What's old, new and especially helpful in cystic renal masses imaging diagnosis?

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Authors: E. M. Preda, G. Popa, I. G. Lupescu; Bucharest/RO
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Learning objectives

To emphasize and illustrate the role of main imaging techniques in detection, characterization and follow-up of kidney cystic masses in order to provide more accurate criteria used to delineate between benign versus malignant cystic lesions.
Background

Renal cysts are a common finding on routine imaging studies.

**Bosniak classification**, proposed in 1986 (with four categories of cystic renal masses), revised in 1993 is usually a CT-based, useful guide for the diagnosis of cystic renal masses. In its current form, there are five categories of cystic renal masses, ordered in increasing probability of malignancy. The four initial categories, from original classification were: category I, simple benign cysts; category II, benign cystic lesions that are minimally complicated; category III, more complicated cystic lesions; and category IV, lesions that are clearly malignant cystic carcinomas.

The classification revised in 1993 include a subset of minimally complicated lesions that could be managed with follow-up (category IIF). [Table 1 on page 7] (Fig. 1 on page 7)

Simple renal cyst imaging appearance is well known: anechoic mass (ultrasound) / fluid densities at CT and fluid signal at MR examination, delimited by a thin, uniform wall. Benign simple cysts, most often discovered incidentally, not require surgery or follow-up imaging, except particulare- complicated renal cysts (bleeding, infection or vascular-ischemic). (Fig. 2 on page 8)

Any other characteristics such as calcification, changes occurring in CT attenuation or inhomogeneous or modified or stratified signal at MR examination as well as septa or multioculat appearance, as thickened or nodular walls require differential diagnostic. While only clearly malignant mass need to be surgically removed and most of renal cysts require maximum follow up is imperative to use optimal imaging technique for both diagnosis and for follow up imaging.

**Ultrasound (US)** is useful to identify simple renal cyst, but is insufficient to characterize complex renal cysts and solid masses. So, simple renal cysts are best defined using sonographic criteria: anechoic contents, without internal echoes, with sharp, thin posterior walls, posterior enhancement and round/oval shape [1].

**Nonenhanced CT** is superior to US in evaluating the calcified wall or septa.

Although Bosniak has opined that the calcifications has not been quantified, we can classified **calcifications** in:

- benign calcification (considered nonsurgical) consisting of a small amount of calcium smoothly deposited in the wall or septum of an otherwise simple cyst.
• surgical calcification (if enhancement, nodularity, or wall thickening within the cystic mass are associated), and
• follow-up calcification (if is seen in complicated, nonmalignant cysts, without associated enhancement, wall thickening, or nodularity) [2, 3, 4, 5, 6].

**On enhanced CT** scans, Bosniak suggest that a change of less than 10 HU from pre-to postcontrast images is considered typical of a benign cyst while more than 15 HU is almost always indicative of a pathologic process although not always a malignancy (cystic angiomyolipomas, oncocytomas, and infections may also enhance). [7, 8]

Do not forget though that attenuation changes may occur because of partial volume artifacts / incorrect placement of the region of interest / or streak artifacts "pseudoenhancement". But if all these are excluded, the lesion is suspicious for neoplasm. Iodinated contrast enhancement of renal tumors (even cystic) is due to tumor microvasculature (minimal in the case of papillary renal cancer unlike renal cell carcinoma). However contrast is dependent on dose and injection flow (ideal: 3-4 ml/sec) and timing scan.

Because papillary cancers enhance less and more slowly compared with other cancers, then late stages may be useful to confirm the enhancement. [9]

**Multislice CT examinations** improved cysts diagnosis, but are operator - dependent. Conditions of exposure, and the thickness, FOV- sections must to remain the same in all 3 phases of the examination for a correct assessment of uptake. The scanning parameters (pitch, tube current, peak voltage) of the unenhanced and contrast-enhanced examinations should remain constant, which will ensure that the most accurate Hounsfield unit readings are compared [10].

Sections of 3-5 mm is sufficient to identify small doses of contrast in complex lesions. But finer sections (1 mm by 0.5 mm overlap) reduce partial volume artifacts, but a 1-mm collimation grows radiation exposure. In return, reducing radiation noise increases and decreases accuracy [2].

**MR Imaging (MRI)** is helpful when renal lesions are detected by others imaging methods but not so well characterized.

**Septations** may occur in the evolution of a complicated cyst (by infection or hemorrhage) or by joining two adjacent cysts under a common wall. Better appreciated MR, they may submit curviliniare fine calcifications (best evaluated CT).

Septations were divided in:

- benign (non-surgical) septations: fine (<1 mm), net and attaches to the wall of the cyst; in small numbers and without nodules; may show calcification.
• surgical septations: thick, irregular septa, with nodular and / or significant contrast outlet;
• follow-up septations: Israel and Bosniak think that if the septal thickness is "greater than hairline" but smooth, the cyst is probably benign and need follow-up. An thickness increase or occurrence of irregularities of the septa at follow-up examination, requires surgical exploration [4, 11].

**Multilocular appearance** of cystic renal masses given by multiple septa (the number is arbitrary, but generally more than 3-4 septa confers the multilocular character) is better assessed at MR examinations than at CT. The two most common entities that may have multilocular appearance in the adult are renal cell carcinoma and multilocular cystic nephroma (not possible to definitely differentiate between them radiologically). Less commonly, certain renal cystic diseases and inflammatory, traumatic, and vascular lesions may manifest multilocular appearance [12].

Unlike CT, where attenuation measurements are reproducible, at MR imaging the arbitrary signal intensity units must be standardized for each examination. We must not forget that motion is often quite variable and can lead to the false impression of lesion enhancement. Both at CT and MR imaging, the comparison of corresponding region-of-interest (ROI) measurements on the unenhanced and contrast-enhanced images must be performed. Moreover, cystic, complex, or necrotic masses require multiple small ROI measurements (to be obtained from all portions of the mass, similarly placed on both the unenhanced and contrast-enhanced images) and image subtraction [4, 13].

The presence of enhancing soft tissue in a renal lesion on cross-sectional imaging is considered diagnostic of a renal tumor. Though, an extensively necrotic or cystic renal tumor may demonstrate little contrast enhancement, and its imaging appearance may overlap with that of complex benign renal cysts on conventional MR images. Particularly in those cases, but generally in renal lesions **MR diffusion-weighted imaging (DWI)** may be useful for characterization. However, data on DWI of focal renal lesions are rare in the literature and only few studies have been performed to compare the apparent diffusion coefficient (ADC) values of nonenhancing tumor tissue with those of cysts in the kidney. According to these studies different renal lesions have different DWI or ADC values: simple T1 hypointense renal cysts have the highest ADC values); T1 hyperintense (hemorrhagic or proteinaceous) benign renal cysts have diffusion values similar to those of T1 hypointense (nonhemorrhagic) necrotic or cystic areas in renal tumor, but they can be differentiated based on the T1 signal intensity. T1 hyperintense (hemorrhagic) necrotic or cystic areas in renal tumor demonstrate low ADC values, similar to those of viable solid tumor tissue. Therefore ADC may be potentially used as an incremental parameter to characterize renal lesions. [14, 15].

**Hyperattenuating Cysts** at CT exam (that measures more than 20 HU at unenhanced CT) or **High-Signal-Intensity Cysts** (with higher signal intensity than water at T1-
weighted MR imaging) are cysts containing hemorrhage, blood breakdown products, high protein content, or colloid. Israel and Bosniak opine that to be considered nonsurgical, a hyperattenuating mass should measure less than 3 cm in diameter with at least one-quarter of the lesion extending outside of the renal parenchyma so a portion of its wall can be evaluated [4].

Closer today, the significance of larger amounts of calcification was modified from requiring surgery to evaluation with follow-up [16].

Rarely biopsy may be recommended, but it is often unnecessary because if you do not confirm the nature of malignant basically do not have a final diagnosis (because often analyzed fragment may be insufficient). In addition, there may be tumor spread along the needle track, cyst rupture, hemorrhage and/or infection.

The length of follow-up needed for category IIF lesions has not yet been clearly determined, but a reevaluation first 3-6 months and 1 year later seems reasonable if there are no changes.

Recently, still the same Bosniak, shares his extensive experience, and try to explain [16] there is a wide range of complexity in category IIF lesions: those that are minimal category IIF with minimal findings that are very likely benign and close to category II in complexity, and those that are more worrisome and closer to category III in complexity. The minimal category IIF lesions may necessitate only 1-2-year follow-up, whereas the more complex category IIF lesions may need to be followed up for a longer period. The total follow-up time is also subjective. Some studies suggest that 5-year follow up would be appropriate for elderly patients, but must be extended for young patients. It is important to compare each exam with the first examination of the lesion and not only the last, as changes may occur very slowly [2, 17, 18].
Table 1: The Bosniak Renal Cyst Classification System

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**Fig. 1:** Drawing of Bosniak Renal Cyst Classification System

- **I:** benign simple cyst
- **II:** benign cystic lesions minimally complicated
- **IIF:** minimally complicated lesions that could be managed with follow-up
- **III:** more complicated cystic lesions
- **IV:** clearly malignant cystic carcinomas

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**Fig. 2:** Simple renal cyst appearance on different techniques: US (anechoic), CT (fluid densities content) and MRI (fluid signal content: hypointens on T1 weighted images, hyperintens on T2 weighted images) mass, delimited by a thin, uniform wall.

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Findings and procedure details

IMAGING TECHNIQUES

Retrospective study on renal cystic lesions explored by US, MSCT (evaluation before and after iodinated contrast injected iv in multiple phases) and / or MR in our clinic in the last 6 years.

Ultrasound (US) technique used in our clinic is:

- patient in the decubitus position and oblique
- frequencies between 2 and 5 MHz,
- optional we use color and power Doppler techniques (useful for the examination of vascularity within a nodule or septum) or tissue harmonic imaging (that reduce unwanted background noise, thus eliminating low-level echoes within an otherwise simple cystic lesion)

CT scanning protocol that we use in our clinic includes unenhanced phase (absolutely necessary to determine the walls/ nodules or septa enhancement), followed by arterial (corticomedullary) phase at 20-40 sec and venous (nephrographic) phase at 80-100 sec. All patients received 1,5 mL/Kg of a nonionic iodinated contrast (350 l mg/mL) with a monophasic injection using a power injector. The contrast material was administrated at a rate of 3 mL/s.

Our MR Protocol is based on T1-weighted FSPGR FS and T2-weighted FSE FS in axial plane; T2 ssFSE short and long TE in coronal and oblique plane and T1-weighted 3D FAME before and after gadolinium (0.1 ml/kgc), with dynamic postcontrast acquisition. The diffusion weighted images (DWI) was performed in selected cases.

T1-weighted sequences (3D FSPGR) - detects hemorrhage, fat (which is used in particular the dual echo sequences) and high protein content in (hypersignal T1).

T2-weighted sequences (usually FSE and SS FSE with short and long TE) - detects the cystic fluid inhomogenities and identify walls or septa nodulation.

IMAGES ANALYSIS
Computed Tomography (CT) is considered the main method for characterization of renal cystic lesions.

Nonenhanced CT allow accurate measurement of both fluid attenuation values (0-20HU), buy also of fatty or tissue or calcified components on unenhanced scans. (Fig. 3 on page 13)

In cystic renal mass analyzed, calcification were seen in the wall or septa of benign or malignant lesions. We classified calcifications in: benign calcification (nonsurgical), surgical calcification and follow-up calcification (seen in complicated, nonmalignant cysts, without associated enhancement). (Fig. 4 on page 13)

The major contribution of CT in renal cystic masses characterization is the possibility to accurately measure the contrast enhancement in the walls, septa or in the tissue components.

Any amount of enhancement was easily detected by placing a region of interest on pre- and postcontrast images.

We considered typical for a benign cyst a change of less than 10 HU from pre- to postcontrast images (criterion suggested by Bosniak). (Fig. 5 on page 14). But, many pathologic process with cystic appearance enhanced more than 15 HU, mimicking malignancy: cystic angiomyolipomas, oncocytomas, and infections may also enhance. (Fig. 6 on page 15)

**Thickening wall and nodularity** within a cystic mass have been observed in cystic renal cell carcinoma. (Fig. 7 on page 16)

Multislice examinations allow us mutiplanare and volume rendering reconstructions, although not proven to substantially improve the diagnosis of cystic renal lesions. (Fig. 8 on page 17)

MR imaging, used instead of CT, in patients with allergy to iodinated contrast material and in young patients (to limit radiation exposure), but also after US and CT, for better caracterisation of complicated renal cysts, allowed better highlight the septa, multilocular appearance, hemorrhagic or proteinaceous contents and solid nodules. (Fig. 9 on page 18)

Better appreciated at MR, compared to US or CT, septations were also divided in benign (non-surgical), surgical septations and follow-up sepatations. (Fig. 10 on page 19)

**Multilocular appearance** was better assesed at MR too. (Fig. 11 on page 20)
Both at unenhanced CT or MR imaging examination, the possibility to determine if a hyperattenuating or high-signal-intensity lesion is a cyst or a solid tumor was a real challenge. Both may be homogeneous and sharply marginated. The distinction is dependent on the presence of vascularity (ie, enhancement). Solid appearance at US examination was sometimes useful. (Fig. 12 on page 21)

The contrast-enhanced images were acquired within a single series with no "tuning" between acquisitions and we have standardized MR signal intensity units system for each examination. (Fig. 13 on page 22)

We started a study on the contribution of DWI and ADC in the differential diagnosis of cystic renal masses, and noticed that different renal lesions have different DWI or ADC values and, generally, the ADC values of the tissues contained calcification, necrosis, and cystic degeneration are lower than those of the solid parts. (Fig. 14 on page 23)

The imaging biomarker potential of DWI and ADC creates hope in the future to simplify the diagnosis of benign / malignant cystic renal masses.

Until then Bosniak classification remain a practical and useful guide for the diagnosis and management of cystic renal masses, widely embraced by radiologists and urologists. (Fig. 15 on page 24, Fig. 16 on page 25, Fig. 17 on page 26)
Fig. 3: Nonenhanced CT images showing different densities of the components of renal cystic lesions: a (fluid densities content), b (hyperdense content), c (wall calcifications) and d (fatty components)

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Fig. 4: Different types of calcifications (arrows): A (Benign, hairline septal calcification, without irregularity, nodularity, or enhancement of septa or the cyst wall), B (Surgical calcification, multiple, irregular nodular calcification with focal nodular enhancement adjacent to the irregular calcification and C (small calcification in a slightly modified cyst, with values attenuations > 20 UH)
Fig. 5: Simple renal cyst CT appearance: Unenhanced scan, arterial and nephrographic phase CT scans show a well-defined, homogeneous cystic lesion, with thin walls, no septa, fluid content (with attenuation of water), without enhancement (region of interest for measurement was in the center of the mass).

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**Fig. 6:** Cystic lesions mimicking malignancy: A (angiomyolipoma with a significant amount of fat) B (renal abscess, with a thickened, enhancing wall and surrounding stranding in the adjacent fat) and C (oncocytomas with small cystic foci).

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Fig. 7: CT appearance of malignant renal cyst: Unenhanced scan, an imprecise defined cystic lesion (fluid attenuation), with septa and nodular intracystic marked enhancement on arterial CT scan and with wash-out on nephrographic phase (Renal cell carcinoma was confirmed at surgery).
Fig. 8: Axial CT scan (a) and coronal reformatted image (b) voluminous cystic tumor mass developed on cranial pole of the left kidney with mass effect on nearby structures

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Fig. 9: a - MR axial T2-weighted sequences (FSE) show simple renal cyst with thin walls (better assessed on b - short TE SS FSE sections), no septa and fluid content (better assessed on c - long TE SS FSE sections)

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Fig. 10: Cyst septations at CT (a, b, c): benign, "hairline" (a); "greater than hairline" and smooth, with thin calcifications but enhancing septa (b, c) requiring surgery; and at MR (d, e, f): surgical septa, that means multiple, thick and enhancing septa (d, e) and irregular, with multiple nodulations (f).

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Fig. 11: Multilocular appearance assessed at MR, on short and long TE SS FSE sequences and on T1-weighted sequences after gadolinium administration.

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Fig. 12: Two patients with polycystic kidney viewing: small cysts in both kidneys spontaneously hyperattenuating in patients examined CT (A) and a voluminous renal cyst as at patient (B) examined by MRI, the last appearing in hypersignal T1, with "liquid - liquid " level on T2-weighted sequence.

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**Fig. 13:** Multiple septated cystic mass of right kidney, clearly enhancing after gadolinium administration

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**Fig. 14:** A: High signal on DWI sequence and ADC map in a patient with benign renal cyst and B: Intense heterogeneous signal of DWI and ADC (with multiple spots with varying low values of ADC) in a patient with Bosniak III cystic lesion (with irregular and multiple calcifications and very small solid components included)

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**Fig. 15:** Bosniak I (simple renal) cysts of left kidney (with water attenuation content, without septa, calcifications, or solid and which not enhance) and Bosniak II cyst of left kidney (uniformly high-attenuating lesions < 3 cm, that are sharply marginated and not enhance)

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**Fig. 16:** Bosniak II F cystic mass of left kidney - with multiple, minimal thickening septa, in which perceived (not measurable) enhancement may be appreciated, no calcification and no enhancing soft-tissue components

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Fig. 17: Bosniak III cystic mass of right kidney (with multiple, minimal thickening and enhancing septa, with nodular calcification and enhancing wall) and Bosniak IV cystic mass of right kidney (multiloculated, with irregular thickened and enhanced septa and wall with distinct enhancing soft-tissue components)

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Conclusion

Beyond the benign vs malignant, the major question to be answered remain whether the kidney cystic mass represents a surgical or nonsurgical lesion, separating benign renal cystic lesions from those that require imaging follow-up or excision with histopathological exam. The most important criteria used in differentiating surgical from nonsurgical renal masses is the enhancement measurement.

The judicious use of the imaging techniques and protocols in correlation with careful analysis of renal cystic masses features are essential to establish the management.

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Personal information

Emi Marinela Preda
Department of radiology, medical imaging and interventional radiology, Fundeni Clinical Institute, Bucharest, Romania
University Assistant, University of medicine and pharmacology "Carol Davila" Bucharest, Romania
emimpreda@gmail.com
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