Is simple enucleation a minimal partial nephrectomy responding to the EAU guidelines' recommendations? Eur Urol 55:1319–1320
30. Minervini A, Raspollini MR, Tuccio A, et al. (2013) Pathological characteristics and prognostic effect of peritumoral capsule penetration in renal cell carcinoma after tumor enucleation. Urol Oncol. doi:10.1016/j.urolonc.2013.07.018