Nephrometry scores: A radiologist’s guide.

Poster No.: C-2372
Congress: ECR 2013
Type: Educational Exhibit
Authors: P. PELECHANO¹, M. BARRIOS BENITO¹, M. Ramírez Backhaus¹, J. Rubio Briones¹, E. Solsona Narbón¹, J. Cervera Deval², ¹Valencia/ES, ²La Eliana/ES
Keywords: Kidney, CT, MR, Surgery, Multidisciplinary cancer care
DOI: 10.1594/ecr2013/C-2372

Any information contained in this pdf file is automatically generated from digital material submitted to EPOS by third parties in the form of scientific presentations. References to any names, marks, products, or services of third parties or hypertext links to third-party sites or information are provided solely as a convenience to you and do not in any way constitute or imply ECR’s endorsement, sponsorship or recommendation of the third party, information, product or service. ECR is not responsible for the content of these pages and does not make any representations regarding the content or accuracy of material in this file.

As per copyright regulations, any unauthorised use of the material or parts thereof as well as commercial reproduction or multiple distribution by any traditional or electronically based reproduction/publication method is strictly prohibited.

You agree to defend, indemnify, and hold ECR harmless from and against any and all claims, damages, costs, and expenses, including attorneys’ fees, arising from or related to your use of these pages.

Please note: Links to movies, ppt slideshows and any other multimedia files are not available in the pdf version of presentations.

www.myESR.org
Learning objectives

• To describe the different renal tumor scoring systems: RENAL, PADUA and C-INDEX.
• To illustrate how renal masses are evaluated and measured.
• To review the main validations published in an attempt to assess relationships between these three scores and perioperative and postoperative variables.
Background

To date, treatment decision making for a given renal mass remains overly subjective because of provider and patient biases, precluding meaningful comparisons between studies due to the lack of standardized and quantifiable tumor descriptors. The score systems currently represent the most comprehensive tools for categorizing patients undergoing surgery into low, moderate, and high complexity based on the tumor characteristics.[1,2,3]

Three anatomic classification and scoring systems are used. RENAL and PADUA scores involve similar components and methodology, enabling a comprehensive description of the tumor size, polarity, location and closeness to the collecting system. The C-INDEX score involves a complex mathematical concept and characterizes tumor centrality based on the ratio of the distance between the tumor and kidney center and tumor radius.

**RENAL Fig. 1 on page 8[4]**

The RENAL nephrometry scoring system was proposed by Kutikov and Uzzo. The five features in the acronym R.E.N.A.L are: R (radius), E (exophytic/ endophytic), N (nearness), A (anterior) and L (location). The RENAL score characterizes tumors using size, depth, location, and nearness to the renal sinus and collecting system. Except for the component (A) describing anterior vs posterior location, a three point scoring scale is used adding up to the score sum, ranging from a minimum of 4 to a maximum of 12.

**Radius**

The (R)adius component represents the maximum diameter of the mass in any single plane (axial images and alternate views, coronal or sagittal, should also be evaluated when deriving this value). **Fig. 2 on page 8**

The (R)adius is quantitated on a 3-point scale. Tumors ≤ 4 cm are assigned 1 point, those > 4 but ≤ 7 cm are assigned 2 points, and those > 7 cm are assigned 3 points. **Fig. 3 on page 9**

**Exophytic/endophytic**
The (E)xophytic/endophytic component describes the tumor relationship to the surface of the kidney. Whereas renal tumors may distort the normal renal cortical contour, the ideal quantification of this variable is relative to where the renal cortex would be if the tumor were not present Fig. 4 on page 10. Moreover, since not all tumors are spherical and some are positioned asymmetrically within the kidney, to determine the percentage of exophycity is recommended comparing the distance from the normal renal surface to the tumor’s most endophytic component, to that of the distance to the most exophytic. The points assigned are a function of the predominant feature of the tumor on any axis. The 2 measurements need not be made on the same axial/ coronal/sagittal imaging cut.

(E)xo/endophytic status is quantitated on a 3-point scale. Tumors that are 50% or more exophytic are assigned 1 point, tumors that are less than 50% exophytic are assigned 2 points, while those that are entirely endophytic are assigned 3 points. Fig. 5 on page 11

**Nearness**

The (N)earness component describes the distance between tumor deepest portion and the closest sinus fat or collecting system. All cross-sectional planes must be considered when deriving this value Fig. 6 on page 12. This variable is easily reproducible and quantifiable in millimeters (rather than centimeters) using digital cross-sectional images with magnified views as necessary Fig. 7 on page 13. The proximity to the collecting system is best determined on excretory images Fig. 8 on page 14.

Tumors again are divided into three categories:7 mm or greater from the collecting system or renal sinus (1 point), tumors > 4 but <7 mm(2 points), and tumors that invade, touch or come within4 mm of the sinus or collecting system are assigned 3 points. Fig. 9 on page 15

**Anterior**

The "a" descriptor designates whether the tumor is anterior or posterior relative to the kidney midline plane on axial images. This plane is best assessed on axial imaging by drawing a line paralleling the direction of hilar structures that bisects the renal parenchyma into anterior and posterior components. The letter a is ascribed to tumors that lie primarily anterior to this axial midline while the letter p designates those in a more posterior location. When the mass grows from the tips of the renal poles or arises from the kidney so that a meaningful anterior or posterior designation is not possible (eg transverses the kidney or lies directly on the coronal plane), the suffix x is assigned to the tumor Fig. 10 on page 16.
The "a/p" descriptor is designated using a nonnumerical suffix. If the tumor lies primarily on the ventral surface of the kidney the anterior (a) descriptor is assigned. Tumors located on the dorsal renal surface are assigned a posterior (p) designation. Fig. 11 on page 17

The a/p/x suffix is used at the end of the nephrometry sum (ie a 7a tumor denotes a nephrometry sum of 7 in an anterior location).

Location

The "L"ocation descriptor defines the position of the tumor with respect to the polar lines. The polar line is designated as the plane of the kidney above or below which the medial lip of parenchyma is interrupted by the renal sinus fat, vessels or the collecting system. Location, is best conceived as identifying the tumor position in the coronal plane, although this component is easily assessed on axial imaging as well. Above the upper or below the lower polar line on axial cuts a concentric rim (enclosed circle) of renal parenchyma exists. Between the polar lines the complete circle of renal parenchyma opens up like a horseshoe and is interrupted by fat, renal vessels and/or collecting system as they enter the hilar center Fig. 12 on page 18.

Tumors that sit entirely above or below the polar lines are assigned a score of 1; if the lesion crosses the polar line, a score of 2 is assigned; and if > 50% of the mass crosses the polar line or the mass is located entirely between the polar lines, a score of 3 is assigned Fig. 13 on page 19. Additional suffix "h" is used to designate hilar location if tumor abuts main renal artery or vein Fig. 14 on page 20.

PADUA Fig. 15 on page 21 [5]

Preoperative aspects and dimensions used for an anatomical (PADUA) score of renal tumors takes into consideration five anatomical aspects of the tumor plus its maximal diameter. This classification differs from the RENAL nephrometry scoring system, with the main differences represented by the definition of the sinus lines and the evaluation of the anatomical relationship between the tumour and the collecting system or renal sinus. ThePADUA classification adds another parameter, the tumor relationship with the lateral or the medial rim. All the other parameters (Radius and (E)xophytic/endophytic) are similar in the two classifications.

Sinus line
To define the longitudinal location on CT images, the renal sinus is used as the topographical landmark to subdivide the kidney into upper, middle, and lower parts (sinus line). The renal sinus appears in the CT images as a hypodense area (the adipose tissue of the renal sinus) inside the renal parenchyma. The upper part of the kidney extends from the upper extremity to the first CT image in which the renal hypodense sinus appears (upper sinus line). The middle part of the kidney corresponds to the extent of the renal sinus. The lower part of the kidney extends from the first CT image in which the renal hypodense sinus disappears (inferior sinus line) to the lower extremity Fig. 16 on page 22. The sinus line is an easily recognisable landmark on a CT axial exam, but it can also be traced on coronal images or MRI examination.

According to longitudinal location, the tumors are classified into two different categories: entirely above the upper or below the lower sinus line, or crossing the sinus line < 50% (1 point); crossing the sinus line > 50% or falling entirely between the sinus lines (2 points). Fig. 17 on page 23

Lateral/Medial Rim

Tumors are classified into two different categories: as being located at the lateral or at the medial rim.

Tumors near lateral rim are assigned 1 point, tumors near medial rim are assigned 2 points. Fig. 18 on page 24

Renal sinus

The renal sinus is a central spacious cavity formed by the extension of the perinephric space into the deep recess located at the medial border of the kidney. The renal sinus is surrounded by the kidney parenchyma laterally and almost filled by the renal pelvis and vessels, with the remaining space being filled by fat. On CT images the low attenuation fat outlines the collecting system and the blood vessels and differentiates the renal sinus from the parenchyma.

The tumors are classified into two groups: (1 point) without renal sinus location, and (2 points) located or extended at the level of the renal sinus.

Collecting system

The major and minor calices of the collecting system are located within the renal sinus.
Tumors are classified into two categories with respect to the collecting system

(1 point) absent a relationship, or (2 points) present a relationship (ie, involving dislocation or infiltration of the collecting system).

C INDEX [6]

The C-Index is based on the ratio of the distance \(c\) between the tumor center and the kidney center, and the tumor radius \(r\). The C-Index is a method to measure tumor centrality. A key concept is that any tumor with a C index of less than 1 has some portion of the tumor superimposed on the kidney center and a C index of 1 equates to a tumor with its edge lying on the center. As the centrality index increases, the tumor periphery becomes more distant from the kidney center (less complexity). This measurement can be made in a straightforward manner using standard 2-dimensional CT images.

To measure the C index a middle plane is identified by averaging image section numbers showing most upper and lower kidney borders. At this middle section, kidney center \((X)\) is placed in center of ellipse drawn around kidney periphery. Fig. 19 on page 25.

The image section showing the largest tumor diameter \((d)\) is then identified.

Distance \(y\) (in cm) is number of sections scrolled up and down between the middle section and the section showing the maximum tumor diameter divided by image slice thickness. Fig. 20 on page 26.

Distance \(x\) (in cm) is measured between the hilar axial reference point and the tumor center. To perform this step the cursor is stabilized on the central axial reference point during scrolling.

Tumor diameter is measured parallel to the line drawn to measure \(x\). Diameter is halved to determine the tumor radius \((r)\).

The C index is calculated with measurements obtained from a 2D CT scan to determine the lengths of two sides of a right triangle. The Pythagorean theorem is used to calculate the hypotenuse of the triangle \((\text{distance c})\). The hypotenuse is indicative of the proximity of the center of the lesion to the center of the kidney. This number \((c)\) is divided by the radius of the tumor to obtain the C-index. Fig. 21 on page 27.
### RENAL

<table>
<thead>
<tr>
<th></th>
<th>1pt</th>
<th>2pts</th>
<th>3pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius (maximum diameter in cm)</td>
<td>≤4</td>
<td>&gt; 4 but &lt; 7</td>
<td>≥7</td>
</tr>
<tr>
<td>Exophytic/endophytic</td>
<td>≥ 50%</td>
<td>≤ 50%</td>
<td>Entirely Endophytic</td>
</tr>
<tr>
<td>Nearest, sinus or collecting system (mm)</td>
<td>≥7</td>
<td>&gt; 4 but &lt; 7</td>
<td>≤4</td>
</tr>
<tr>
<td>Anterior/Posterior</td>
<td></td>
<td>Nonnumerical suffix a, p, x, h.</td>
<td></td>
</tr>
<tr>
<td>Location, Polar lines</td>
<td>Entirely above or below the polar lines</td>
<td>The lesion crosses the polar lines</td>
<td>&gt;50% of the mass crosses the polar line or the mass is located entirely between the polar lines</td>
</tr>
</tbody>
</table>

**Fig. 1:** RENAL

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 2: A. Tumor larger than 4 cm but smaller than 7 cm, 2 points are given (coronal cut).
B. Tumor smaller than 4 cm, 1 point is given (axial cut).

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 3:** Radius. Tumors $\leq$ 4 cm are assigned 1 point, those $> 4$ but $< 7$ cm are assigned 2 points, and those $\geq 7$ cm are assigned 3 points.

© Radiology, Valencian Institute of Oncology - Valencia/ES
**EXOPHYTIC/ENDOPHYTIC**

**Fig. 4:** Broken line shows expected renal contour used to determine "E" exophytic/endophytic attribute. Tumor projects more than 50% outside renal cortex and should be assigned "E" score of 1.

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 5:** Lesions that project more than 50% outside the renal cortex are assigned 1 point, those less than 50% are assigned 2 points, and those that are entirely endophytic are assigned 3 points.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 6: All cross-sectional planes must be considered when deriving this value. In this patient tumor relationship to sinus fat cannot be assessed in axial plane (A). Coronal imaging (B) must be used to assess relationship between tumor and sinus fat.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 7: This variable is easily reproducible and quantifiable in millimeters using digital cross-sectional images with magnified views as necessary (B, magnified view).

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 8: The proximity to the collecting system is best determined on excretory images.

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 9:** Tumors 7 mm or greater from the collecting system or renal sinus (1 point), tumors > 4 but < 7 mm (2 points), and tumors that invade, touch or come within 4 mm of the sinus or collecting system are assigned 3 points.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 10: This tumor is centrally located. Suffix "x" is assigned to tumor if anterior or posterior designation is not possible.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 11: If the tumor lies primarily on the ventral surface of the kidney, the anterior (a) descriptor is assigned. Tumors located on the dorsal renal surface are assigned a posterior (p) designation.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 12: The superior and inferior polar lines are defined by the renal vascular pedicle and can be determined on either axial or coronal images. Coronal. Polar line is designated as the plane of the kidney above or below which the medial lip of parenchyma is interrupted by the renal sinus fat, vessels or the collecting system. Axial. Above the upper or below the lower polar line on axial cuts a concentric rim of renal parenchyma exists. Between the polar lines the complete circle of renal parenchyma opens up like a horseshoe and is interrupted by fat, renal vessels and/or collecting system as they enter the hilar center.

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 13:** Tumors that sit entirely above or below the polar lines are assigned a score of 1; if the lesion crosses the polar line, a score of 2 is assigned; and if > 50% of the mass crosses the polar line or the mass is located entirely between the polar lines, a score of 3 is assigned.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 14: Tumor touches main renal vasculature. Additional suffix "h" is used to designate hilar location if tumor abuts main renal artery or vein.

© Radiology, Valencian Institute of Oncology - Valencia/ES
<table>
<thead>
<tr>
<th>PADUA</th>
<th>1pt</th>
<th>2pts</th>
<th>3pts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius (maximum diameter in cm)</td>
<td>( \leq 4 )</td>
<td>( &gt; 4 ) pero ( &lt; 7 )</td>
<td>( \geq 7 )</td>
</tr>
<tr>
<td>Exophytic/endoophytic</td>
<td>( \geq 50% ) Exophytic</td>
<td>( &lt; 50% ) Exophytic</td>
<td>Entirely Endophytic</td>
</tr>
<tr>
<td>Location, sinus line</td>
<td>Entirely above or below, or crossing the sinus line ( &lt; 50% )</td>
<td>Crossing the sinus line ( &gt; 50% ), or falling entirely between the sinus line</td>
<td></td>
</tr>
<tr>
<td>Renal Rim</td>
<td>Lateral</td>
<td>Medial</td>
<td></td>
</tr>
<tr>
<td>Renal sinus</td>
<td>Absent relationship</td>
<td>Renal sinus location</td>
<td></td>
</tr>
<tr>
<td>Collecting system</td>
<td>Absent relationship</td>
<td>Dislocated/Infiltrated</td>
<td></td>
</tr>
</tbody>
</table>

**Fig. 15:** PADUA

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 16:** The first CT image in which the renal hypodense sinus appears is the upper sinus line. The first CT image in which the renal hypodense sinus disappears is the inferior sinus line.

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 17:** If the tumor is entirely above the upper or below the lower sinus line, or crossing the sinus line < 50% (1point) ; crossing the sinus line >50% or falling entirely between the sinus lines (2points).

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 18:** Tumors near lateral rim are assigned 1 point, tumors near medial rim are assigned 2 points.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 19: Identify sections showing the most upper and lower kidney borders, i.e. the last section where kidney tissue is visualized. Image numbers from these border sections are averaged to provide the middle image section number. Right kidney, upper limit in section 78 and lower limit in section 140, we calculate an average of 109. At this middle section, 109, kidney center (X) is placed in center of ellipse drawn around kidney periphery.

© Radiology, Valencian Institute of Oncology - Valencia/ES
**Fig. 20:** The image section showing the largest tumor diameter (d) is then identified (section 113). The number of sections required to traverse between the middle section and the section showing the maximum tumor diameter is recorded (4 sections) and divided by image slice thickness, in this case 2mm, to calculate distance y in cm.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Fig. 21: Distance \( x \) (in cm) is measured between the hilar axial reference point and the tumor center (\( x \)). To perform this step the cursor is stabilized on the central axial reference point during scrolling. We measured tumor diameter parallel to the line drawn between the hilar reference point and the tumor center, and recorded it. Diameter is halved to determine the tumor radius (\( r \)). The ratio \( c/r \) allow calculation of the C-Index.

© Radiology, Valencian Institute of Oncology - Valencia/ES
Assigning a nephrometry score has become more common in urologic literature. We review the main validations published in an attempt to assess relationships between these three scores and perioperative and postoperative variables. To date, nephrometry has been shown to associate with technique selection, operative isquemic duration, complication rates, and postoperative functional outcomes. Also, studies have verified the relative ease of use and reproducibility of the R.E.N.A.L score system.

We summarize the principal conclusions for each article.

1. **Surgical treatment decision-making.**

1.1 Identify preoperative variables associated with choice of partial nephrectomy (PN) vs radical nephrectomy (RN) in 203 patients treated for clinical T1a renal cortical tumours. In conclusion, the choice of PN vs RN in the management of clinical T1a renal cortical tumors is associated with tumor size, complexity, and the chosen surgical approach. The RENAL score predicts nephrectomy type in clinical T1a renal cortical tumors in patients without imperative indication for Nephron-sparing surgery (NSS) [7].

1.2 Specifically looked for the association of C- index score with surgical selection and PN success. In this study, 148 patients with kidney tumors who underwent kidney surgery are revised. Patients who required RN had a median CI score of 1, whereas those who successfully underwent PN had a median CI score of 2 ( P <0.001). A subset analysis was conducted in patients in whom PN was attempted but failed. The median CI in those patients was 1.3. Based on those data, it was determined that tumors with scores of < 1.3 were >9 times more likely to require RN [8].

2. **Surgical complications.**

2.1 Showed that patients with a low-complexity nephrometry score were less likely to experience a postoperative bleed or urinary fistula compared with moderate-complexity masses, whereas lesions with scores between 12 and 14 were five times more likely to have a postoperative urologic complication [9,10].
2.2 Reported that each unit increase in RENAL score was associated with an increased likelihood of a postoperative urine leak, with the "E" score being a significant predictor of the risk [11].

2.3 R.E.N.A.L score is predictive of overall complications and warm ischemia time (WIT) following minimally invasive nephron-sparing surgery (MINSS). Their data also suggest that nearness to the collecting system may be used as a simple predictor of overall complications and postoperative hemorrhage following MINSS [12].

2.4 In a multivariate analysis that included 133 patients, C index and tumor size were the only significant predictors of warm ischemia time [13].


3.1 C-Index has been shown to independently correlate with both nadir estimated glomerular filtration rate (e GFR) and percent decrease in short-term e GFR outcomes after LPN. Perioperative kidney function was examined in 131 consecutive patients who underwent PN. In multivariante analysis the percent decrease in e GFR after surgery was correlated with both CI (P= 0.005) and duration of ischemia (P<0.001). Reported a that higher complexity tumors as measured by CI were associated with prolonged ischemia time and subsequent, decreased postoperative e GFR [14].

3.2 Reported that patients with greater "nephrometric variables," (R) and (E), were more likely to experience postoperative renal impairment after PN [15].

4. Histologic features

4.1 Investigators found a high correlation between the nephrometry score and tumor grade (P.0001) and histologic features (P.0001). Specifically, papillary RCCs had the lowest total nephrectomy score and clear cell RCCs had greater nephrectomy scores. Furthermore, benign lesions tended to be smaller, more endophytic, and nonhilar [16].

4.2 Higher nephrometry scores have been shown to correlate with pathologic stage, nuclear grade, and death from renal cell carcinoma [17].

5. Clinical trial measurements
Patients with unresectable RCC were treated with neoadjuvant sunitinib and were assigned a RENAL nephrometry score. At baseline, 81% of tumors were categorized as high complexity and 46% were downgraded to moderately complex after treatment, which facilitated surgery. Decrease in the tumor proximity to the central hilar structures was the main parameter that reduced the nephrometry score and decreased the surgical complexity [18].

6. Reproducibility of the R.E.N.A.L score system

6.1 Retrospective study of 95 patients, six reviewers (staff urologists, radiologists, house staff, and one medical student), independently assigned a RENAL score. The highest concordance was with the "R" designation, and the "N" component had the lowest concordance. The authors concluded that assigning a nephrometry score was reliable and required minimal training [19].

6.2 Three fellowship-trained urological oncologists evaluated the preoperative imaging studies of 51 patients who underwent partial nephrectomy, and scored them according to the RENAL-NS system. The RENAL nephrometry scoring system had good interobserver reliability. Quantifying the tumor location (L) was more challenging and the least reliable of the 5 components [20].

6.3 Reviewed prospectively 149 patients who underwent laparoscopic partial nephrectomy (LPN). The images preoperatives were independently read by two urology residents who assigned RENAL score (RS). The Pearson test was used to assess interobserver variability of total RS as well as each of the five components of the scoring system. From the data presented, they found strong reproducibility of the RENAL score and high interobserver fidelity (0.92, P < 0.001) [21.]
Conclusion

All three scoring systems represent methods of quantitatively describing renal tumors in a standardized manner with reproducible interobserver assessments. Use of these systems in the literature and in practice will afford meaningful comparisons among series and standardization of patterns of clinical care. Radiologists must understand how to calculate the nephrometry score and include this number in diagnostic reports.

Although evidence supports the three anatomic classification systems in predicting surgical outcome, it is difficult to state that one of these methods is superior to the others on the basis of currently available evidence.
References


