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ORIGINAL ARTICLE

Robotic-assisted partial nephrectomy: single-layer cortical renorrhaphy is associated with reduced rate of renal artery pseudoaneurysm compared to double-layer renorrhaphy

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Abstract
The study compares the outcome of patients who underwent single-layer outer cortical renorraphy (SLOCR) and double-layer cortical renorraphy (DLR) in our institution. The retrospective analysis of 181 patients who underwent RAPN was performed. Propensity score matching was accomplished on 67 patients using age, BMI, size, distance from collecting system, hilar location and pathological stage. Intraoperative factors assessed included warm ischemia time, renorraphy time, blood loss and operative duration (Levey et al. in Clin Chem 53:766–772, 2007) Post-operative hospital stay, complications like renal artery pseudoaneurysm (RAP), hemorrhage, urine leak and reduction in eGFR were measured. The 67 patients in SLOCR group were compared with similar number in the DLR group using propensity score matching. Warm ischemia time ($P < .001$), renorraphy time ($P < .001$) and symptomatic pseudoaneurysm (RAP) rate ($P < .001$) were significantly less in SLOCR group. SLOCR is associated with reduced rate of symptomatic post-operative RAP.

Keywords Pseudoaneurysm · Renorraphy · Robotic partial nephrectomy · Warm ischemia time · Renal tumor

Introduction

Advent of modern imaging methods has facilitated early diagnosis of renal mass, this has paved way for an increased number of nephron-sparing surgeries being performed [1]. Robotic-assisted partial nephrectomy (RAPN) has the advantage of minimizing the morbidity along with preserving renal function, while achieving complete tumor resection [2]. Numerous modifications of surgical techniques for RAPN has been suggested to achieve the "trifecta" which comprises of minimizing surgical complications, achieving negative surgical margins and maximizing preservation of normal renal parenchyma [3]. The technique of reconstruction of the parenchyma can potentially impact the preservation of healthy parenchyma and prevention of surgical complications [3–5]. Four proposed methods of parenchymal reconstruction in partial nephrectomy are: (1) single-layer outer cortical renorraphy (SLOCR) [6, 7], (2) single inner-layer renorraphy (SLIR) with early unclamping [8], (3) double-layer renorraphy (DLR) [2] and (4) sutureless with coagulation of the bed. [9] The renorraphy methods can a have an influence on post-operative surgical complications like hemorrhage, renal artery pseudoaneurysm (RAP) and urine leak [7, 10]. It can also have a possible impact on warm ischemia time, preservation of parenchyma and long-term renal functions [7, 10]. The results of the studies which have dealt with renorraphy methods are contradictory and further evidence is required to determine the ideal methods of reconstruction [7, 8]. William et al. in their study has suggested that collecting system repair can be safely omitted with single-layer sliding clip renorraphy [7]. In another study, Bahler et al. has suggested that inner-layer renorraphy alone is safe and elimination of the cortical renorraphy will increase parenchymal preservation [8]. In this study, we are comparing our outcomes of SLOCR to DLR and its influence on post-operative renal function and complications.

Materials and methods

The retrospective analysis of patients who underwent RAPN was performed. Data extraction was performed after obtaining approval from institutional review board. All patients

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with a small renal mass who underwent RAPN were included in the study.

Surgical technique

RAPN was performed using a da vinci Si system (Intuitive Surgical, Sunnyvale, CA, USA). The patients were placed in lateral position, after insufflation of pneumoperitoneum, three robotic ports, camera port and two assistant ports were placed. Additional port was placed on right side for liver retraction. The colon was reflected, renal vessels were isolated, mobilization of the kidney and tumor dissection was performed. Bulldog clamps (Scanlan International Inc., MN USA) were placed on vessels and tumor excision was performed. In SLOCR group monopolar cauterization of the base and the small arterial branches were done. In cases were collecting system were opened it was selectively repaired using 4.0 Stratafix (Ethicon Inc., NJ, USA) and this was followed by sliding clip cortical renorraphy using 0 Vicryl on a CT-1 needle (Ethicon, NJ, USA) (Fig. 1). In DLR initial inner-layer continuous closure of the parenchyma was performed using 4.0 Stratafix followed by cortical renorraphy (Fig. 2). Subsequently bull dog clamps were released and hemostasis attained.

Data analysis

Preoperative parameters considered were age, sex, body mass index (BMI), estimated glomerular filtration by MDRD formula (eGFR), comorbidities, renal nephrometry score, distance from the collecting system, size of the tumor and hilar location. Renal nephrometry score was categorized into low, intermediate and high risk. Intraoperative factors assessed include warm ischemia time, renorraphy time, blood loss and operative duration [11]. Post-operative hospital stay, complications like symptomatic RAP, hemorrhage, urine leak and reduction eGFR were measured.

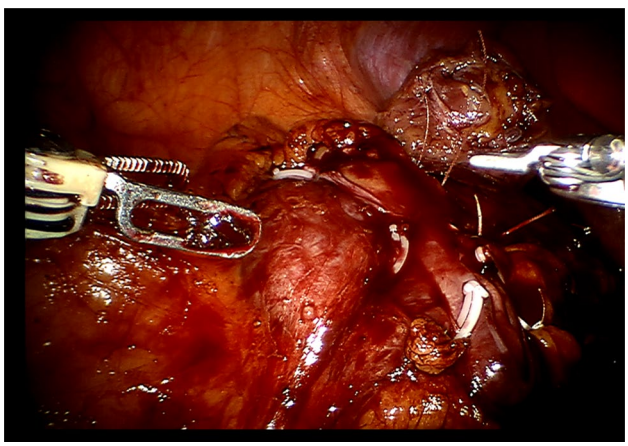

Fig. 1 Outer cortical renorrhaphy

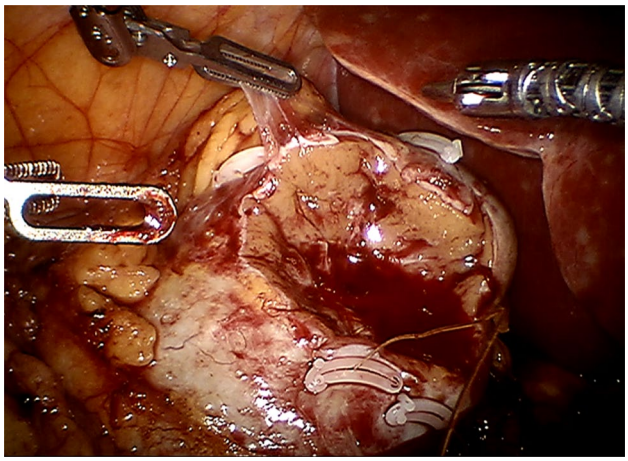

Fig. 2 Inner layer cortical renorrhaphy

Statistical methods

Data were coded and recorded in MS Excel spreadsheet program. SPSS v23 (IBM Corp.) was used for data analysis. Descriptive statistics were elaborated in the form of means/standard deviations and medians/inter quartile ranges for continuous variables. For categorical variables it was described in frequencies and percentages. Group comparisons for continuously distributed data were made using independent sample '*t*' test when comparing two groups. If data were found to be non-normally distributed, appropriate non-parametric tests in the form of Wilcoxon test were used. Chi-squared test was used for group comparisons for categorical data. In case the expected frequency in the contingency tables was found to be <5 for $>25\%$ of the cells, Fisher's exact test was used instead. Linear correlation between two continuous variables were explored using Pearson's correlation in a normally distributed data and Spearman correlation non-normally distributed data. Propensity score matching was performed using the nearest neighbour technique with variables age, gender, BMI, size, depth, hilar location and pathological stage. Statistical significance was kept at $P<0.05$.

Results

Of the 181 patients who were included in analysis 114 had DLR and 67 had SLOCR. In the initial analysis, there was significant difference in size of the tumor ($P<0.001$), warm ischemia time ($P<0.001$), renorraphy time ($P<0.001$), total operative time ($P<0.001$) and symptomatic RAP rate ($P<0.001$) (Table 1). To eliminate bias, 67 patients

Table 1 Association between group and parameters

Parameters	Group		*P* value
	Single layer (*n* = 67)	Double layer (*n* = 114)	
Age	53.52 ± 13.06	53.39 ± 11.26	0.703[1]
BMI	26.44 ± 4.08	27.74 ± 5.32	0.271[1]
Nephrometry grading			0.279[2]
Low	40 (59.7%)	81 (71.1%)	
Intermediate	19 (28.4%)	22 (19.3%)	
High	8 (11.9%)	11 (9.6%)	
Depth of tumor	6.43 ± 1.34	6.54 ± 1.28	0.700[1]
Size of tumor***			< 0.001[2]
< 4 cm	34 (50.7%)	5 (4.4%)	
4–7 cm	26 (38.8%)	106 (93.0%)	
> 7 cm	7 (10.4%)	3 (2.6%)	
T staging			0.087[3]
T1	53 (79.1%)	96 (84.2%)	
T2	11 (16.4%)	18 (15.8%)	
T3	3 (4.5%)	0 (0.0%)	
Hilar location	1 (1.5%)	2 (1.8%)	1.000[3]
Warm ischemia time***	19.48 ± 5.62	22.96 ± 6.99	0.001[1]
Renorrhaphy time***	9.30 ± 4.41	14.78 ± 6.03	< 0.001[1]
Total operative time***	135.84 ± 23.05	156.83 ± 43.61	0.001[1]
Pseudoaneurysm ***	0 (0.0%)	11 (9.6%)	0.008[3]
Urine leak	0 (0.0%)	2 (1.8%)	0.531[3]
Other complications	1 (1.5%)	8 (7.0%)	0.157[3]

***Significant at $P < 0.05$

[1]Wilcoxon–Mann–Whitney *U* Test

[2]Chi-squared test

[3]Fisher's exact test

in SLOCR group were compared with similar number in the DLR group using propensity score matching. In the matched cohort it was found that warm ischemia time ($P < 0.001$), renorraphy time ($P < 0.001$) and symptomatic RAP rate ($P < 0.001$) were significantly less in SLOCR group (Table 2).

Discussion

Primary objective of renorraphy is to achieve hemostasis with secure closure of collecting system [10, 12, 13]. The introduction of sliding clip renorraphy in 2009 by Benway et al. has gained wide spread acceptance. This facilitates to perform the renorraphy without any parenchymal tear and allow adequate pressure for hemostasis [14]. The renorraphy techniques have been subjected to various modifications to maximize parenchymal preservation and reduce complication [13].

Table 2 Association between group and parameters after propensity matching

Parameters	Group		*P* value
	Single layer (*n* = 67)	Double layer (*n* = 67)	
Age	53.52 ± 13.06	52.87 ± 10.73	0.661[1]
Gender***			0.011[2]
BMI	26.44 ± 4.08	25.57 ± 3.05	0.055[1]
Nephrometry grading			0.282[2]
Low	40 (59.7%)	48 (71.6%)	
Intermediate	19 (28.4%)	15 (22.4%)	
High	8 (11.9%)	4 (6.0%)	
Depth of tumor in mm	6.43 ± 1.34	6.78 ± 0.92	0.241[1]
Size of tumor			0.639[2]
< 4 cm	34 (50.7%)	36 (53.7%)	
4–7 cm	26 (38.8%)	27 (40.3%)	
> 7 cm	7 (10.4%)	4 (6.0%)	
T staging			0.316[2]
T1	53 (79.1%)	48 (71.6%)	
T2/T3	14 (20.9%)	19 (28.4%)	
Hilar location	1 (1.5%)	0 (0.0%)	1.000[3]
Warm ischemia time***	19.48 ± 5.62	24.48 ± 7.68	< 0.001[1]
Renorrhaphy time***	9.30 ± 4.41	15.01 ± 6.15	< 0.001[1]
Total operative time	135.84 ± 23.05	156.33 ± 51.97	0.081[1]
Pseudoaneurysm ***	0 (0.0%)	19 (28.4%)	< 0.001[2]
Urine leak	0 (0.0%)	0 (0.0%)	1.000[2]
Other complications	1 (1.5%)	1 (1.5%)	1.000[3]
Propensity score	0.62 ± 0.30	0.62 ± 0.30	0.859[1]

***Significant at $p < 0.05$

[1]Wilcoxon–Mann–Whitney *U* Test

[2]Chi-squared test

[3]Fisher's exact test

A standard method of reconstruction DLR were an inner-layer suturing is performed to control the vessels [2]. The inner-layer renorrhaphy could be an interrupted selective suturing of bleeding vessels and calyceal system [15]. The premise is that it provides a secure closure to preventing hemorrhagic complications and urinary leak. Outer-layer cortical renorraphy is commonly performed using an interrupted sliding Weck clip technique or by continuous sutures [14]. The drawback of this technique included inability to visualise bleeding from the base of the defect after clamp release. The inner-layer cortical renorraphy also potentially increases the rate of RAP [16–18]. It is postulated that repeated and failed passage of need through small arterioles can produce laceration and resultant RAP [16–18].

SLIR with early unclamping has been suggested by authors to obviate certain disadvantages of DLR. It is suggested that it would improve visualisation of the bleeding and allow selective control of the vessels. It is also proposed

that omission of the outer cortical renorraphy may improve parenchymal preservation [8]. Bahler in a study found that renal function was affected less while performing SLIR (8%) compared to DLR (17%) [8]. Another advantage of this technique would be reduced warm ischemia due to early unclamping leading to improved long-term renal function [8]. Though SLIR has shown less reduction of renal function, the complications like RAP are still prevalent with this technique [8].

In SLOCR technique, the arterioles at the base of the defect is coagulated and pressure from cortical renorraphy helps to achieve hemostasis from opened veins. The interrupted sutures placed by sliding clip renorraphy allows secure closure without any resultant ischemia. In a study by Williams et al., omitting collecting system repair during RAPN with SLR decreased warm ischemia time without altering complication rate [7]. SLOCR has been reported in laparoscopic enucleation with high degree of success [19, 20]. Enucleation involved less aggressive resection without entry into the renal sinus obviating the need for elaborate reconstruction [19, 20]. Low incidence of symptomatic RAP (< 1%) with SLOCR is similar to what we observed in our study [7, 19, 20].

Techniques of suture less partial nephrectomy has been described by many authors. Takagi et al. showed that asymptomatic RAP diagnosed radiologically in 15% of patients and it resolved in some patients without any treatment [21]. Tanaka et al. demonstrated the complete absence of asymptomatic RAP on computed tomography after minimally invasive partial nephrectomy using clampless and sutureless techniques [9]. Total reduction of RAP in patients who did not have an inner-layer suturing in our study also strongly support this hypothesis. In a comparative study on open approach, Hidas et al. compared renal function following PN using tissue adhesive only versus PN using standard suturing technique using quantitative ^{99m}Tc-dimercaptosuccinic acid uptake by the kidney [22]. The use of tissue sealant to close the parenchymal defect demonstrated a significant advantage in terms of renal functional preservation compared with suture renorrhaphy [22]. Use of monopolar coagulation with n-Butyl cyanoacrylate had been described in clampless and sutureless laparoscopic partial nephrectomy for renal tumors with low RENAL nephrometry scores [23]. Sutureless minimally invasive partial nephrectomy has been reported by many authors with good results recently [24–27].

The complete absence of RAP in SLOCR points that inner-layer renorraphy could be the incriminating factor. Although there was significant difference in warm ischemia time and total operating time between the two groups this could not be extrapolated in change in post-operative renal function. Our study being a retrospective analysis has inherent limitations. This was a single-institution study with a small patient population. Our symptomatic RAP rates in DLIR group (9.6%) is higher 0.9–5.6% described in literature [28, 29]. Most of the DLR was performed early in our series which could have had an influence on the outcome. Finally, we did not discuss the long-term renal oncological outcomes and renal function. An ongoing trail NCT0213176 evaluating the role of renorraphy as a modifiable factor during robotic partial nephrectomy would give more accurate insight into the impact of renorraphy on complication and renal function.

Conclusion

Our study shows that inner-layer renorraphy dramatically increased the pseudoaneurysm rates. SLOCR reduced the warm ischemia time, total operating time with reduced rate of RAP. Suture less partial nephrectomy with hemostatic agents may further reduce the complications and hold great promise for the future [30].

Author contributions All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by KT, BSS, and VR. The first draft of the manuscript was written by BSS and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

Ethics approval This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Aster Medcity, Kochi.

Consent to participate Informed consent was obtained from all individual participants included in the study.

Consent to publish The authors affirm that human research participants provided informed consent for publication of the images in Figure(s) 1, 2.

References

1. Uzzo RG, Novick AC (2001) Nephron sparing surgery for renal tumors: indications, techniques and outcomes. J Urol 166:6–18
2. 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
3. Hung AJ, Cai J, Simmons MN, Gill IS (2013) "Trifecta" in partial nephrectomy. J Urol 189:36–42

4. Shatagopam K, Bahler CD, Sundaram CP (2020) Renorrhaphy techniques and effect on renal function with robotic partial nephrectomy. World J Urol 38:1109–1112
5. Bertolo R, Campi R, Mir MC, Klatte T, Kriegmair MC, Salagierski M, Ouzaid I, Capitanio U, Young Academic Urologists Kidney Cancer Working Group of the European Urological Association (2019) Systematic review and pooled analysis of the impact of renorrhaphy techniques on renal functional outcome after partial nephrectomy. Eur Urol Oncol. 2:572–575
6. Porpiglia F, Bertolo RG, Amparore D, Angusti T, Di Dio M, Piramide F, Fiori C (2016) Single-layer versus double-layer renorrhaphy during minimally-invasive partial nephrectomy: are there effects on renal function? Eur Urol Suppl 15(7):236
7. Williams RD, Snowden C, Frank R, Thiel DD (2017) Has sliding-clip renorrhaphy eliminated the need for collecting system repair during robot-assisted partial nephrectomy? J Endourol 31:289–294
8. Bahler CD, Dube HT, Flynn KJ, Garg S, Monn MF, Gutwein LG, Mellon MJ, Foster RS, Cheng L, Sandrasegaran MK, Sundaram CP (2015) Feasibility of omitting cortical renorrhaphy during robot-assisted partial nephrectomy: a matched analysis. J Endourol 29:548–555
9. Tanaka H, Fujii Y, Ishioka J, Matsuoka Y, Saito K, Kihara K (2017) Absence of renal artery pseudoaneurysm on computed tomography after minimally-invasive partial nephrectomy using clampless and sutureless techniques. Int J Urol 24:472–473
10. Bahler CD, Cary KC, Garg S, DeRoo EM, Tabib CH, Kansal JK, Monn MF, Flack CK, Masterson TA, Sandrasegaran MK, Foster RS, Sundaram CP (2015) Differentiating reconstructive techniques in partial nephrectomy: a propensity score analysis. Can J Urol 22:7788–7796
11. Levey AS, Coresh J, Greene T, Marsh J, Stevens LA, Kusek JW, Van Lente F, Chronic Kidney Disease Epidemiology Collaboration (2007) Expressing the modification of diet in renal disease study equation for estimating glomerular filtration rate with standardized serum creatinine values. Clin Chem 53(4):766–772
12. Bahler CD, Sundaram CP (2016) Effect of renal reconstruction on renal function after partial nephrectomy. J Endourol 30(Suppl 1):S37-41
13. Kotamarti S, Rothberg MB, Danzig MR, Levinson J, Saad S, Korets R, McKiernan JM, Badani KK (2015) Increasing volume of non-neoplastic parenchyma in partial nephrectomy specimens is associated with chronic kidney disease upstaging. Clin Genitourin Cancer 13:239–243
14. Benway BM, Wang AJ, Cabello JM, Bhayani SB (2009) Robotic partial nephrectomy with sliding-clip renorrhaphy: technique and outcomes. Eur Urol 55:592–599
15. Delto JC, Paulucci D, Helbig MW et al (2018) Robot-assisted partial nephrectomy for large renal masses: a multi-institutional series. BJU Int 121:908–915
16. Singh D, Gill IS (2005) Renal artery pseudoaneurysm following laparoscopic partial nephrectomy. J Urol 174:2256–2259
17. Kondo T, Takagi T, Morita S, Omae K, Hashimoto Y, Kobayashi H, Iizuka J, Yoshida K, Fukuda N, Tanabe K (2015) Early unclamping might reduce the risk of renal artery pseudoaneurysm after robot-assisted laparoscopic partial nephrectomy. Int J Urol 22:1096–1102
18. Hyams ES, Pierorazio P, Proteek O et al (2011) Iatrogenic vascular lesions after minimally invasive partial nephrectomy: a multi-institutional study of clinical and renal functional outcomes. Urology 78:820–826
19. Minervini A, Serni S, Tuccio A, Siena G, Vittori G, Masieri L, Giancane S, Lanciotti M, Khorrami S, Lapini A, Carini M (2012) Simple enucleation versus radical nephrectomy in the treatment of pT1a and pT1b renal cell carcinoma. Ann Surg Oncol 19:694–700
20. Lu Q, Zhao X, Ji C, Guo S, Liu G, Zhang S, Li X, Gan W, Guo H (2017) Modified laparoscopic simple enucleation with single-layer suture technique versus standard laparoscopic partial nephrectomy for treating localized renal cell carcinoma. Int Urol Nephrol 49:239–245
21. Takagi T, Kondo T, Tajima T, Campbell SC, Tanabe K (2014) Enhanced computed tomography after partial nephrectomy in early postoperative period to detect asymptomatic renal artery pseudoaneurysm. Int J Urol 21:880–885
22. Hidas G, Lupinsky L, Kastin A, Moskovitz B, Groshar D, Nativ O (2007) Functional significance of using tissue adhesive substance in nephron-sparing surgery: assessment by quantitative SPECT of 99m Tc-Dimercaptosuccinic acid scintigraphy. Eur Urol 52:785–789
23. Zhang F, Gao S, Chen XN, Wu B (2019) Clampless and sutureless laparoscopic partial nephrectomy using monopolar coagulation with or without N-butyl-2-cyanoacrylate. World J Surg Oncol 17(17):72
24. Tiscione D, Cai T, Luciani LG, Puglisi M, Mattevi D, Nesi G, Barbareschi M, Malossini G (2019) Sutureless laparoscopic partial nephrectomy using fibrin gel reduces ischemia time while preserving renal function. Arch Ital Urol Androl 29(91):30–34
25. Corongiu E, Grande P, Di Santo A, Pagliarella G, Squillacciotti S, Liberati E, Zampelli A, Olivieri V, Innocenzi M, Forte F (2019) Safety and efficacy of retroperitoneal sutureless zero ischemia laparoscopic partial nephrectomy for low nephrometry score masses. Arch Ital Urol Androl. https://doi.org/10.4081/aiua.2019.3.157
26. Simone G, Papalia R, Guaglianone S, Gallucci M (2012) 'Zero ischaemia', sutureless laparoscopic partial nephrectomy for renal tumours with a low nephrometry score. BJU Int 110:124–130
27. Introini C, Di Domenico A, Ennas M, Campodonico F, Brusasco C, Benelli A (2020) Functional and oncological outcomes of 3D clampless sutureless laparoscopic partial nephrectomy for renal tumors with low nephrometry score. Minerva Urol Nefrol 72:723–728
28. Connor J, Doppalapudi SK, Wajswol E, Ragam R, Press B, Luu T, Koster H, Tamang TL, Ahmed M, Lovallo G, Munver R, Stifelman MD (2020) Postoperative complications after robotic partial nephrectomy. J Endourol 34:42–47
29. Chavali JSS, Bertolo R, Kara O, Garisto J, Mouracade P, Nelson RJ, Dagenais J, Kaouk JH (2019) Renal arterial pseudoaneurysm after partial nephrectomy: literature review and single-center analysis of predictive factors and renal functional outcomes. J Laparoendosc Adv Surg Tech A 29:45–50
30. Hupe MC, Büttner M, Tabrizi PF, Merseburger AS, Kuczyk MA, Imkamp F (2021) Hemopatch® as a hemostatic agent is safe in partial nephrectomy: a large, single-surgeon retrospective evaluation. Adv Ther 38:1024–1034