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Laparoscopic Partial Nephrectomy with Diode Laser: A Promising Technique

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Abstract

Objective: The aim of this study was to evaluate application of diode laser in laparoscopic partial nephrectomy (LPN), and to question this technique in terms of ease of tumor excision and reduction of warm ischemia time (WIT). ***Background data:*** LPN is the standard operative method for small renal masses. The benefits of LPN are numerous, including preserving renal function and prolonging overall survival. However, reduction of WIT remains main challenge in this operation. In order to shorten WIT, many techniques have been developed, with variable results. ***Patients and methods:*** We performed a prospective collection and analysis of health records for patients who were operated on between March 2011 and August 2012. Inclusion criteria were single tumor ≤4 cm, predominant exophytic growth and intraparenchymal depth ≤1.5 cm, with a minimum distance of 5 mm from the urinary collecting system. ***Results:*** We operated on 17 patients. Median operative time was 170 min. In all but two patients, we had to perform hilar clamping. Median duration of WIT was 16 min. Pathohistological evaluation revealed clear cell renal cancer and confirmed margins negative for tumor in all cases. Median size of the tumor was 3 cm. Median postoperative hospitalization was 5 days. Average follow up was 11.5 months. There were no intraoperative complications. One postoperative complication was noted: perirenal hematoma. ***Conclusions:*** Laser LPN is feasible, and offers the benefit of shorter WIT, with effective tissue coagulation and hemostasis. With operative experience and technical advances, WIT will be reduced or even eliminated, and a solution to some technical difficulties, such as significant smoke production, will be found.

Introduction

Renal cancer (RC) accounts for ~2% of all malignancies occurring in adults.[1] Epidemiological studies report increasing incidence of renal cancer during the past two decades until recently, both worldwide and in Europe.[2] The incidence of RC in Croatia is 9.4/100.000,[3] which is significantly higher than the worldwide rate of 3.9/100.000.[4] There are some indications that a recent increase in incidence together with a stage shift to more organ-confined stages can be observed.[5] This is partially attributable to increased frequency of diagnostic imaging, such as ultrasound and computed tomography. This renders a higher number of small renal masses (SRM) (i.e., tumors < 4 cm). The most profound change among the many that have occurred in the management of RC is current recommendation for treatment of SRMs, if possible, with nephron sparing surgery (NSS).[6] Open partial nephrectomy, the erstwhile reference standard treatment for small renal masses, has demonstrated no difference in either overall or cancer-specific survival compared with radical nephrectomy, with the benefit of better preservation of renal function.[7] Reports have confirmed equal oncological outcomes with laparoscopic partial nephrectomy, but with the advantages of minimally invasive surgery.[8] However, the main challenge, to reduce the morbidity associated with this procedure, still remains.

The need for hilar clamping in cases of laparoscopic partial nephrectomy (LPN) is currently necessary to create a bloodless field for renal excision. However, hilar clamping causes time constraints for the surgeon, and increased warm ischemia time (WIT) compromises renal function in the subsequent postoperative period. As none of the current operative techniques is the most effective, there are many techniques that have been developed to achieve hemostasis, including conventional suture repair, tissue sealants, radiofrequency ablation, water dissection, microwave tissue coagulation, and lasers.[9] Studies of different *ex vivo* laser-assisted LPN have been published.[10] However, few *in vivo*

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surgery series are available.[11] The aim of this study was to evaluate the application of diode laser in laparoscopic partial nephrectomy, and to question this technique in terms of ease of tumor excision and reduction of WIT.

Patients and Methods

We performed a prospective collection and analysis of health records for patients who were operated on laparoscopically with application of laser for SRMs at University Hospital Center Zagreb, Zagreb, Croatia, from March 2011 to August 2012. Diagnosis of SRM was based on computed tomography scans and/or magnetic resonance imaging. Inclusion criteria were single tumor with size ≤4 cm, predominant exophytic growth and intraparenchymal depth ≤1.5 cm, with a minimum distance of 5 mm from the urinary collecting system. R.E.N.A.L nephrometry score was used to describe renal mass anatomy.[12] Exclusion criteria were American Society of Anesthesiologists (ASA) score ≥3, centrally located tumor, and (functional) single kidney. Both medical and surgical complications were recorded according to the modified Dindo–Clavien classification.[13] One laparoscopic surgeon (N.K.) performed all procedures.

Surgical technique

Conventional laparoscopic lateral transperitoneal approach with four trocars was used in all cases. First, the renal tumor was identified and the kidney was fully mobilized, allowing the manipulation for circumferential laser resection (Fig. 1; see supplementary video at www.liebertpub.com/pho). Hilar vessels were always identified. For renal resection we used diode laser 980 nm (Ceralas ® HPD, Biolitec AG, Jena, Germany) with end fire 1000 μm laser fiber BFF-1003-dl (Biolitec AG, Jena, Germany). For the last case we used Dual diode laser 980 and 1470 nm (Ceralas®HPD DUAL , Biolitec AG, Jena, Germany). Chromophore target for the 980 nm laser is hemoglobin, and for dual laser 980/1470 nm, it is hemoglobin/water. Laser fiber was introduced through a 10 mm trocar with a special holder designed for laparoscopic application, and in the last case we used a special holder with simultaneous irrigation and suction (S064 Jet Suction Irrigator, SUS, Barnsley, UK). Power settings were continuous mode with power settings 20–80 W. Demarcation of the safe initial resection line around the tumor was done with a laser (power settings initially were 20–40 W, and in later cases 40–60 W). We would continue with laser tumor resection with adequate free resection margins in contact fashion (up to 80 W) (Fig. 2). At times of more significant bleeding caused by resection of larger blood vessels, we would tighten a previously placed laparoscopic tourniquet at the renal artery. Diode laser 980 nm proved to be more efficient, with faster resection time in ischemic conditions. When the tumor was resected, cellulose mesh was placed on the resection bed and fixed with one parenchymal suture (2-0 Vicryl) (Fig. 3). Finally, the tourniquet could be released without significant bleeding. If needed, additional parenchymal sutures were placed. The tumor was removed using a laparoscopic retrieval bag (Memo Bag, 200 mL, Rüsch, Teleflex Medical). After removal, the specimen was checked to ensure a macroscopically tumor-free surgical margin. Figure 4 illustrates representative preoperative CT images.

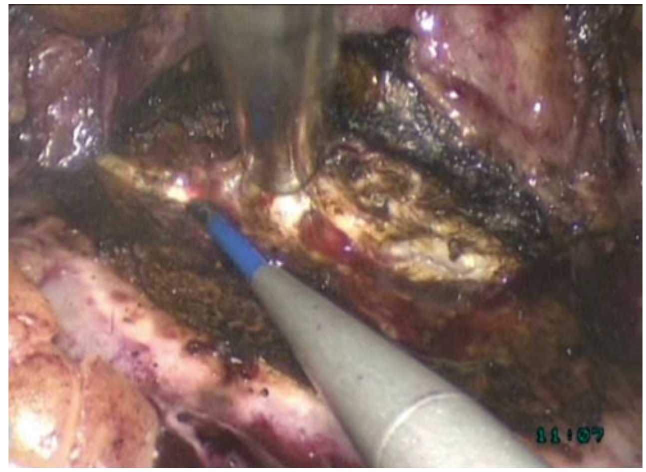

FIG. 2. Laser resection and concomitant smoke suction.

Results

We operated on 17 patients with small peripherally placed renal tumors (Table 1). All operations were successfully

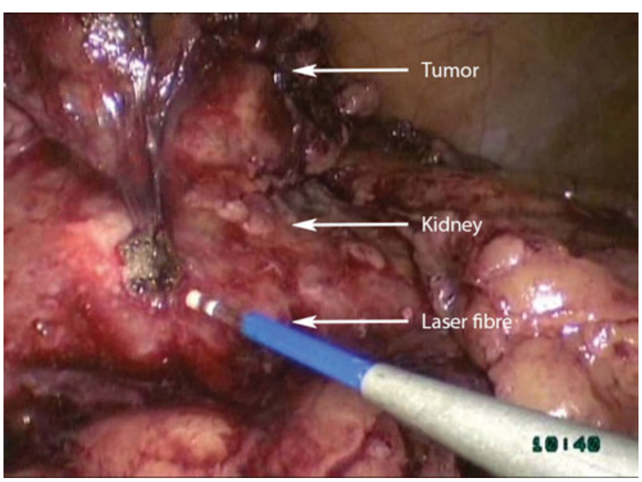

FIG. 1. Beginning of the resection with the laser.

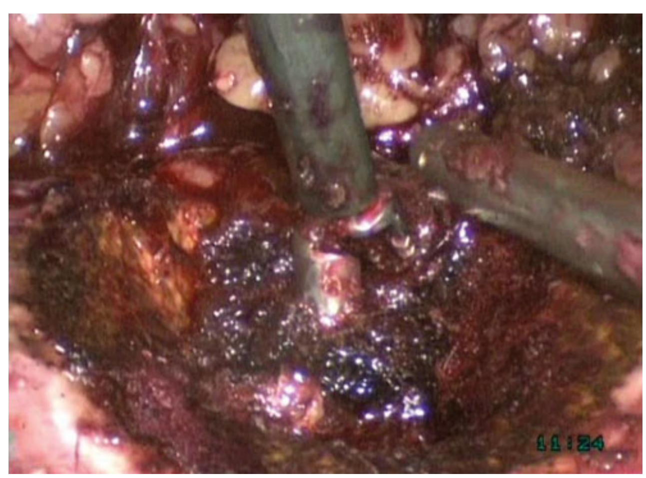

FIG. 3. View of the transection bed.

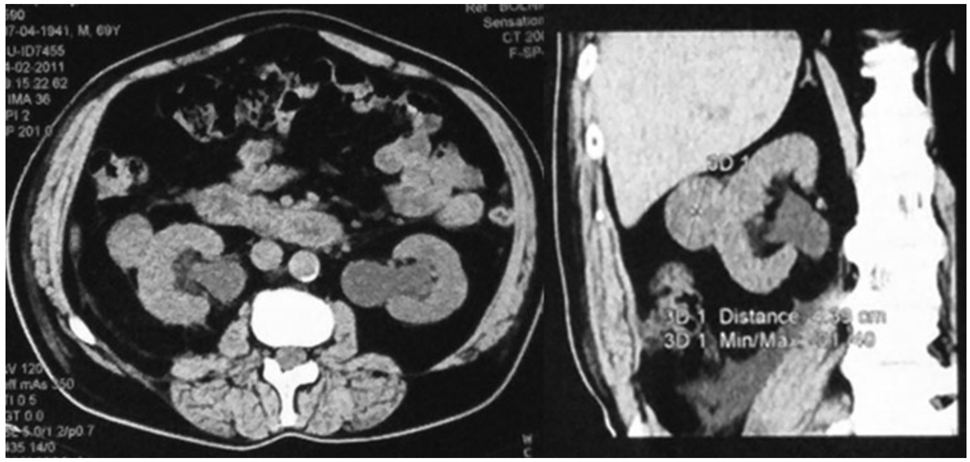

FIG. 4. Preoperative CT images of renal tumor.

performed laparoscopically. Median operative time was 170 min (140–240 min). In all but two patients, we had to perform hilar clamping. Median laser activity prior to hilar clamping was 15 min, and was followed with median duration of WIT 16 min. One patient who did not require hilar clamping had small (2 cm) SRM, mostly exophytic. The second patient had a 3.5 cm tumor that was resected with Dual diode laser. This laser system proved more effective regarding hemostasis; however, because of excessive smoke production and the resulting impaired visibility, this laser resection lasted for 40 min. Median blood loss was 70 mL (50–200 mL), and none of patients required postoperative transfusion.

Pathohistological evaluation revealed clear cell renal cancer and confirmed margins negative for tumor in all cases. There were no intraoperative complications. One postoperative complication was noted, perirenal hematoma, which was treated conservatively (Clavien grade 2).

Discussion

The present study includes a series of patients with SRMs treated effectively laparosopically, and utilizing laser as a method of renal resection. Our series indicates that laparoscopic partial nephrectomy with laser is feasible, and offers the benefit of shorter WIT with more effective tissue coagulation, hemostasis, and potential for omission of hilar clamping.

Table 1. Summary of Demographic, Intraoperative, and Postoperative Data for Laser-Assisted Laparascopic Partial Nephrectomy

No. of patients	17
Average age (years)	61.6 (41.5–75.3)
Sex (M/F)	10/7
Side (left/right)	9/8
Median operative time (min)	170 (140–240)
Median blood loss (mL)	70 (50–200)
Median warm ischaemia time (min)	16 (9–20)
Median hospitalization (days)	5 (5–9)
Average follow up (months)	11.5 (1–18)
Pathohistologic evaluation	
Clear cell renal cancer	17
Median tumor size	3 (2–4.8)

The location, size, and exophytic properties of the lesion determine the potential complexity of the operation; therefore, objective characterization of renal mass anatomy facilitates treatment selection and prediction of surgical outcomes. R.E.N.A.L nephrometry score was developed for this purpose and in our series all tumors were scored ≤6, suggesting a clear selection of patients at low risk for complications.

Partial nephrectomy is the prevailing method for small tumors and is proven to be better in preservation of renal function than radical nephrectomy.[7] LPN is a technically challenging procedure, mainly because of the lack of reliable methods of hemostasis and requiring prolonged WIT. The effect of WIT on postoperative renal function is one of the central questions regarding LPN. Therefore, new techniques are needed to abandon hilar clamping. Laser technology presents a promising alternative for achieving tumor excision and renal hemostasis, with or without hilar occlusion. Laser offers the possibility of both open and laparoscopic partial nephrectomy.

Several experimental studies have demonstrated the efficiency of laser-assisted open or laparoscopic partial nephrectomy in various experimental setups. Ogan et al. have reported the first experiences with diode laser 980 nm laparoscopic partial nephrectomy in pigs, coming to the conclusion that clinical trials in humans should be limited to small exophytic tumors.[14] To date, 12 research groups have published small series concerning clinically tested laser-assisted open or laparoscopic partial nephrectomies.[11,15–25] To our knowledge, this is largest published series of laser-assisted laparoscopic partial nephrectomy.

It has been reported that renal damage is proportional to the WIT, with the current recommendation that WIT should stay within 20 min.[26] Lane et al. estimated a decline in glomerular filtration rate (GFR) of 2.2 mL/min/1.73 m^2 per every 5 min of WIT.[27] It has been traditionally considered that LPN has a longer WIT than open partial nephrectomy. In the developmental stages of LPN, mean WIT was in the 30 min range. However, modifications to standard LPN techniques have helped improve WIT.[28] In recently published comparative series of LPN versus open or robotic partial nephrectomy, mean WIT for LPN was in a range of 13.0–36.4 min.[29,30] Our series with a median WIT of 16 min and with two cases without WIT is example of this improvement. Additionally, complications of partial nephrectomy include hemorrhage, urinary leak, infection, formation of urinary fistula, and the development of renal insufficiency.[31]

Laser function is achieved through absorption of its energy on chromophores.[32] Absorbed laser radiation is converted into heat, causing a local rise in temperature. Depending upon the amount of heat produced, tissue will coagulate or even vaporize. Chromophores are chemical groups capable of absorbing light at a particular frequency, and thereby imparting color to a molecule. In surgery, chromophores that are most often used are hemoglobin and water. Diode 980 nm laser is absorbed on hemoglobin and we have noticed that if during kidney resection some bleeding is present, it is inadequate in further resection. At this time, we had to clamp the artery to reduce bleeding, and were able to continue with even faster resection. As dual diode 980/1470 nm laser is simultaneously absorbed on water and hemoglobin, it offers the possibility of tissue coagulation even if larger bleeding is present. Our experience with dual laser is limited (one case) but it proved more effective and faster, and had better coagulation properties. However, it also produced more smoke. In our opinion, there are several factors that can help in achieving 0 min WIT: careful patient selection (small and exophytic tumors) and lasers that are absorbed on water (e.g., Dual diode lasers or Thulium lasers). Until we have further clinical experience, cellulose mesh and/or parenchymal sutures will continue to be used for larger tumors.

The major disadvantage of the laser is remarkable smoke production obstructing adequate visibility in laparoscopic surgery. There are several possibilities for dealing with this situation. Slow saline irrigation could lower smoke production, with questionable effect on laser coagulation efficiency.[33] Liang et al. investigated Thulium-YAG laser and the influence of several irrigation rates on coagulation efficiency. They reported acceptable influence on coagulation with suitable effect on smoke production.[34] This might be even more acceptable in lasers with wavelength absorbed on hemoglobin, such as diode laser 980 nm. We have tested this effect in some parts of the operation. While there was bleeding, we used water irrigation to clear the resection line. However, at that time, because of an inability to utilize suction at the same time, we used continuous irrigation in a limited fashion. The second method to improve visibility was gas suction; however, this requires a capacitive insufflation system. Also, this could require an additional trocar for the assistant. However, we managed to acquire one instrument that can deliver laser fiber, irrigation, and suction canal at the same time. We have tested it with Dual laser and found that although a small rate of irrigation is successful in reducing smoke production, it reduces the effectiveness of wavelength 1470 nm, therefore slowing resection and reducing the coagulation effect. Furthermore, suction, even though placed near the tip of the laser fiber, did not adequately evacuate produced smoke, although it significantly lowered pneumoperitoneum pressure.

Currently, the European Association of Urology guidelines consider that a minimal tumor-free margin is sufficient to avoid local tumor recurrence.[6] One possible disadvantage of laser LPN is impaired intraoperative visibility of the resection plane caused by coagulated and burned tissue, which might increase the occurrence of positive surgical margins (PSM). However, with adequate surgical technique and prior demarcation of the resection line around the tumor, one can achieve tumor-free margins. Positive surgical margins in laparoscopic partial nephrectomy are in a range of 0.7–4%,[35] and in our series, none of the patients had PSM. Frozen section analysis for evaluation of resection margins during LPN is of minor clinical significance, as the surgeon's gross assessment of macroscopically negative margins provides reliable results.[35] It is also notable that the tissue necrosis zone after laser resection creates an additional safety margin that may render PSM clinically insignificant.

Study limitations include the small sample size, the lack of a control group, and the short follow-up period.

Conclusions

Laparoscopic partial nephrectomy with laser is feasible, and offers the benefit of shorter WIT, with more effective tissue coagulation, hemostasis, and potential for omission of hilar clamping. Laser cutting should be performed at a small distance from the tissue with a slow velocity of fiber movement to achieve the best cutting and coagulation properties. With operative experience and technical advances in laser and fiber production, WIT will be reduced or even eliminated, and a solution to some technical difficulties, such as significant smoke production, will be found. LPN with laser should be attempted in carefully selected patients with favorable features of tumor anatomy. Further studies with longer follow-up are needed to establish oncological efficacy of the procedure.

Author Disclosure Statement

No competing financial interests exist.

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