A comparative analysis of various surgical approaches of nephron-sparing surgery and correlation of histopathological grade with RENAL nephrometry score in renal cell carcinoma

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Abstract

Background: Nephron-sparing surgery (NSS) is the standard of care for small renal masses whenever feasible. This study aims to evaluate the perioperative outcomes of NSS performed by open (open partial nephrectomy [OPN]) or laparoscopic (laparoscopic PN [LPN]) or robotic (robotic PN [RPN]) approach over the past 6 years and to study the correlation of histopathological grade of renal cell carcinoma with the RENAL score.

Materials and Methods: A retrospective analysis of prospectively collected data of all patients who underwent NSS was done.

Results: A total of 135 patients underwent NSS. The mean tumour size was 4.4 cm. About 61 patients underwent OPN, 24 had LPN and 50 had RPN. Although tumour size was larger in OPN group (P = 0.01), tumour complexity based on the RENAL score was similar in OPN and RPN groups (P = 0.15). The OPN group had shorter operative time (P = 0.008) but more blood loss (P = 0.001) and length of hospital stay (P = 0.049) as compared to LPN or RPN group. Maximum radiological diameter of tumour (P = 0.017) appeared to be a significant predictor of operative time, while the open surgical approach (P = 0.003) and tumour stage (P = 0.044) were found to be significant predictors of blood loss. Hilar clamping time was similar in OPN and RPN groups (P = 0.054) but higher in LPN group (P = 0.01). However, post-operative decline in renal function (estimated glomerular filtration rate) (P = 0.08) and margin status were comparable among the three groups. The most common histopathology was clear cell carcinoma (70%), and RENAL score was identified as a significant predictor of histopathological grade of tumour (P = 0.008).

Conclusion: Open, laparoscopic and robotic approaches to PN provide similar patient outcomes. OPN was usually preferred for larger tumours. The post-operative decline in renal functions and complications were comparable among the three approaches. RENAL score correlated significantly with histopathological grade and hence could help in predicting tumour behaviour pre-operatively.

Keywords: Laparoscopic partial nephrectomy, nephron-sparing surgery, open partial nephrectomy, RENAL score, robotic partial nephrectomy

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INTRODUCTION

Widespread use of modern abdominal imaging has resulted in a stage migration in renal cell cancer. Today, more cases are diagnosed at a smaller size, mostly localised to the kidney and are amenable to nephron-sparing surgery (NSS). Conventionally, all such masses were managed by radical nephrectomy, and partial nephrectomy (PN) was contemplated only in the solitary kidneys. However, the concerns of new-onset chronic kidney disease due to significant loss renal parenchyma and subsequent cardiovascular risks and reduced overall survival have initiated a move away from radical nephrectomy. NSS provides equivalent long-term oncologic outcomes with the advantage of parenchymal preservation and is the standard of care whenever feasible.

NSS used to be performed by an open approach, but with technical advancement and increasing experience, laparoscopic PN (LPN) was shown to have equivalent oncologic outcomes with lower morbidity and faster convalescence. However, LPN is a technically challenging procedure requiring a complex time-dependent reconstruction and thus has a steep learning curve. To an extent, it reduced the utilisation of NSS and laparoscopic radical nephrectomy was preferred because of its ease. Robot-assisted laparoscopy overcomes these challenges with its EndoWrist instrument providing unmatched dexterity, a three-dimension high-definition vision and ergonomic operating position. By duplicating the operative technique of open PN (OPN) and LPN, robotic PN (RPN) offers all the advantages of minimally invasive technique, a similar oncologic and surgical outcomes with a shorter learning curve.

As the indications of NSS are expanding and larger tumours (4–7 cm) or those in perihilar locations are also offered NSS, the choice of approach (OPN or LPN or RPN) not only depends on availability of resource and expertise but also tumour characteristics. Few Asian studies and, in particular, Indian studies have reported outcomes of minimal invasive PN. Moreover, RENAL nephrometry score is a standardised tool to study tumour complexity in pre-operative imaging, and its correlation with histopathological grade has been scarcely reported.

This study aims to evaluate tumour characteristics and perioperative oncologic and perinephrectomy outcomes after NSS performed by open or laparoscopic or robotic approach at our centre in the past 6 years and to study the correlation between RENAL nephrometry score and histopathological grade of renal cell carcinoma (RCC).

MATERIALS AND METHODS

A retrospective analysis of all patients undergoing NSS for renal mass at our department over the past 6 years (from April 2011 to December 2016) was done. All patients underwent standard pre-operative workup along with a cross-sectional imaging, contrast-enhanced computed tomography if renal function was normal otherwise magnetic resonance imaging. Staging of the RCC was done according to the 7th American Joint Committee on Cancer version. RENAL nephrometry score was used to study tumour complexity on imaging. All patients who underwent PN or had intra-operative conversion to radical nephrectomy were included in this study. The choice of surgical approach (OPN vs. LPN vs. RPN) was either patient’s or the surgeons’ preference considering the tumour characteristics but was never financial. OPN was performed by retroperitoneal approach using the standard flank incision and ribs were cut if required. In all these patients, adequate post-operative pain relief was ensured by an epidural catheter, which was placed in the immediate pre-operative period and kept for 72 h after surgery. For LPN and RPN, transperitoneal approach was used. No patient underwent retroperitoneoscopic minimal invasive approach. LPN utilised standard four ports on the right and three on the left, whereas 4th arm of robot was used in all cases of RPN requiring six ports on the right and five on the left. The port placement was modified according to the built of the patient to avoid clashing of the robotic arms. Renal hilar control was taken in almost all cases of LPN and RPN and in selected OPN cases. Renal artery and vein were separately clamped using bulldog clamps and intravenous mannitol was given before clamping in all cases. Cold ischaemia (ice slush), hypotensive anaesthesia or manual parenchymal compression was used in selective cases as per surgeon’s discretion. Renorraphy was performed in all cases in a similar fashion and bolster was used if the defect was large as per the surgeon’s discretion.

A two-layer sliding renorraphy using a continuous 3-0 vicryl or 3-0 V-loc suture for inner layer and 2-0 vicryl or 2-0 V-loc for outer layer with hem-o-lok clips to prevent suture cut through was used. If excision of the tumour created a rent in the pelvicalyceal system, a double J (DJ) stent was placed in selected cases as per surgeon discretion and an additional layer of 3-0 vicryl continuous suture was used to close it. Similar perioperative care provided to all patients and adequate analgesia was ensured. Preoperative data such as age, gender, co-morbidities, tumour size, tumour location, stage, presence of chronic kidney disease (CKD) and perioperative outcomes such as operative time, blood loss, warm ischaemia time, post-operative complication, length of stay, final histology and margin status were recorded for all patients. Estimated glomerular filtration
rate (eGFR) was calculated from serum creatinine using CKD-Epidemiology Collaboration equation and CKD was defined as eGFR <60 ml/min. Complications were recorded as per Clavien–Dindo scale.[13] Urine leak was defined as high drain output (>100 ml) lasting for more than 48 h with high drain fluid creatinine levels. To assess perioperative outcomes, these patients were divided into three groups depending on the mode of surgery that is, OPN, LPN and RPN. The study was approved by the Institutional Ethics Committee (Reference number IECPG-500/2018).

Statistical analysis
Continuous variables were expressed as mean ± standard deviation (SD) or median (interquartile range [IQR]) as appropriate. Categorical variables were compared using Chi-square test and continuous variables were compared using Student’s t-test, multiple ANOVA or Mann–Whitney test as appropriate. The correlation between two variables was assessed using Spearman’s Rank Correlation or Pearson’s coefficient as appropriate. Multivariate regression analysis was used to study the predictors of surgical approach, perioperative outcomes and histopathological grade. Statistical significance was taken as \( P < 0.05 \). Data were analysed using IBM SPSS Statistics software (version 20.0, Chicago, IL, USA).

RESULTS
Out of 324 patients who underwent surgery for suspicious renal mass over the period of study, 141 patients were planned for PN. The mean age (±SD) of the study population was 49 (±14) years, 65 patients were males and 68 patients had a right-sided renal mass. Five patients had bilateral disease. Out of these 135 patients, 61 patients underwent open surgery, 24 had laparoscopic surgery and rest 50 had RPN. The preoperative characteristics of these groups are shown in Table 1. Fifteen (11.1%) had baseline CKD with mean eGFR (±SD) of 42.5 (±13.5) ml/min. Mean age of patients, co-morbidities, location and preoperative haemoglobin levels were comparable among the three groups.

The mean radiologic tumour size (±SD) of the study population was 4.3 (±2) cm in maximum diameter and the mean RENAL score (±SD) was 6.2 (a/p) (±1.8). On stratifying the data according to operative procedure [Table 2], the patients who underwent OPN had significantly larger tumour size (5.1 ± 2.5 cm, \( P = 0.02 \)) and higher RENAL score (6.4 ± 1.5, \( P = 0.04 \)) as compared to LPN (3.9 ± 1.5 cm and 5.8 ± 1.3), respectively. However, RENAL score was statistically similar in OPN and RPN groups (6.4 ± 1.5 vs. 6.1 ± 1.5, \( P = 0.15 \)) in spite of larger tumour size in OPN group. Out of 141 patients planned to undergo PN, 135 underwent the procedure and 6 were converted to radical nephrectomy. Out of six patients who were converted to radical nephrectomy intraoperatively, three were from RPN and two were from OPN groups. Five of these patients had RENAL score >9. The conversions were due to small amount of residual renal parenchyma. One patient in the RPN group underwent open radical nephrectomy due to post-operative bleeding in the recovery room.

Using multinomial regression analysis, preoperative factors including age, tumour size, RENAL score, preoperative haemoglobin or renal function status could not be identified as predictors of surgical approach [Table 3].

The perioperative characteristics of patients who underwent PN are shown in Table 4. The mean operative time was shorter in OPN (152.9 ± 35.2 min) as compared to that for LPN (175.8 ± 41.2 min) or RPN (156.1 ± 39.9 min), but the difference was statistically significant only between OPN and LPN groups (\( P = 0.005 \)). Using generalised linear model regression analysis, the operative time for laparoscopic approach was significantly higher compared

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**Table 1: Characteristics of patients undergoing partial nephrectomy**

| Overall | Open PN | Laparoscopic PN | Robotic PN | \( P \) |
|---------|---------|----------------|------------|------|
| Number of patients, \( n \) (%) | 135 | 61 (45.2) | 24 (17.8) | 50 (37) |
| Age±SD, years | 49±14 | 50±16 | 49±13 | 50±13 | 0.99 |
| Gender (male/female) | 65/70 | 28/33 | 12/12 | 25/25 | 0.96 |
| Co-morbidities | | | | | |
| Diabetes (\( n \)) | 32 | 15 | 8 | 9 | 0.81 |
| Hypertension (\( n \)) | 50 | 22 | 7 | 21 | 0.67 |
| Coronary artery disease (\( n \)) | 6 | 3 | 3 | 0 | 0.62 |
| eGFR (<60 ml/min/1.73 m\(^2\)) (\( n \)) | 15 | 10 | 1 | 4 | 0.18 |
| Mode of detection, \( n \) (%) | | | | | |
| Incidental | 87 (64.5) | 42 | 14 | 31 | 0.62 |
| Pain | 35 (25.9) | 14 | 8 | 13 | | |
| Haematuria | 6 (4.5) | 2 | 2 | | |
| Pain and haematuria | 7 (5.2) | 3 | 0 | | |
| Haemoglobin SD (g/dl) | 12.3±2.1 | 12.7±2.1 | 12.8±2.1 | 12.6±2.0 | 0.91 |

**Table 1**: Characteristics of patients undergoing partial nephrectomy

\( \text{eGFR: Estimated glomerular filtration rate, PN: Partial nephrectomy, SD: Standard deviation} \)
to open and robotic groups ($P = 0.001$). Maximum radiological diameter of tumour ($P = 0.017$) appeared to be a significant predictor of operative time; however, RENAL score did not appear to predict the operative time ($P = 0.079$) [Table 3].

The median blood loss (IQR) was significantly higher in OPN group (500 [200–600] ml) as compared to LPN (240 [200–500] ml) or RPN (200 [150–300] ml) groups ($P = 0.001$). Using generalised linear regression analysis, only open surgical approach and tumour stage ($P = 0.044$) were found to be significant predictors of blood loss ($P = 0.003$) [Table 3]. About 24 patients (17.7%) required blood transfusion in perioperative period, 16 (26.3%) patients in open, 5 (10%) in robotic and 3 (12.5%) LPN groups. Only intra-operative blood loss appeared to be a significant predictor ($P = 0.001$) for the need of blood transfusion. In 24 patients (17.8%), renal hilum was not clamped: 17 (27.8%) OPN, 4 (8%) RPN and 3 (12.5%) LPN groups. Out of 17 OPN performed without renal hilar clamp, cold ischaemia (ice slush) was used in 6 patients. Renal hilum was clamped in 111 patients (82.2%)
and the overall mean hilar clamping time (±SD) was 20.6 (±6.5) min. Although the mean Warm ischemia time (WIT) was shorter for OPN (18.9 ± 5.6 min) as compared to LPN (24.1 ± 8.3 min) and RPN (20.6 ± 6.0 min) groups (P = 0.01) overall, only LPN group had significant difference as compared to OPN and RPN groups (P = 0.02). Using multivariate regression analysis, only laparoscopic approach appeared to be a significant predictor of longer WIT (P = 0.034). eGFR was calculated based on pre-operative serum creatinine and serum creatinine on the 30th post-operative day. There was significant change in eGFR in post-operative period (P < 0.001); however, this difference was similar across the three surgical approaches (P = 0.08). Fifteen patients (11.1%) had GFR <60 ml/min in pre-operative period and 12 patients (10%) developed de novo eGFR <60 ml/min. Warm ischaemia time and surgical approach did not appear to be significant predictors of change in eGFR.

The pelvicalyceal system was opened in 50 (37%) patients and a DJ stent was placed in 12 patients. The mean duration (±SD) of drain was 3.4 (±2.9) days and mean hospital stay was 5.1 (±2.8) days. The mean hospital stay was significantly higher in open group compared to minimal invasive group, while duration of drain used was higher in open group but not statistically significant [Table 4]. Using generalised regression analysis, open surgical approach (P = 0.044) and duration of drain used (P = 0.021) were significant predictors of duration of hospital stay [Table 3].

A total of 37 patients (27.5%) developed post-operative complications and most (75.7%) were low grade (Clavien I–II). About 20 patients developed low-grade fever in post-operative period, and in 17 patients, it could be ascribed to atelectasis on the operative side (9 after OPN, 3 after LPN and 5 after RPN). Five patients had high drain output (urine leakage), two resolved spontaneously within 5 days, but three patients required DJ stenting for persistent urine leak on the post-operative day 5 (Clavien IIIA). Two patients had gross haematuria in post-operative period after RPN and were found to have pseudoaneurysm-requiring endovascular coiling (Clavien IIIA). There were two re-explorations: one in open group and another in robotic group (Clavien IIIB complication). On multivariate regression analysis, no significant predictor could be identified for perioperative complications [Table 3].

The most common histologic diagnosis of renal mass was clear cell in 97 patients (71.8%) and 10 patients (7.4%) had benign lesion with 6 patients (4.4%) having angiomyolipoma. A total of 12 (8.9%) patients had resection margin positive 4, 2 and 6 after OPN, LPN and RPN, respectively, the difference was statistically insignificant. The histopathology outcomes are described in Table 5.

ARENAL score was studied for correlation with Fuhrman’s grading of RCC. About 97 patients had clear cell RCC with 40 having Fuhrman’s Grade 1 tumour, 41 having Fuhrman’s Grade 2 tumour and 16 having Fuhrman’s Grade 3 tumours. Using Kruskal–Wallis test, there was significant association between RENAL score and grade (P < 0.001) with progressively increasing mean RENAL score from 5.1 ± 1.0 to 6.6 ± 0.8 to 7.7 ± 0.7 for Grades 1, 2 and 3, respectively [Figure 1]. Using generalised regression analysis, RENAL score appeared to be a significant predictor of histopathological grade (P = 0.008) [Table 3].

**DISCUSSION**

On comparing the outcomes between OPN, LPN and RPN, the patients undergoing OPN had significantly larger tumour and the operative time was reduced by 23 min in OPN as compared to LPN. However, OPN resulted in

| Table 5: Histopathological outcomes in patients undergoing partial nephrectomy |
|-----------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                             | Overall   | Open      | Laparoscopic | Robotic   | PN        |
| Histopathology type         |           |           |             |           |           |           |
| Clear cell RCC              | 97        | 48        | 12          | 37        | 0.91      |
| Papillary RCC               | 17        | 3         | 6           | 8         |           |
| Oncocytoma                  | 4         | 0         | 2           | 3         |           |
| Chromophobe RCC             | 5         | 3         | 1           | 1         |           |
| Other benign pathology      | 12        | 7         | 3           | 2         |           |
| Margin status               |           |           |             |           |           |
| Margin positive             | 12        | 4         | 2           | 6         | 0.32      |

PN: Partial nephrectomy, RCC: Renal cell carcinoma

**Figure 1:** Depicting association between RENAL nephrometry score and Fuhrman’s grade in patients with clear cell renal cell carcinoma undergoing partial nephrectomy

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higher blood loss by 300 ml as compared to RPN and by 260 ml as compared to LPN. The hilar clamping time was significantly longer in LPN group, while it was similar in OPN and RPN groups. The duration of hospital stay was higher in OPN group as compared to LPN or RPN group. There was no significant difference between the groups in terms of post-operative complications, margin positive rates and decrease in renal function. Compared to pre-operative value, the post-operative reduction of eGFR was seen in all three groups on the 30th post-operative day. The change in eGFR was not statistically significant between the three groups. The most common histopathology was clear cell RCC, and on multivariate regression analysis, pre-operative RENAL score was a significant predictor of histopathological grade of the tumour.

In the current study, the mean tumour size at presentation was larger than that is usually reported (mean: 4.3 cm) for PN and about 43% of the patients had T1b or larger lesion. About 64.5% of the cases were diagnosed incidentally as compared to 74% reported in literature. These indicate delayed presentation suggesting either non-availability or underutilisation of health-care resources as commonly witnessed in a developing country. Further, the mean tumour size of patients undergoing LPN or RPN was higher (3.5 cm for RPN and 3.9 cm for LPN) than that is reported in literature (1.9–3.1 cm) and was similar to the reports assessing feasibility of PN in complex renal lesions (3.8 cm–5 cm). This trend was also seen in patients undergoing OPN who also had larger tumour size than what is reported in literature (5.1 cm as compared to 2.3–3.9 cm).

On stratification of tumour characteristics according to the procedure type, we found that mean tumour size of patients undergoing OPN was larger by 1.1–1.6 cm as compared to those undergoing either LPN or RPN. However, on stratifying according to the stage of disease, 77 patients (57.0%) had T1a lesion, 46 patients (34.0%) had T1b lesion and 12 patients (9%) had a T2 lesion. Of the T1a tumours, most (70.1%) underwent minimally invasive PN (RPN or LPN) (37 [48.1%] were RPN and 17 [22.1%] underwent LPN), while only 39.1% of the T1b lesions underwent minimally invasive PN (28.2% were RPN). Of the T2 lesion, 10 (83.3%) underwent OPN and only two underwent LPN and none had RPN. The RENAL score, assessing the tumour complexity, was similar in open (6.4) and robotic group (6.1) while lower in laparoscopic group (5.8). After regression analysis, neither size, stage nor RENAL score could be asserted as predictors of surgical approach. In a systematic review involving 1103 robotic and 1921 OPNs, Shen et al. reported smaller tumour size in robotic group compared to open group but similar RENAL score.

Our study showed a conversion rate of 4.2% to radical nephrectomy which is in line with published literature. Various studies have reported the rate of conversion to radical nephrectomy. A recent study by Petros et al. involving 1857 patients planned for PN had 5% conversion rate with larger tumour size, higher tumour complexity, hilar location and laparoscopic approach as significant predictors of conversion. Robotic approach has not been related to increased rate of conversion to radical nephrectomy. Arora et al. reported conversion rate of 4.99% among 501 patients planned for robot-assisted PN and RENAL score did not appear to be a significant predictor of conversion. In our study, the conversion rate was 6% (3/50) in robotic group and 3.2% (2/61) in open group. RENAL score was more than 9 in five of these patients. Owing to small sample size, we did not study the predictors for conversion to radical nephrectomy systematically.

We noted that LPN had significantly longer operative time and clamping time as compared to OPN despite larger and complex tumours in OPN group. Tumour size appeared to be a significant predictor of the operative time. Similar results were reported by Porpiglia et al. This could be explained by the longer time taken for colon mobilisation, dissection of renal hilum and tumour localisation and isolation in LPN as compared to the more direct flank approach of OPN where tumour localisation and hilar dissection is relatively easier. Renorrhaphy also took longer time in laparoscopic group owing to technical difficulty with intra-corporeal suturing. Similarly, RPN also takes longer than OPN probably for the same reason. However, RPN is swifter than LPN as the dissection is faster because of the better vision and greater dexterity of EndoWrist instruments provided by the robotic platform despite the extra time required for docking and instrument exchanges. While Shen et al. also reported longer operative time with robotic approach compared to open approach, Masson-Lecomte et al. showed insignificant difference in robotic and open arm when ‘skin-to-skin’ operating time excluding setup and docking of robot was used.

As for estimated mean blood loss, OPN was associated with maximum amount of blood loss, which was significantly higher as compared to LPN or RPN. This could be attributed to a larger muscle cutting flank incision and performing the procedure without the hilar clamp in 27.8% of the patients. Furthermore, the presence of high intra-abdominal pressures due to pneumoperitoneum lowers the amount of blood lost in LPN or RPN. Our
operative times and blood loss compare favourably with the wide range reported in the literature suggesting adequate experience of the operating surgeons.\(^8,^{18,24-28}\)

Twenty-four (17.8%) PN were performed without hilar clamp and 70.8% were in OPN group and all used manual compression with additional ice slush in six patients. In seven cases of minimal invasive PN without hilar clamp, hypotensive anaesthesia was utilised. In 111 (80%) patients who underwent hilar clamping, the clamping time was longest in laparoscopic group while comparable between the RPN and OPN group. In 7 patients (6.3%), the WIT was more than 30 min, 1 in OPN, 3 in LPN and 3 in RPN. Overall, it suggested that LPN takes slightly longer time for renoraphy owing to technical difficulty associated with intra‑corporeal suturing even in experienced hands. Our hilar clamping time compares favourably with that reported in literature and lies within the safe limit of <30 min in most patients.\(^8,^{16,20-22}\)

Although there was a significant change in eGFR after surgery, surgical approach as well as WIT did not appear to be the predictors of change in eGFR. Shen et al.\(^{16}\) also showed similar change in eGFR comparing open and RPN groups, while the results of studies involving comparison of laparoscopic approach with open or robotic surgery are conflicting. Gill et al.\(^{17}\) showed higher WIT but similar change in eGFR in laparoscopic approach compared to open, while Choi et al.\(^{18}\) showed higher WIT with greater decline in eGFR in laparoscopic approach as compared to robotic approach. It must be understood that no absolute cut-off for WIT exists and WIT <30 min achieved with either of the surgical approach may not have much impact on eGFR.\(^{19}\)

The duration of drain used and length of hospital stay were higher in OPN group as compared to minimal invasive group. However, the post‑operative complication rate, post‑operative decrease in renal function and margin positivity rates were comparable in the three groups. The open surgical approach and duration of drain used were significant predictors of hospital stay. Pulmonary complications associated with open approach could also be a contributing factor. These findings are consistent with the published literature.\(^{8,16,22}\) However, the mean hospital stay in OPN group was 5.6 days as compared to 4.5 days in minimal invasive group, and this small difference could be explained by the use of epidural catheter for post‑operative pain relief in conjunction with aggressive chest physiotherapy for expediting recovery and shortening length of stay. Resected margin was positive in 12 patients (8.9%), which correlates with that reported in literature.\(^{16,20}\)

Histopathological distribution was similar to those published in literature with 70% having clear cell RCC. Studying the grade of RCC in relation with RENAL score, RENAL score was a significant predictor of Fuhrman’s grade \((P = 0.008)\). This was first suggested by Kutikov et al.,\(^{15}\) but very few studies have reported this aspect. Bagrodia et al.\(^{19}\) reported high predictive value of RENAL score with area under curve of 0.95 (0.91–0.99) for discriminating low‑grade (Fuhrman Grade I/II) versus high‑grade tumours (Fuhrman Grade III/IV) in a study involving 181 patients. RENAL score can help in predicting the grade of the disease pre‑operatively.

This study has several strengths. To the authors’ best knowledge, this is the first study on the Indian population comparing the outcomes of open versus minimal invasive PN. Use of RENAL score for studying the tumour complexity allowed a better comparison between the three modes of surgery. Another unique aspect drawn from the study was significant predictive value of RENAL score for histopathological grade of tumour.

This study has certain limitations owing to its non‑randomised retrospective nature. First, the choice of procedure depended on surgeons’ and patients’ preference, thereby introducing selection bias. Charlson Comorbidity Index was not used to study the baseline co‑morbidities. Assessing pain scores would have added to the information but was not available. The post‑operative change in renal function has been assessed in the post‑operative period at day 30 and not at 3 months; only eGFR has been used as split renal function was not available in most cases. Long‑term follow‑up is not available, especially of those with resection margin positive or with baseline CKD. The number of cases of LPN was small because of its greater technical difficulty and preference of robotic platform by some surgeons at our centre.

**CONCLUSION**

Open, laparoscopic and robotic approaches to PN provide similar patient outcomes. Of all three approaches, OPN was usually preferred for larger tumours. OPN may result in shorter operative times with more blood loss and longer hospital stay, but this may have little clinical significance. The warm ischaemia time was longer in laparoscopic group compared to open or robotic group; however, the post‑operative decline in renal functions and complications were comparable between the three approaches. RENAL score, used to assess tumour complexity, correlated significantly with histopathological grade and could be useful in predicting tumour behaviour pre‑operatively.
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Conflicts of interest
There are no conflicts of interest.

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