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PADUA and R.E.N.A.L. nephrometry scores correlate with perioperative outcomes of robot-assisted partial nephrectomy: analysis of the Vattikuti Global Quality Initiative in Robotic Urologic Surgery (GQI-RUS) database.

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OBJECTIVES:
To evaluate and compare the correlations between Preoperative Aspects and Dimensions Used for an Anatomical (PADUA) and R.E.N.A.L. [Radius (tumour size as maximal diameter), Exophytic/endophytic properties of the tumour, Nearness of tumour deepest portion to the collecting system or sinus, Anterior (a)/posterior (p) descriptor and the Location relative to the polar line] nephrometry scores and perioperative outcomes and postoperative complications in a multicentre, international series of patients undergoing robot-assisted partial nephrectomy (RAPN) for masses suspicious for renal cell carcinoma (RCC).

PATIENTS AND METHODS:

We retrospectively evaluated the clinical records of patients who underwent RAPN between 2010 and 2013 for clinical N0M0 renal tumours in four international centres that completed all the data required for the Vattikuti Global Quality Initiative in Robotic Urologic Surgery (GQI-RUS) database. All patients underwent preoperative computed tomography or magnetic resonance imaging to define the clinical stage and anatomical characteristics of the tumours. PADUA and R.E.N.A.L. scores were retrospectively assessed in each centre. Univariate and multivariate analyses were used to evaluate the correlations between age, gender, Charlson comorbidity index, clinical tumour size, PADUA and R.E.N.A.L. complexity group categories and warm ischaemia time (WIT) of >20 min, urinary calyceal system closure, and grade of postoperative complications.

RESULTS:

Overall, 277 patients were evaluated. The median (interquartile range) tumour size was 33.0 (22.0-43.0) mm. The median PADUA and R.E.N.A.L. scores were eight and seven, respectively; 112 (40.4%), 86 (31.0%) and 79 (28.5%) patients were classified in the low-, intermediate- or high-complexity group according to PADUA score, while 118 (42.5%), 139 (50.1%) and 20 (7.2%) were classified in the low-, intermediate- or high-complexity group according to R.E.N.A.L. score, respectively. Both nephrometry tools significantly correlated with perioperative outcomes at univariate and multivariate analyses.

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CONCLUSION:

A precise stratification of patients before PN is recommended to consider both the potential threats and benefits of nephron-sparing surgery. In our present analysis, both PADUA and R.E.N.A.L. were significantly associated with predicting prolonged WIT and high-grade postoperative complications after RAPN.

Introduction

Partial nephrectomy (PN) has become the standard of care for the conservative management of clinically localized RCC for many years [1,2], as it demonstrate equivalent oncological results [3,4] but reduced renal function impairment [5,6] in comparison with radical nephrectomy (RN). Despite the functional benefits offered by conservative surgery, patients undergoing PN are at higher risk of postoperative complications compared with those undergoing RN, especially in the case of complex renal tumors [7-10]. In complex cases, laparoscopic PN generally represents a more challenging procedure, with longer warm ischemia times (WIT), a higher rate of urinary calyceal system (UCS) entry, and more frequent postoperative complications rates than those reported for easier and smaller lesions. [8]. In this scenario, the utilization of the da Vinci® platform has been increasing over time [9]. Proposed as the natural evolution and simplification of the traditional laparoscopy, the robotic approach allows surgeons to perform a very precise tumor excision, with easier parenchymal reconstruction, especially in those patients with more complex renal masses [10,11]. These important advantages could lead to a reduction in the hilar clamping time in comparison with laparoscopic approach, allowing minimization of renal function impairment [12].
Recently, in order to categorize and stratify patients into different anatomical complexity groups and allow urologists to estimate the potential perioperative outcomes, several standardized anatomical classification-scoring systems have been described [11-16]. The most frequently used are the RENAL nephrometry and the PADUA classifications [13,14]. Despite several differences between these two nephrometric scores, both have been demonstrated to effectively correlate with perioperative outcomes after partial nephrectomy, as well as useful tools for strategic surgical planning [17-20]. However, studies comparing the different predictive value of these two nephrometry scores are limited. In this study, we sought to evaluate the role of both the PADUA and RENAL scores in the association with perioperative outcomes and postoperative complications in a multicenter, international series of patients undergoing RAPN for masses suspicious of RCC.

Patients and methods

The Vattikuti Global Quality Initiative in Robotic Urologic Surgery (GQI-RUS) database is an Institutional Review Board-approved database including data of 10 worldwide centres. In this institutional review board–approved report all participating centres provided the necessary institutional data sharing agreements before initiation of the study. A computerized databank was generated for data transfer. After combining the data sets, reports were generated for each variable to identify data inconsistencies and other data integrity problems. Through regular communication with all centres, resolution of all identified anomalies was achieved. Before final analyses, the database was frozen, and the final data set was produced for the current study.
In this multicenter, international study, we evaluated retrospectively the clinical records of patients who underwent RAPN between 2010 and 2013 for clinical N0M0 renal tumours in four centers that completed all the data required for the study. All the clinical and pathological data were prospectively evaluated for each patient: age, gender, clinical tumor size, anatomic tumor parameters according to PADUA and RENAL classifications; WIT, urinary calyceal system (UCS) closure, pathological results, console time, blood loss, transfusion rate, intraoperative and postoperative complications. Before surgery all patients underwent three-dimensional computed tomography scans or magnetic resonance imaging to define the clinical stage and anatomic characteristics of the tumors. All the radiologic images were retrospectively reviewed by each participant center with the aim of assigning the PADUA and the RENAL scores (13-14). Tumors were stratified into low-complexity (score 6–7), intermediate-complexity (score 8–9), and high-complexity groups (score >9) according to the PADUA score and into low-complexity (score 3-6), intermediate-complexity

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(score 7-9), and high-complexity groups (score >9) according to the RENAL score.
Partial nephrectomy was performed according to the standard criteria for RAPN. Regional lymph node dissection was not routinely performed. Surgeons with extensive prior robotic experience, including robotic radical prostatectomy, robotic radical nephrectomy, and radical cystectomy, performed all the procedures.
Three-months postoperative complications were classified according to the Dindo modification of the Clavien system [21]. Then, postoperative complications were distinguished as minor (grade 1–2) and major (grade 3–4).

Pathologic Evaluation

All surgical specimens were processed according to standard pathologic procedures at each institution. Tumors were staged according to the 2010 American Joint Committee on Cancer–Union Internationale Contre le Cancer TNM classification [22]. Histological subtype was defined according to the Heidelberg classification [23]. Tumor grade was assessed according to the Fuhrman system [24]. Positive surgical margin (PSM) status was defined as the presence of tumor tissue on the inked surface of the tumor on final pathologic assessment.

Statistical Analysis

T-test was used for normally distributed continuous variables, and results are shown as mean with standard deviation (SD); Wilcoxon rank sum testing was used for non-normally distributed variables, and results are shown as median and interquartile range (IQR). Categorical variables are shown as number and percentage and associations were tested with Pearson Chi-square, linear by linear association or Anova test.
Clinical parameters, including age, gender, Charlson comorbidity index (CCI), clinical tumor size, PADUA (6-7 vs. 8-9 vs. >9) and RENAL (3-6 vs. 7-9 vs. >9) scores were evaluated to estimate WIT>20 minutes, UCS closure, any grade and grade 3-4 postoperative complications with univariable and multivariable logistic regression models. The multivariable models included only the variables significant at univariable analysis and considered PADUA score or RENAL score separately; as clinical tumor size is part of the nephrometry scores, it was not included in the multivariable model. Statistical significance was set as $p \leq 0.05$. All reported p values are two-sided. Analyses were performed with SPSS version 20.0 (SPSS Inc, Chicago, IL, USA).

Results

Overall, 277 patients with complete perioperative data have been evaluated. Clinical and pathological characteristics are summarized in Table 1. Of the entire cohort, 243 (87.7%) subjects were operated in elective condition, with median clinical tumor size of 33.0 millimeters (22.0-43.0).
Preoperative median Padua and RENAL score were 8 and 7 respectively; 112 (40.4%), 86 (31.0%) and 79 (28.5%) were classified in the low, intermediate or high-complexity group according to PADUA score, while 118 (42.5%), 139 (50.1%) and 20 (7.2%) were classified in the low, intermediate or high-complexity group according to RENAL score, respectively.
Table 2 shows the distribution of the 277 patients according to PADUA and RENAL scoring systems, which were concordant in 171 (61.7%) patients.
Table 3 shows the incidence of perioperative and postoperative outcomes according to PADUA and RENAL complexity groups: longer WIT, need for UCS closure, higher console time and grade 3-4 postoperative complications significantly raised with the increasing of both PADUA and RENAL complexity group, while any grade of postoperative complications was correlated only with RENAL score. On the contrary, intraoperative blood loss was not correlated to the scoring systems.
A detailed report of intraoperative and postoperative complications, as well as the related Clavien grade and specific treatment are showed in table 4. Globally, 12 (4%) intra-operative complications occurred and 43 (15.5%) postoperative complications have been reported with four (1%) re-interventions. Overall, 25 (9.0%) and 18 (6.4%) patients experienced low grade (grade 1-2) and high grade (grade 3-4) postoperative complications according to Clavien-Dindo classification respectively.
Table 5 summarizes the correlations between PADUA and RENAL scores and perioperative and postoperative outcomes at univariate and multivariate analysis.
On univariable analysis, the clinical tumor size as well as PADUA score was significantly correlated to both WIT (table 5a) and grade 3-4 postoperative complications (table 5d), with differences being recorded

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between intermediate and high complexity groups. Conversely only the high complexity group according to RENAL score was significantly correlated to WIT and grade 3-4 postoperative complications, with no difference between low and intermediate complexity groups. Similarly, gender, clinical tumor size and intermediate vs. high complexity groups according to both PADUA and RENAL scores were significantly correlated to UCS closure in univariable analysis (table 5b). At multivariate analysis gender and intermediate vs. high complexity groups according to both PADUA and RENAL remained significant but the OR of high complexity group according to RENAL was inferior to the OR of intermediate one (table 5b). Finally, only high-complexity group according to both PADUA and RENAL score was correlated to the incidence of any grade of postoperative complications (table 5c). The accuracy of each nephrometric score in the prediction of warm ischemia time > 20 minutes and high grade (Clavien 3-4) postoperative complications were evaluated by using Receiver Operating Characteristic (ROC) analyses (Figure 1). Both RENAL and PADUA scores demonstrated to be effective and comparable predictors of these perioperative outcomes, even though a slightly higher area under the curve (AUC) was reported for the latter in terms of WIT longer than 20 minutes (0,609 vs. 0,580) and high grade postoperative complications (0,638 vs. 0,620).

Discussion

In the present multi-institutional, international retrospective study, we demonstrated that the RENAL and PADUA nephrometric scores correlated with the perioperative outcomes after RAPN. In particular, WIT, console time and need for UCS closure as well as postoperative complications were significantly correlated to both scores in univariable and multivariable analysis. Furthermore, the logistic regression found that the calibration of the PADUA scoring is more accurate as the distribution of the cases in the three groups of low, intermediate and high-complexity is homogeneous and progressively correlated to the outcomes. Indeed, with regard to WIT, patients with intermediate to highly complex renal tumors according to the PADUA classification were found to have a 2.3- and 2.6-fold higher risk of WIT > 20 minutes (p=0.011 and p=0.004, respectively). Conversely, only those patients with high RENAL complexity experienced significantly longer WIT than the low complexity group. Similarly, intermediate to highly complex renal tumors according to the PADUA classification experienced a 2.3- and 2.7-fold higher incidence of grade 3-4 postoperative complications (p=0.011 and p=0.004, respectively), while only the high complexity group category according to RENAL score experienced a significantly higher risk of grade 3-4 complications than the low complexity group. Finally, intermediate and highly complex renal tumors according to the PADUA classification experienced a 2.3- and 3-fold higher incidence of UCS closure (p=0.005 and p<0.001, respectively), while the intermediate complexity according to RENAL score experienced a higher risk of UCS closure than high-complexity group (2.8- vs. 2.4-fold, p=0.015 and p=0.043, respectively).

To the best of our knowledge, this is the largest contemporary series comparing the accuracy of both PADUA and RENAL scores in a multi-institutional pure RAPN cohort. The present paper clearly showed that both RENAL and PADUA score were significantly correlated with perioperative results.

The correct characterization of renal tumors and vascular complexity by using a validated and reproducible nephrometry score may assist urologists in selecting the best surgical approach for each patient and potentially estimate the outcome [15-19]. Since partial nephrectomy is associated with a not negligible risk of perioperative complications, a careful evaluation of tumor's anatomy before surgery is crucial, allowing balancing the potential adverse outcomes of PN with its expected functional benefits [25,26].

Many nephrometry scores have been developed to estimate perioperative outcomes after partial nephrectomy [13-19]. The C-index is a morphometric descriptor of renal masses that incorporates tumor size and site and was associated to the postoperative nadir estimated glomerular filtration rate and the percent decrease in the estimated glomerular filtration rate after laparoscopic partial nephrectomy [15]. The score is widely investigated and externally validated but can be considered quite complex. Recently, Spaliviero et al [16] proposed the arterial-based complexity (ABC) score, to evaluate the size of the renal arterial branches needed to be dissected to achieve radical tumor excision, considering that the larger the arterial branch, the more complex the surgery will be. The score was significantly associated with WIT, postoperative complications and blood loss and it is quite simple. However, at the present time, the score has not been externally validated. Among the currently available scoring systems, PADUA and RENAL score are well-established systems and clearly demonstrated to be accurate tools associated with relevant

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perioperative and clinical aspects, such as WIT duration, rate of postoperative complications and residual glomerular filtration rate after nephron-sparing surgery for RCC [17-20]. In a retrospective analysis of 162 patients, Bylund et al. evaluated the correlations between nephrometric scores and surgical outcomes after PN [19]: PADUA score, RENAL score and C-index showed a statistically significant correlation with warm ischemia time ($p<0.001$). Notably, the total PADUA score performed slightly better than the other systems in terms of WIT and, unsurprisingly, correlated with the absolute change of estimated glomerular filtration rate after surgery. Desantis et al. recently reported data of 118 patients diagnosed with clinically localized renal tumors in a single Canadian Institution [27]: After adjusting for age and medical comorbidities, only the PADUA score was found to be significantly correlated with surgical (OR: 1.31, $p=0.02$) and overall (OR: 1.12, $p=0.04$) complications within 30 days after surgery. Conversely, the RENAL score and C-index failed to show such correlations. In a multi-institutional, international RAPN series by Ficarra et al, 347 patients have been retrospectively evaluated [20]. In multivariable analyses, PADUA stratification turned out to be independently correlated with WIT > 20 min, once adjusted for the effects of surgeon experience. The same group stratification demonstrated to beindependently associated with perioperative complications. Long and co-workers reported results of a single-institutional cohort of 177 PN patients [28]. Tumor's anatomical complexity was classified according to the RENAL nephrometry score. On multivariate analysis, RENAL categories only were independently correlated with WIT ($p=0.03$), while no significant correlations between complexity groups and any grade or severe postoperative complications were found ($p=0.51$). In the same way, Ellison and colleagues, reporting data of 298 patients who underwent laparoscopic and robotic partial nephrectomy, found significant correlations between RENAL score and major postoperative complications ($p<0.001$) [29]. Borghesi et al., in 96 patients treated with open or laparoscopic partial nephrectomy, found that PADUA and RENAL scores were significantly associated with longer warm ischemia time and higher postoperative complications, especially in those patients with more challenging and complex renal tumors [30]. Others authors have published different results. Zhang et al [31] analyzed the correlations between the two scoring system and both WIT and perioperative complications and. In their series of 245 patients treated with laparoscopic PN, they found that only RENAL score was significantly correlated with warm ischemia time ($P=0.03$). No significant associations between PADUA Score and WIT ($P=0.22$) and between the PADUA and RENAL score and the occurrence of any grade of postoperative complications were observed ($p=0.26$ and $p=0.44$, respectively).
It is not surprising that with increasing of the complexity of renal tumors a longer hilar clamping time should be required in order to achieve safe excision and reconstruction. Consequently, nephrometry scores and, above all, the corresponding group categories could better correlate with perioperative outcomes than the tumor dimension alone. In the same way, the need of UCS closure and the postoperative complications may be directly correlated to the complexity of renal tumors, , as well shown by the present paper.
The present paper is not devoid of limitations. Firstly, pre-operative CT images have not been re-evaluated by a single physician, thus potentially biasing the assignment of nephrometric scores. Secondly, different surgeons, with different level of expertise in RAPN operated the patients and this could impact on many perioperative outcomes. However, those issues turn out to increase external validity and reproducibility of our results. Thirdly nephrometry scores do not take into account other patient factors such as BMI and perinephric fat adherence, which could affect surgical outcomes and may differ between centres and nephrometry categories. Finally, the study population might be relatively small, which could effect on the final results.

In this multi-institutional, international RAPN series, we showed the potential associations among RENAL and PADUA scoring systems and perioperative outcomes and postoperative complications. A slightly higher accuracy in the estimation of prolonged WIT and high-grade postoperative complications, although not statistically significant, was found for the PADUA score. Accordingly, an accurate stratification of patients should be always done, thus balancing the potential threats and benefits of a conservative surgery in each patient with renal tumor suitable for partial nephrectomy.
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