EUROPEAN UROLOGY SUPPLEMENTS 8 (2009) 753–757

available at www.sciencedirect.com
journal homepage: www.europeanurology.com

European Association of Urology

Parenchymal-Sparing Surgery for Renal Lesions: Open versus Laparoscopic/Robotic Surgery

Sarel Halachmi [a], *Antonio Finelli* [b], *Alex Mottrie* [c], *Ofer Nativ* [a,*]

[a] *Department of Urology, Bnai Zion Medical Center and the Faculty of Medicine Technion, Israeli Institute of Technology, Haifa, Israel*
[b] *Department of Surgical Oncology, Division of Urology, Princess Margaret Hospital, University Health Network, Toronto, Canada*
[c] *Department of Urology, OLV Clinic Aalst, Aalst, Belgium*

Article info

Keywords:
Laparoscopic surgery
Parenchymal-sparing surgery
Renal cancer
Renal masses
Robotic surgery

* Corresponding author. Department of Urology Bnai Zion M.C., 47 Golomb Street, Haifa 31048, Israel
Tel.: +972 4 8359523; Fax: +972 4 8359524.
E-mail address: ofer.nativ@b-zion.org.il (O. Nativ).

1. Introduction

The incidence of renal masses and renal cancer has continued to increase in recent years. This is mainly a result of widespread adoption of noninvasive diagnostic imaging modalities such as ultrasonography and computed tomography for the evaluation of abdominal and musculoskeletal symptoms. Most of these incidentally detected tumours (70%) are small, asymptomatic, and confined to the kidney [1]. Consequently, more surgical procedures are now performed to treat these new lesions. The optimal therapeutic modality for the management of renal masses is surgical removal. In the past, removal of the whole kidney, including perirenal fat and adrenal gland, was considered the gold standard. In recent years, parenchymal-sparing surgery (PSS), in which just the tumour and the adjacent nonmalignant parenchymal rim are removed, has produced equivalent oncologic outcomes with the advantage of sparing functioning renal tissue. Initially, PSS was limited to patients with small lesions, a solitary kidney, or compromised renal function. However, today, PSS is the treatment of choice for any patient with a normal contralateral kidney and renal masses up to 4 cm, and there is preliminary evidence to support application to tumours 4–7 cm in diameter [2].

There are several surgical techniques to perform PSS: open surgery, laparoscopic surgery, and, recently, robot-assisted laparoscopic surgery. Alternative ablative procedures include cryotherapy, radiofrequency ablation, high-focused ultrasound, microwave thermotherapy, and laser interstitial thermotherapy [3].

The aim of this manuscript is to review the advantages and limitations of the different surgical approaches to PSS. Points for consideration will be based on the following parameters: oncologic outcome, renal function preservation, complications, ability to treat complex cases, cost, and effect on quality of life.

2. Evidence acquisition

This paper was based on presentations given at a satellite symposium on parenchymal-sparing surgery for renal lesions that was held during the 2nd World Congress on Controversies in Urology (CURy) on 7 February 2009 in Lisbon, Portugal. Data were retrieved from original and recent review articles on parenchymal-sparing surgery for renal lesions.

 doi:10.1016/j.eursup.2009.07.003

3. Evidence synthesis

3.1. Oncologic outcome

3.1.1. Positive surgical margins

The main aim of renal cancer surgery is the removal of the whole tumour. In the past, verification of complete tumour resection was conducted using intraoperative frozen-section analysis of the tumour bed. Currently, the oncologic significance of tumour-bed sampling at the time of PSS is not clear; however, it is more practically achieved with the open approach. In a retrospective survey that included 17 academic centres in Europe and the United States, Breda et al. [4] analysed the status of the surgical margins of 855 cases of laparoscopic partial nephrectomy (LPN). The mean tumour size was 2.7 cm, 467 (54.6%) of the lesions were exophytic, and 123 (14.3%) were deep parenchymal lesions. Positive surgical margins were reported in 21 cases (2.4%). Two centres never performed frozen-section analysis of the surgical margins during surgery, 10 centres performed frozen-section analysis selectively based on clinical suspicion of positive margins, and only 5 centres performed frozen-section analysis in all cases. Other studies reported a 2–3.5% incidence of positive surgical margins following laparoscopic PSS [5–7]. Gill et al. [8] compared 1800 cases of laparoscopic and open PSS and found that the rate of positive surgical margins following laparoscopic PSS was 2.9% (22 of 771) versus 1.3% (13 of 1029) for open PSS. Two recent publications by Shapiro et al. [9] and Simmons et al. [10] have shown a reduced rate of positive surgical margins in both robotic and laparoscopic PSS. In another review by Zimmermann and Janetschek [11], the functional and oncologic outcomes were reported to be similar between LPN and open partial nephrectomy (OPN). The positive margin rate (3.5%) is not different from OPN results (0–14.3%) and continues to improve with the application of new surgical techniques.

The impact of positive surgical margin status on patients' oncologic outcome is not clear. Recent studies [12,13] showed that in selected cases, positive surgical margins might not impair cancer-specific survival (CSS). However, further studies and longer follow-up are needed to clarify the effect of positive surgical margins on patients' oncologic outcome [12].

3.1.2. Tumour seeding

No comparison of tumour seeding rate between the different approaches is available in the English literature.

Seeding during open surgery is very rare and may be related to vigorous tumour handling and spillage during the operation. In laparoscopic PSS [14–16], seeding might be attributed to a "chimney effect" of pneumoperitoneum at trocar sites and tumour cell aerosolization, instrument contamination, tumour spillage due to vigorous grasping with the laparoscopic instruments, or tumour extraction without an entrapment sac.

3.1.3. Cancer-specific survival

In most of the published studies, the oncologic results are similar for the three surgical approaches. It should be mentioned that most of the robotic PSS series are limited by the relatively short follow-up time. Gill et al. [8] reported a 3-yr CSS for patients with a single cT1N0M0 renal cell carcinoma of 99.3% and 99.2% after LPN and OPN, respectively. Similar CSS rates for the two techniques were also described by other groups [8,17,18]. Longer-term follow-up studies and an increased number of patients will be needed to define this issue.

3.2. Renal function preservation

In recent years, several studies have demonstrated that renal function is important for patients' overall survival. Decrease in glomerular filtration rate (GFR) correlates with a rise in overall and cardiovascular death. Hence, the remaining normal functioning tissue after PSS will affect patients' survival. Indeed, several publications have demonstrated improved noncancer survival for patients after PSS compared with radical nephrectomy [19].

Renal function preservation is related to several factors, including the amount of normal functioning renal tissue removed with the tumour, surface cooling to reduce the metabolic needs of the kidney during vascular clamping, and duration of warm ischemia. Patients' age, comorbidities, and baseline renal function are also important predictors of functional preservation. These variables, however, are not related to the type of PSS.

3.2.1. Cold and warm ischemia

Visibility during tumour excision is critical to successful PSS. In order to achieve a bloodless field, vascular control is required, which may result in ischemic damage to the kidney. To diminish metabolic activity and preserve functioning tissue, surface cooling is employed. Creation of cold ischemia provides more time for excision and reconstruction in a bloodless surgical field without compromising renal function. Thompson et al. [20] showed that cold ischemia >35 min and warm ischemia >20 min were associated with increased postoperative risk for acute and chronic renal failure, increase in creatinine >0.5 mg, and permanent dialysis.

Surface cooling is difficult to achieve during laparoscopic PSS compared to open surgery. Placement of ice slush through the laparoscopic ports is possible but cumbersome and time consuming. Indeed, many surgeons are not cooling the kidney during laparoscopic procedures. Alternative strategies for cooling include intrarenal cooling via special endovascular catheterization of the renal artery or by using a ureteral catheter to irrigate the kidney with cold solution [21,22]. However, these methods are associated with complications, and, thus, most laparoscopic and robotic PSS is done with warm ischemia only. The duration of warm ischemia is one of the factors that directly affects residual renal function, especially if exceeding 20–30 min [23]. In most endoscopic PSS, even in experienced centres, the length of warm ischemia may exceed the desired threshold of 20 min. Nadu et al. [24] reviewed 140 laparoscopic PSSs, (among them, 30 were considered as learning curve and 110 post–learning curve) and reported a mean warm ischemia time of 30 min. Turna et al. [25] evaluated their experience with 507 laparoscopic PSSs and reported an average warm ischemia time of 32 min (range: 4–68 min). Improvement in overall operative time (mean: 82 min) and warm ischemia time (mean: 21.7 min) was reported in a recent publication by Ho et al. [26], who used robotic PSS to treat 20 patients for renal cell carcinomas with a mean tumour size of 30.2 mm.

In our series of about 400 consecutive open PSSs, including complex cases, the mean warm ischemia time was 24 min [27]. In summary, cold ischemia is practically feasible in open PSS but rarely performed in laparoscopic and robotic procedures. In endoscopic PSS, as warm ischemia time is usually used, clamping time should not exceed 20–30 min.

3.2.2. *Parenchymal damage during tumour bed closure*

One of the major developments in PSS is the use of tissue-adhesive substances to fill and close the tumour bed after removal of the lesion. The sealant promotes haemostasis and may prevent urine leak without compromising the remaining renal tissue. Prior to the use of such biomaterials, multiple figure-eight sutures and through-and-through sutures were needed for closure of the renal parenchymal defect to achieve haemostasis. Hidas et al. [28,29] showed the advantages of tissue sealant over sutures for closing the tumour bed. The use of sealant significantly decreases blood loss and transfusion rates as well as the warm ischemia and operative times. Moreover, in the tissue sealant group, the average renal function loss as measured by technetium-99m dimercaptosuccinic acid (99m-Tc DMSA) scintigraphy was 11.49% and 20.36% for the tissue sealant and suture closure groups, respectively ($p = 0.02$). In laparoscopic and robotic surgery, additional tissue sealant is usually applied over the sutures to assure adequate haemostasis. In robotic surgery, the three-dimensional magnified vision can theoretically enable more accurate and precise suturing, which may result in less tissue damage during tumour-bed closure.

3.2.3. *Conversion to radical nephrectomy*

PSS is a challenging, especially for central and hilar tumours. The high blood flow to the kidney (25% of cardiac output) and the high vascularization of renal tumours can cause significant intraoperative haemorrhage that may necessitate conversion to radical nephrectomy. Rais-Bahrmi et al. [30] summarized the experience of the urologic institute at Johns Hopkins and reported a 13.6% rate of conversion from laparoscopic PSS to radical nephrectomy. Predicting factors for conversion were tumours >4 cm and age >70 yr. Gill et al. [8] compared 771 laparoscopic PSSs to 1039 open PSSs and found that the rate of functioning kidney loss within 90 d following surgery was 2.1% (18 of 771) in the laparoscopic group and 0.4% (4 of 1039) in the open PSS group.

In summary, the ability to use surface cooling more frequently, the usually shorter ischemic time, and the reduced rate of viable parenchymal loss observed in open PSS may translate into better functional preservation.

3.3. *Complications*

In a collaborative project of the Cleveland Clinic, the Mayo Clinic, and the Johns Hopkins urologic institute, Gill et al. [8] compared open to laparoscopic PSS and reported a rate of 1.8% (laparoscopic) versus 1% (open) for intraoperative complications. The rates of postoperative nonurologic and urologic complications were also higher in the laparoscopic group; 15.7% versus 14.3% for nonurologic complications and 9.2% versus 5% for urologic complications, respectively. Postoperative bleeding was reported to be 4.2% for the laparoscopic group versus 1.6% in the open group. Urine leak was noted in 3.1% of the laparoscopic group and in 1.3% of the open group. Postoperative mortality was 0.3% in the laparoscopic group and 0.5% in the open group. Thompson et al. [31] reported the complications in 480 patients undergoing open PSS in a single centre. The rate of medical complications was 0.8%, bleeding 1.2%, wound infection 0.2%, urine leak 0.6%, ileus 2.2%, pneumothorax 0.2%, and perioperative mortality 0.2%. Recent publications summarizing the experience of high-volume specialised centres who used both robotic and laparoscopic techniques have demonstrated significant reduction of complications rates compared to the earlier studies [8,9,11].

Overall, the rate of surgical complications is slightly higher with the endoscopic approach and is mainly related to surgeon experience and case complexity, although in robotic partial nephrectomy, intraoperative complications are relatively rare.

3.4. *Ability to treat complex cases*

Complex cases such as large centrally located tumours, hilar tumours, multiple tumours, recurrent tumours after prior surgery or ablative procedures, or the presence of associated pathologies (nephrolithiasis or renal artery stenosis) could be treated with open or laparoscopic PSS. However, the laparoscopic approach would be highly demanding, and one might expect a prolonged surgical time and higher rate of complications, particularly with inexperienced surgeons. Hafez et al. [32,33] reported on concomitant repair of renal artery and aortic aneurysm in conjunction with PSS for renal tumours. Rogers et al. [34] reported on 11 successful laparoscopic robotic PSSs for hilar lesions. Mean tumour size was 3.8 cm (range: 2.3–6.4 cm). Mean warm ischemia time was 28.9 min (range: 20–39 min), and mean operating time was 202 min (range: 154–253 min). Average blood loss was 220 ml (range: 50–750 ml), and mean hospital stay was 2.6 d (range: 1–4 d). Rogers et al. [34,35] presented encouraging results using robotic PSS for complex cases (hilar, endophytic and multiple tumours), with a mean operating time and ischemia time of 192 min and 31 min, respectively. Latouff et al. [36] described 18 laparoscopic PSSs for hilar lesions with a mean surgical time of 238 min (range: 150–420 min) and mean duration of ischemia of 42.5 min (range: 27–63 min) and 34.1 min (range: 24–56 min) for the cold and warm ischemia groups, respectively. The average estimated intraoperative blood loss was 165 ml (range: 50–500 ml), and there were two cases (11%)

with vascular injury; namely, a segmental renal artery in one patient and a segmental renal vein in another, both of which were managed laparoscopically. One patient underwent laparoscopic reexploration for urine extravasation in the immediate postoperative period.

Prior renal surgery might compromise a laparoscopic approach; however, for patients with previous abdominal surgery, an extraperitoneal laparoscopic approach would be a reasonable option [37,38].

Obese patients can be treated with either approach; however, it seems that the laparoscopic technique is easier in these patients [39].

3.5. Cost

In the United States, the operative time and the hospital stay are the major determinant of the calculated cost of any surgical procedure. Link et al. [40] found that an open PSS was 1.2-fold more expensive compared to laparoscopic PSS and could achieve cost equivalence only with operative times of <2.8 h or hospitalisation of <3 d. Mouraviev et al. [41] found that laparoscopic PSS is more expensive than open surgery, and Lotan et al. [42] showed cost equality between the two approaches. The expense of the surgery is related to the cost of the various components, which may vary in different countries. In general, during laparoscopic PSS, the major cost determinant is operating time, while for open surgery, the hospital stay comprises the major expense. For robotic surgery, there is an increased cost mainly due to disposable instruments estimated at approximately 2000 euros per procedure. Further studies will have to be performed to evaluate the cost–benefit ratio for RPN.

3.6. Quality of life

Laparoscopic PSS appears to have a great advantage over open surgery in this regard. This is mainly due to smaller incisions, lack of a flank incision and its associated morbidity (bulge and pain), reduced postoperative analgesia, shorter hospital stay, and an earlier return to daily activity [17].

4. Conclusions

PSS is a challenging surgical procedure using an open approach, and it is even more so when it is performed laparoscopically. Currently, open surgery has the advantage of tumour removal with fewer positive surgical margins, although overall oncologic outcome seems to be equal for the two approaches. Considering renal function preservation, the open approach is superior due to the ability to create surface hypothermia and usually a shorter warm ischemia time. This is more beneficial in complex cases, which require longer duration for resection and reconstruction. Perioperative complications are slightly higher in most laparoscopic PSS series; however, patients may benefit from a shorter hospital stay and earlier resumption of daily activities.

After reviewing the relevant literature, we currently agree with the European Association of Urology guidelines considering open PSS as the standard of surgical treatment for renal masses. Laparoscopic and robotic PSS should be performed in specialised centres. We anticipate continued improvement in endoscopic devices and modification of the methods for cooling the kidney and closure of the tumour bed, which should translate into widespread application of the endoscopic techniques. Robotic surgery is an emerging technology with the potential of being the preferred endoscopic approach for PSS.

Conflicts of interest

The authors have nothing to disclose.

Funding support

None.

References

[1] Kane CJ, Mallin K, Ritchey J, Cooperberg MR, Carroll PR. Renal cell cancer stage migration: analysis of the National Cancer Data Base. Cancer 2008;113:78–83.

[2] Leibovich BC, Blute ML, Cheville JC, Lohse CM, Weaver AL, Zincke H. Nephron sparing surgery for appropriately selected renal cell carcinoma between 4 and 7 cm results in outcome similar to radical nephrectomy. J Urol 2004;171:1066–70.

[3] Matin SF, Ahrar K. Nephron-sparing probe ablative therapy: long-term outcomes. Curr Opin Urol 2008;18:150–6.

[4] Breda A, Stepanian SV, Liao J, et al. Positive margins in laparoscopic partial nephrectomy in 855 cases: a multi-institutional survey from the United States and Europe. J Urol 2007;178:47–50.

[5] Link RE, Bhayani SB, Allaf ME, et al. Exploring the learning curve, pathological outcomes and perioperative morbidity of laparoscopic partial nephrectomy performed for renal mass. J Urol 2005;173: 1690–4.

[6] Moinzadeh A, Gill IS, Finelli A, Kaouk J, Desai M. Laparoscopic partial nephrectomy: 3-year followup. J Urol 2006;175:459–62.

[7] Venkatesh R, Weld K, Ames CD, et al. Laparoscopic partial nephrectomy for renal masses: effect of tumor location. Urology 2006;67: 1169–74.

[8] Gill IS, Kavoussi LR, Lane BR, et al. Comparison of 1,800 laparoscopic and open partial nephrectomies for single renal tumors. J Urol 2007;178:41–6.

[9] Shapiro E, Benway BM, Wang AJ, Bhayani SB. The role of nephron-sparing robotic surgery in the management of renal malignancy. Curr Opin Urol 2009;19:76–80.

[10] Simmons MN, Weight CJ, Gill IS. Laparoscopic radical versus partial nephrectomy for tumors >4 cm: intermediate-term oncologic and functional outcomes. Urology 2009;73:1077–82.

[11] Zimmermann R, Janetschek G. Complications of laparoscopic partial nephrectomy. World J Urol 2008;26:531–7.

[12] Bensalah K, Pantuck AJ, Rioux-Leclercq N, et al. Positive surgical margin appears to have negligible impact on survival of renal cell carcinomas treated by nephron-sparing surgery. Eur Urol. In press. doi:10.1016/j.eururo.2009/03.048.

[13] Yossepowitch O, Thompson RH, Leibovich BC, et al. Positive surgical margins at partial nephrectomy: predictors and oncological outcomes. J Urol 2008;179:2158–63.

[14] Castillo OA, Vitagliano G, Diaz M, Sanchez-Salas R. Port-site metastasis after laparoscopic partial nephrectomy: case report and literature review. J Endourol 2007;21:404–7.

[15] Greco F, Wagner S, Reichelt O, et al. Huge isolated port-site recurrence after laparoscopic partial nephrectomy: a case report. Eur Urol. In press. doi:10.1016/j.eururo.2009.04.004.

[16] Masterson TA, Russo P. A case of port-site recurrence and locoregional metastasis after laparoscopic partial nephrectomy. Nat Clin Pract Urol 2008;5:345–9.

[17] Beasley KA, Al OM, Shaikh A, et al. Laparoscopic versus open partial nephrectomy. Urology 2004;64:458–61.

[18] Porpiglia F, Volpe A, Billia M, Scarpa RM. Laparoscopic versus open partial nephrectomy: analysis of the current literature. Eur Urol 2008;53:732–42.

[19] Russo P. Functional preservation in patients with renal cortical tumors: the rationale for partial nephrectomy. Curr Urol Rep 2008;9:15–21.

[20] Thompson RH, Frank I, Lohse CM, et al. The impact of ischemia time during open nephron sparing surgery on solitary kidneys: a multi-institutional study. J Urol 2007;177:471–6.

[21] Beri A, Lattouf JB, Deambros O, et al. Partial nephrectomy using renal artery perfusion for cold ischemia: functional and oncologic outcomes. J Endourol 2008;22:1285–90.

[22] Landman J, Rehman J, Sundaram CP, et al. Renal hypothermia achieved by retrograde intracavitary saline perfusion. J Endourol 2002;16:445–9.

[23] Gill IS, Colombo Jr JR, Frank I, Moinzadeh A, Kaouk J, Desai M. Laparoscopic partial nephrectomy for hilar tumors. J Urol 2005;174:850–3.

[24] Nadu A, Mor Y, Laufer M, et al. Laparoscopic partial nephrectomy: single center experience with 140 patients—evolution of the surgical technique and its impact on patient outcomes. J Urol 2007;178:435–9.

[25] Turna B, Frota R, Kamoi K, et al. Risk factor analysis of postoperative complications in laparoscopic partial nephrectomy. J Urol 2008;179:1289–94.

[26] Ho H, Schwentner C, Neururer R, Steiner H, Bartsch G, Peschel R. Robotic-assisted laparoscopic partial nephrectomy: surgical technique and clinical outcomes at 1 year. BJU Int 2009;103:663–8.

[27] Halachmi S, Farfara R, Gross M, et al. Pattern of oncological failure following nephron sparing surgery (NSS) for unilateral unifocal renal cancer. J Urol 2009;181:441.

[28] Hidas G, Kastin A, Mullerad M, Shental J, Moskovitz B, Nativ O. Sutureless nephron-sparing surgery: use of albumin glutaraldehyde tissue adhesive (BioGlue). Urology 2006;67:697–700.

[29] Hidas G, Lupinsky L, Kastin A, Moskovitz B, Groshar D, Nativ O. Functional significance of using tissue adhesive substance in nephron-sparing surgery: assessment by quantitative SPECT of 99m Tc-dimercaptosuccinic acid scintigraphy. Eur Urol 2007;52:785–90.

[30] Rais-Bahrami S, Lima GC, Varkarakis IM, et al. Intraoperative conversion of laparoscopic partial nephrectomy. J Endourol 2006;20:205–8.

[31] Thompson RH, Leibovich BC, Lohse CM, Zincke H, Blute ML. Complications of contemporary open nephron sparing surgery: a single institution experience. J Urol 2005;174:855–8.

[32] Hafez KS, Krishnamurthi V, Campbell SC, Novick AC. Contemporary management of renal cell carcinoma with coexistent renal artery disease: update of the Cleveland Clinic experience. Urology 2000;56:382–6.

[33] Hafez KS, El Fettouh HA, Novick AC, Ouriel K. Management of synchronous renal neoplasm and abdominal aortic aneurysm. J Vasc Surg 2000;32:1102–10.

[34] Rogers CG, Metwalli A, Blatt AM, et al. Robotic partial nephrectomy for renal hilar tumors: a multi-institutional analysis. J Urol 2008;180:2353–6.

[35] Rogers CG, Singh A, Blatt AM, Linehan WM, Pinto PA. Robotic partial nephrectomy for complex renal tumors: surgical technique. Eur Urol 2008;53:514–23.

[36] Lattouf J-B, Beri A, D'Ambros OFJ, Grüll M, Leeb K, Janetschek G. Laparoscopic partial nephrectomy for hilar tumors: technique and results. Eur Urol 2008;54:409–18.

[37] Abbou CC, Hoznek A, Salomon L, Ben Slama MR, Chopin D. Is open surgery for partial nephrectomy an obsolete surgical procedure? Curr Opin Urol 1999;9:383–9.

[38] Celia A, Zeccolini G, Guazzoni G, et al. Laparoscopic nephron sparing surgery: a multi-institutional European survey of 592 cases. Arch Ital Urol Androl 2008;80:85–91.

[39] Feder MT, Patel MB, Melman A, Ghavamian R, Hoenig DM. Comparison of open and laparoscopic nephrectomy in obese and nonobese patients: outcomes stratified by body mass index. J Urol 2008;180:79–83.

[40] Link RE, Permpongkosol S, Gupta A, Jarrett TW, Solomon SB, Kavoussi LR. Cost analysis of open, laparoscopic, and percutaneous treatment options for nephron-sparing surgery. J Endourol 2006;20:782–9.

[41] Mouraviev V, Nosnik I, Robertson C, Albala D, Walther P, Polascik TJ. Comparative financial analysis of minimally invasive surgery to open surgery for small renal tumours $\leq$3.5 cm: a single institutional experience. Eur Urol 2007;51:715–21.

[42] Lotan Y, Cadeddu JA. A cost comparison of nephron-sparing surgical techniques for renal tumour. BJU Int 2005;95:1039–42.