Received:
10 December 2018

Revised:
04 April 2019

Accepted:
24 April 2019

<https://doi.org/10.1259/bjr.20181038>

Cite this article as:

Mu J, Mao Y, Li F, Xin X, Zhang S. Superb microvascular imaging is a rational choice for accurate Bosniak classification of renal cystic masses. *Br J Radiol* 2019; **92**: 20181038.

FULL PAPER

Superb microvascular imaging is a rational choice for accurate Bosniak classification of renal cystic masses

¹JIE MU, ¹YIRAN MAO, ²FANGXUAN LI, ¹XIAOJIE XIN and ¹SHENG ZHANG

¹Department of Ultrasound, Tianjin Medical University Cancer Institute and Hospital; National Clinical Research Center for Cancer, China; Key Laboratory of Cancer Prevention and Therapy, Tianjin; Tianjin's Clinical Research Center for Cancer, China

²Department of Cancer Prevention Center, Tianjin Medical University Cancer Institute and Hospital; National Clinical Research Center for Cancer, China; Key Laboratory of Cancer Prevention and Therapy, Tianjin; Tianjin's Clinical Research Center for Cancer, China

Address correspondence to: Dr Sheng Zhang
E-mail: zs19620112@126.com

The authors Jie Mu and Yiran Mao contributed equally to the work.

Objective: Bosniak classification system provides a fine imaging evaluation for the malignant cystic renal masses. Superb microvascular imaging (SMI) is a new ultrasonic technique which apply advanced clutter suppression to reflect microflow information. The aim of this study was to evaluate the performance of ultrasound Bosniak classification aided by SMI in diagnosis of cystic renal masses.

Methods: By comparing with contrast-enhanced ultrasound (CEUS) and pathology, we evaluated the sensitivity, specificity and accuracy of conventional ultrasound and SMI combination in the diagnosis of renal cystic masses.

Results: Color Doppler Flow image (CDFI) and SMI had significant difference in evaluation the blood flow and Bosniak classification for cystic renal mass of II_f, III and IV ($p = 0.020$). SMI was consistent with CEUS for cystic renal mass Bosniak classification of II_f, III and

IV. Although, CEUS had highest sensitivity of 97.4%, SMI had the highest area under curve in differential diagnosis malignance from benign masses [area under curve = 0.869 (0.743 – 0.995), $p < 0.001$].

Conclusion: SMI can display better in observing blood flow in septa and solid structures of renal cystic lesions compared with CDFI, thus, it can perform more accurate Bosniak classification for renal cystic mass. SMI and CEUS are consistent in Bosniak classification. Bosniak classification aided by SMI maybe an accurate non-invasive ultrasonic examination in distinguishing benign and malignant renal cystic lesions.

Advances in knowledge: Conventional ultrasound had limited ability to distinguish malignance in Bosniak classifications II_f and III. SMI can display better in observing blood flow in septa and solid structures of renal cystic lesions compared with CDFI.

INTRODUCTION

Cystic renal masses were usually detected in incidental imaging examinations, and the rational treatment of these masses may be challenging. The definition of “cystic” in imaging is a mass which has a mostly fluid-filled spaces more than one-fourth of the lesion.¹ Cystic renal mass account for nearly 15% of all renal mass lesions. While, malignant cystic renal lesions prefer to better prognosis in comparing with malignant solid renal mass lesions.^{2,3}

The challenge for cystic renal masses diagnosis is how to distinguish benign and malignant complex cystic renal lesion. The Bosniak classification system is commonly applied in the world urologic and radiologic communities for its utility in helping diagnosis of cystic renal masses.⁴ The Bosniak classification system subgrounded renal cysts into five classifications according to imaging features. However,

the limited ability to distinguish malignance in classifications II_f and III lesions result some patients receiving unnecessary surgical treatments, cancer may be missed as well.⁵ 15% of renal cell carcinomas appear as complex cystic renal masses, while, some benign renal cysts present complex appearance because of hemorrhagic, infectious, or ischemic processes in the lesion. Conventional ultrasound is not a preferred diagnostic tool for complex cystic renal lesions that require the application of CT, MRI, or histological examination (biopsy or surgical removal), as well as contrast-enhanced ultrasound (CEUS), which was reported as a sensitive diagnostic tool which can detect the microvascularization of cystic wall and septa, as well as the solid components of the complex cystic renal masses.⁶ However, more evaluation time is needed to undergo CEUS, and the cost of the CEUS is expensive than common ultrasound because of application of the ultrasound contrast drug.

Superb microvascular imaging (SMI) is a new ultrasonic technique which apply advanced clutter suppression to reflect micro-flow information. Unique algorithm which makes visualizing of minute vessels with slow velocities without assistance of contrast agent, so that the imaging of very slow flow is can be detected.⁷ Many previous research have found the SMI can evaluate micro-vascular flow signals in breast cancers⁸ and thyroid cancers.⁹ Concentrated on previous researches, we proposed that SMI technique could also provide accurate evaluation for the micro-vascular flow of cystic renal masses, thus, help the characterization of these masses. The aim of present study was to explore if SMI technology could improve accuracy of Bosniak classification based on ultrasound in diagnosis of benign and malignance.

METHODS

This study was approved by the ethics committee of Tianjin Medical University Cancer Institute and Hospital. Written consents were obtained from each patient.

Patients

From Jan 2015 to Feb 2017, 55 patients diagnosed with solitary cystic renal mass at the Tianjin Medical University Cancer Institute and Hospital were included. These patients received conventional ultrasound, Color Doppler Flow image (CDFI) and SMI. Complex indeterminate Bosniak category IIf, III, IV renal cystic masses were performed CEUS after conventional ultrasound

Final diagnosis

44 cases received the surgical resection of renal cystic masses and got the final pathological diagnosis. 11 patients have not received surgical resection, in them, 6 cases of cystic renal masses were final diagnosed as simply cyst after a mean follow-up of 27 months (12–36 month); 5 cases with complex cystic renal lesion in Bosniak category IIf-IV performed CEUS, then diagnosed as radiologically benign and confirmed at least 1 year after follow-up. The general conditions of patients were shown in Table 1.

There were 38 cases of malignancy and 17 cases of benign; the detailed pathological pattern are shown in Table 1.

Equipment and ultrasound examination

All patients were examined via transabdominal ultrasound examination in the horizontal position by a Toshiba Aplio 500 ultrasound machines (Toshiba America Medical Systems Inc, Tustin, Calif., USA). Ultrasonic images were recorded and analyzed by atleast two independent sonologists; each of them was blinded to the each other's pathological diagnosis. If the scores were not in line with each other, the third sinologist (being blind to pathology results), served to achieve consistency. All the sonographers have been attending doctors and had at least 9 years' experience in the abdominal disease diagnosis.

The following morphological information was recorded for each patient from ultrasonography: location, maximum diameter of lesion (cm), septum, echogenic content, thick wall, solid nodules, calcifications, and contrast enhancement were evaluated.

CDFI were fundamental for identifying vascularization. These settings were applied for the CDFI evaluation: the color velocity scale was adjusted to slower than 5 cm/s, the wall filter was adjusted to between 50 and 100 Hz, the color gain was adjusted appropriately so as to suppress the background color and detect small vessels. The region of interest (ROI) was adjusted to contain the mass and normal kidney tissue adjacent to the mass.

SMI mode examinations, these settings were applied: the color velocity scale was adjusted to between 1.0 and 2.0 cm/s, the color frequency was adjusted to between 5 and 7 MHz, and the vascular signals were enhanced via adjusting the temporal smoothing. The sensitivity of SMI decreases with the increase of depth. In abdominal ultrasound, the deepest range SMI observed is about 5–8 cm, within which SMI is basically satisfactory, so our ROI is generally within this range in all 55 patients. SMI technology detects low-speed blood flow signals, and it has strict requirements for ultrasound physicians during examination. If the probe cannot scan smoothly, the velocity of blood vessel movement will be too high, which may cause motion artefacts and affect the imaging quality. The probe should be kept as smooth, slowly, gently as possible. Adjust the color gain to precisely suppress the

Table 1. The general condition and pathological type of enrolled patients.

Groups	Malignancy (<i>n</i> = 38)	Benign (<i>n</i> = 17)
Age (Range, years)	57 (35 ~ 68)	49 (34 ~ 72)
Sex (Male/Female)	29/9	10/7
Location (Right/left)	17/22	9/8
Surgical resection (Yes/No)	38/0	6/11
Pathological pattern	Cystic renal cell carcinoma (<i>n</i> = 6)	Simple cyst(<i>n</i> = 9)*
	Papillary renal carcinomas (<i>n</i> = 2)	Multilocular cyst(<i>n</i> = 6) [#]
	Renal clear cell carcinoma (<i>n</i> = 28)	Multilocular cyst with atypical hyperplasia(<i>n</i> = 1)
	Metastatic renal cell carcinoma (<i>n</i> = 2)	Angiomyolipoma(<i>n</i> = 1)

CEUS, contrast-enhanced ultrasound.

*: 3 cases of simple cyst were confirmed by CEUS and at least 1 years follow-up; 6 cases of simple cyst were confirmed by conventional ultrasound and at least 1 years follow-up.

#: 2 cases of multilocular cyst were confirmed by CEUS and 1 years follow-up.

noise. After the twin-view image is stabilized, we place the cursor in the image. If the blood flow is shown on both SMI and conventional ultrasound image, it will be judged as the blood flow. If only the conventional ultrasound image is displayed, it is judged to be artefacts.

CEUS was processed via transabdominal ultrasound examination of Philips iU22 digital ultrasound scanner system (Philips Bothell, Washington, DC) by the coded phase-inversion mode with the mechanical index of 0.4. The focus depth was about 9 cm to the kidney's inferior margin, while the frame rate was between 10 and 12 Hz. The ultrasonic contrast agent Sonazoid was intravenously injected within 3–5 s at a 0.015 mL/kg bolus. Then, real-time scanning processed immediately during inspiratory breath, so that to hold the lateral position. TIC software of the ultrasound system was applied for building-in perfusion subsequently. ROI were placed in the area of the solid content of the cystic masses and normal parenchyma with 3 mm diameters each. Both ROIs were selected as same depth as possible.

The ROI of the tumor was placed in the peripheral most visualized area of blood flow. We analyzed at least three ROIs and use the mean value as the final value. Contrast enhancement was evaluated in the ROI and TICs. The time to the contrast enhancement peak (TTP), the intensity changes from the baseline to peak (ΔI) and ratio of ΔI /TTP were accessed by the TIC.

The Bosniak classification

Bosniak classification for renal cystic masses probability of malignancy system is based on ultrasound features including five categories and provides an apriority risk estimation of probability of malignancy.¹ The Bosniak classification system and suggested management protocol based on risk of malignancy are shown in Table 2. Figures 1–2 represented ultrasonic images for Bosniak classification I–IV.

Statistical methods

Bowker test was used to analyses the difference of CDFI and SMI in evaluation the Bosniak classification of cystic renal

Table 2. The Bosniak classification system for cystic renal masses.

Bosniak classification	Differential Diagnosis	Ultrasound features details	Follow-up
I	Definitive benign: simple renal cyst	A benign simple cyst with fluid attenuation with a pencil-thin wall. This cyst does not contain soft tissue, septa, or calcifications. There is no enhancement.	No further evaluation is needed.
II	Very probably benign (Nearly 99%): hemorrhagic, proteinaceous or posttraumatic cyst	A benign cyst with a pencil-thin wall that may contain a few pencil-thin septa where faint minimal enhancement may be perceived in the septa. Thin calcifications or short segments of thickened calcification may be present. Homogeneous high attenuation non-enhancing lesions less than 3 cm with a well-defined wall are in this category.	No further evaluation is needed.
IIf (f indicate follow-up)	Probably benign (>95%): hemorrhagic, proteinaceous, posttraumatic cysts, infected cyst/abscess, localized cystic disease of the kidney, pyelocalyceal diverticula, milk of calcium cysts, CN/MEST. Malignant (1–4%): MLCRCC, cystic clear cell carcinoma, tubulocystic carcinoma, clear cell tubulopapillary RCC	Cysts have multiple thin septa or minimal smooth thickening of the septa or wall. Faint minimal enhancement and calcifications of the septa or wall may be present; however, no associated measurable contrast enhancement is seen. These lesions are well circumscribed. Endophytic, intrarenal non-enhancing high attenuation renal lesions greater than 3 cm are in this category.	Require follow-up imaging to prove benignity.
III	Benign (>50%): hemorrhagic, proteinaceous, posttraumatic cysts, infected cyst/abscess, localized cystic disease of the kidney, pyelocalyceal diverticula, milk of calcium cysts, CN/MEST. Malignant (5–50%): MLCRCC, cystic clear cell carcinoma, tubulocystic carcinoma, clear cell tubulopapillary RCC.	Cystic lesions have a thickened wall or septa (smooth or irregular) with measureable (<i>i.e.</i> via region of interest placement) enhancement.	Surgical management
IV	Very probably malignant (>50%): MLCRCC, cystic clear cell carcinoma, tubulocystic carcinoma, clear cell tubulopapillary RCC. Benign (uncommon): CN/MEST.	Cystic lesions have the features described in category III as well as a solid enhancing soft tissue component separate from the wall or septum.	Surgical management

Figure 1. The comparison of SMI and CDFI in kidney cystic mass of Bosniak classification I-II. A: A Bosniak classification I cystic mass was a benign simple cyst with fluid attenuation with a pencil-thin wall, SMI showed no blood flow signal in this cyst. B: CDFI showed no blood flow signal in Bosniak classification I cystic mass; C: Bosniak classification II cystic mass was a benign cyst with a pencil-thin wall, SMI showed this cyst contain faint minimal blood flow signal; D: CDFI showed no blood flow signal in Bosniak classification II cystic mass. CDFI, Color Doppler Flow image; SMI, superb microvascular imaging.

mass. κ analysis was assessed to evaluate the consistence of Bosniak classification based on SMI, CDFI and CEUS. ROC curves were applied to describe and compare the accuracy of diagnostic performance. The p -value of 0.05 (two-sided) was set as statistically significance. All analyses were performed by SPSS v. 19.0.

RESULTS

Bosniak classification based on SMI and CDFI of cystic renal mass

As shown in Figures 1–2, SMI can clearly show the solid component with abundant and chaotic blood flow signal in renal cystic masses, which cannot be detected by CDFI, so as to get the more accurate Bosniak classification. The Table 3 showed the Bosniak classification of renal cystic masses based on SMI and CDFI. We used Bowker test to analyze the difference of CDFI and SMI in evaluation the cystic renal mass classified into IIf, III and IV. CDFI and SMI had significant difference in evaluation the blood

flow and Bosniak classification for cystic renal mass of IIf, III and IV (Bowker = 7.800, $p = 0.020$).

Consistence of Bosniak classification based on SMI, CDFI and CEUS

κ analysis was applied to evaluate the consistence of SMI, CDFI and CEUS. Table 4 showed that in re-evaluating cystic renal mass by CDFI and SMI for those classified as IIf, III and IV based on CEUS, SMI is more consistent with CEUS (κ value = 0.866; $p = 0.000$). As shown in Figures 1–2, SMI can show the solid component with extensive and chaotic blood flow signal, which was consistent with CEUS.

Diagnostic performance of Bosniak classification based on CDFI, SMI and CEUS in diagnosing benign and malignance cystic renal mass

To determine whether Bosniak classification based on CDFI and SMI have diagnostic values for malignant cystic renal

Table 3. Bosniak classification based on SMI, CDFI of cystic renal mass

Bosniak classification	I	II	IIf	III	IV
CDFI	3 (5.5)	6 (10.9)	17 (30.9)	20 (36.4)	9 (16.4)
SMI	3 (5.5)	3 (5.5)	8 (14.5)	23 (41.8)	18 (32.7)
<i>Bowker test</i>	0.417			7.800	
<i>P</i>	0.508			0.020	

mass, the ROC curve was used to evaluate their diagnostic sensitivity and specificity (Figure 3 and Table 5). Positive were defined as Bosniak classification III and IV; Negative were defined as I, II, IIf. Among them, SMI had the highest area under curve (AUC) in diagnosing malignant masses

from benign masses [AUC = 0.869(0.743–0.995)]. The sensitivity and specificity of SMI were 94.8 and 75.0%. CEUS had moderate distinguishing efficacy with the higher sensitivity of 97.4% and relatively higher specificity of 70.6% [AUC = 0.840(0.763–0.977)]. The AUC of CDFI was the lowest

Figure 2. The comparison of SMI, CDFI and CEUS in kidney cystic mass of Bosniak classification IIf–IV. A: a Bosniak classification IIf cystic mass have minimal smooth thickening of the septa and wall, SMI showed thin linear blood flow signal in the thick septa and wall. B: CDFI showed no blood flow signal in this Bosniak classification IIf cystic mass. C: CEUS showed faint enhanced blood flow signal in thick septa and wall in this IIf cystic mass. D: a Bosniak classification III cystic mass had a thickened wall and septa, SMI showed chaotic blood flow signal in thickened wall and septa. E: CDFI showed dotted blood flow signal in this Bosniak classification III cystic mass. F: CEUS showed enhanced blood flow signal in solid component of Bosniak classification III cystic mass. G: Bosniak classification IV cystic mass has a thickened wall, septa and soft tissue component, SMI showed solid component with abundant and chaotic blood flow signal; H: CDFI showed small amount of blood flow signal in this Bosniak classification IV cystic mass; I: CEUS showed enhanced blood flow signal in solid component IV cystic mass. CDFI, Color Doppler Flow image; CEUS, contrast-enhanced ultrasound; SMI, superbmicrovascular imaging.

Table 4. The κ agreement index of CDFI, SMI and CEUS

		CDFI			SMI		
		IIf	III	IV	IIf	III	IV
CEUS	IIf	6	0	0	6	0	0
	III	5	18	0	2	21	0
	IV	0	8	12	0	2	18
	κ value	0.574			0.866		
	P	<0.001			<0.001		

CDFI, Color Doppler Flow image; SMI, superb microvascular imaging.

with the 76.3% sensitivity and 88.2% specificity [AUC = 0.823(0.702–0.944)], as shown in Table 4.

DISCUSSION

Cystic renal lesions are a diagnostic challenge in common ultrasound. Yet, renal cystic lesions are relatively common in clinical practice, which was mainly manifested as fluid zone, accompanied by thick-walled, papillary and parenchymal masses.

Cystic renal malignancies are correlated with a lower morbidity and better prognosis than solid renal malignancies. Due to more indolent biological behavior of cystic renal malignancies than solid malignancies, more sensitive and specific imaging diagnostic tool was needed for cystic renal lesions prior to definitive surgical intervention. The Bosniak classification is an evaluation system for distinguishing benign and malignant cystic renal lesions.

Ultrasonic is preferred screening method for kidney disease. Generally, because CDFI showed the blood flow with the velocity more than 10 cm/s, conventional ultrasound with CDFI are unable to effectively detect the slow blood flow signals or tiny blood vessels signals in septa and nodules of cystic renal lesions.¹⁰ Thus, accurate Bosniak classification relying on conventional ultrasound is difficulty, especially for complexity renal cystic lesion with relatively a bit thick wall, septa and small nodules.

CEUS can obviously increase sensitivity of ultrasound examination in detecting blood flow, thin septa and small nodules. Previous studies confirmed that CEUS can be applied in Bosniak classification in access blood flow and diagnosis of cystic renal masses.^{6,11} However, the cost of CEUS is expensive, and contrast agents have some risk of allergy, additional evaluation time is needed for CEUS, which limits its application in first time. SMI makes it easier to detect blood vessels in a lesion with extremely low blood flow velocity by recognizing the noise generated by relative movement blood flow and tissue.

In this study, SMI can show blood flow with the velocity lower to 0.5 cm/s, and the lowest blood flow frequency is about 2 cm/s. At present, SMI technology applied in perforators arteries of breast tumors,⁸ blood flow of focal lesions in the liver^{12,13} and new blood vessels within the carotid atherosclerotic plaques,¹⁴ all of these have evidenced the SMI had prefer ability to show tiny blood flow than of a CDFI.

This study shows that SMI can improve the detection rate of microflow in cystic septa and tiny solid papilla on septa significantly. Due to few cystic septa and less blood flow, CDFI and SMI have not significant difference in diagnosis benign renal capsule lesions which usually graded at Bosniak classification I and II. In nine cases, three cases were found a small amount of blood flow in the cystic by SMI, and the Bosniak classification changed from II to IIf, which was still considered as benign lesions, and confirmed by CEUS and follow-up.

Due to the application SMI, certain tiny blood flow, which were can not found by CDFI, could be observed. Bosniak classification III, IV in 29 cases by CDFI were increased to 41 by SMI. Given the masses of Bosniak classification above IIf, blood flow accessed in Bosniak classification had significant difference between by CDFI and SMI. SMI can show richer and subtle blood flow signals, has lower range and more sensitivity. As well as, the detection rate of blood flow in cystic septa and tiny solid papilla on septa can be improved by SMI in cystic renal masses of Bosniak classification III, IV, which can aid getting more accurate

Figure 3. The ROC curve calculation on SMI, CDFI, CEUS for the differential diagnosing benign and malignant renal cystic lesions. CDFI, Color Doppler Flow image; CEUS, contrast-enhanced ultrasound; ROC, receiver operating characteristic; SMI, superb microvascular imaging.

Table 5. Diagnostic performance of Bosniak classification based on CDFI, SMI and CEUS in diagnosing benign and malignance cystic renal mass.

	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)	Youden index (%)	AUC	
CDFI	76.3	88.2	93.5	62.5	80.0	64.5	0.823 (0.702–0.944)	<0.001
SMI	94.8	75.0	89.1	90.2	89.7	69.8	0.869 (0.743–0.995)	<0.001
CEUS	97.4	70.6	88.1	92.3	89.9	68.0	0.840 (0.763–0.977)	<0.001

AUC, area under the curve; CDFI, Color Doppler Flow image; CEUS, contrast-enhanced ultrasound; NPV, negative predictive value; PPV, positive predictive value; SMI, superb microvascular imaging.

The accuracy = (True positive + true negative) / (True positive + true negative + false positive + false negative). Youden's index = Sensitivity + Specificity - 1. AUC: Area under curve. The sensitivity, specificity, PPV, NPV, accuracy and Youden index were calculated based on the number of positive cases and negative cases. PPV: positive predictive value; NPV: negative predictive value.

Bosniak classification. Bosniak classification according SMI was in coincidence with CEUS in κ analysis (κ value of 0.866), which implies that SMI can be a useful tool for accessing blood flow to get high accurate Bosniak classification.

One renal cystic mass had a bit thick cystic wall and flocculent echoes in the cyst. Bosniak classification was accessed as IIf. SMI also indicate to Bosniak classification IIf, because only a bit of blood flow can be observed in visible cystic wall in SMI. In further CEUS, cystic wall showed low enhancement. Then, patients received surgical resection, the pathological diagnosis of renal carcinoma with necrosis were confirmed. Although SMI is superior CDFI, SMI did not allow to visualize very low blood flow, so that very low blood flow cannot be excluded by SMI. Here the application of CEUS is still necessary. What's more, small blood flow can be observed in SMI examination, but it cannot assess the whole blood flow and blood flow enhancement changes which can be show by CEUS. In addition, this study of cystic lesion shows that can improve the blood flow to the Bosniak classification, meanwhile, it also misdiagnoses two cases of multilocular renal cyst to malignant lesions.

Due to the relatively small number of benign cases, the results may be somewhat biased. In further studies, the sample size of benign cases should be increased. No comparative study was conducted between SMI and ultrasound contrast microangiography to analyze the vascular configuration of the tumor. Beside SMI from Toshiba Aplio 500 ultrasound machines, Power Doppler imaging (PDI) measures the power of the temporal differences

in backscattered echoes, and can provide higher sensitivity with small vessel and slow flow detection than color Doppler imaging at the expense of direction and velocity information. The value of PDI for renal cystic lesions can be explored and compared with SMI in the future. But, PDI blood flow signal only depends on the presence or absence of red blood cell scattering energy (power) and does not show the direction and velocity.

SMI can display better blood flow signals in septa and solid structures of renal cystic lesions compared with conventional ultrasound, thus, it can perform more accurate Bosniak classification of renal cystic mass. SMI and CEUS were more consistent. The combination of SMI and Bosniak Classification can improve the accuracy of non-invasive ultrasonic examination in distinguishing benign and malignant renal cystic lesions. SMI may be an accurate and a less expensive substitute for CEUS.

ETHICS APPROVAL

This research project was approved by the Ethics Committee of Tianjin Cancer Institute and Hospital. Written consents were obtained from each patient.

DISCLOSURE

The datasets used during the current study are available from the corresponding author on reasonable request.

PATIENT CONSENT

Written consents were obtained from each patient to publishing their pathological images as represent Figures.

REFERENCES

- Hindman NM. Imaging of cystic renal masses. *Radiol Clin North Am* 2017; **55**: 259–77. doi: <https://doi.org/10.1016/j.rcl.2016.10.004>
- Hindman NM, Bosniak MA, Rosenkrantz AB, Lee-Felker S, Melamed J. Multilocular cystic renal cell carcinoma: comparison of imaging and pathologic findings. *AJR Am J Roentgenol* 2012; **198**: W20–W26. doi: <https://doi.org/10.2214/AJR.11.6762>
- Winters BR, Gore JL, Holt SK, Harper JD, Lin DW, Wright JL. Cystic renal cell carcinoma carries an excellent prognosis regardless of tumor size. *Urol Oncol* 2015; **33**: 505.e9–505.e13. doi: <https://doi.org/10.1016/j.urolonc.2015.07.017>
- Bosniak MA. The current radiological approach to renal cysts. *Radiology* 1986; **158**: 1–10. doi: <https://doi.org/10.1148/radiology.158.1.3510019>
- O'Malley RL, Godoy G, Hecht EM, Stifelman MD, Taneja SS. Bosniak category IIF designation and surgery for complex renal cysts. *J Urol* 2009; **182**: 1091–5. doi: <https://doi.org/10.1016/j.juro.2009.05.046>
- Graumann O, Othter SS, Karstoft J, Hørlyck A, Osther PJS. Bosniak classification system: a prospective comparison of CT, contrast-enhanced us, and MR for categorizing complex renal cystic masses. *Acta Radiol*

- 2016; **57**: 1409–17. doi: <https://doi.org/10.1177/0284185115588124>
7. Gabriel M, Tomczak J, Snoch-Ziólkiewicz M, Dzieciuchowicz Łukasz, Strauss E, Oszkinis G. Comparison of Superb microvascular ultrasound imaging (SMI) and contrast-enhanced ultrasound (CEUS) for detection of endoleaks after endovascular aneurysm repair (EVAR). *Am J Case Rep* 2016; **17**: 43–6. doi: <https://doi.org/10.12659/AJCR.895415>
8. Ma Y, Li G, Li J, Ren W-dong. The diagnostic value of Superb microvascular imaging (SMI) in detecting blood flow signals of breast lesions: a preliminary study comparing SMI to color Doppler flow imaging. *Medicine* 2015; **94**: e1502. doi: <https://doi.org/10.1097/MD.0000000000001502>
9. Machado P, Segal S, Lyshchik A, Forsberg F. A novel microvascular flow technique: initial results in thyroids. *Ultrasound Q* 2016; **32**: 67–74. doi: <https://doi.org/10.1097/RUQ.0000000000000156>
10. El-Mokadem I, Budak M, Pillai S, Lang S, Doull R, Goodman C, et al. Progression, interobserver agreement, and malignancy rate in complex renal cysts ($\geq$ Bosniak category IIF). *Urol Oncol* 2014; **32**: 24.e21–24.e27. doi: <https://doi.org/10.1016/j.urolonc.2012.08.018>
11. Sanz E, Hevia V, Gómez V, Álvarez S, Fabuel J-J, Martínez L, et al. Renal complex cystic masses: usefulness of contrast-enhanced ultrasound (CEUS) in their assessment and its agreement with computed tomography. *Curr Urol Rep* 2016; **17**: 89. doi: <https://doi.org/10.1007/s11934-016-0646-7>
12. Lee DH, Lee JY, Han JK. Superb microvascular imaging technology for ultrasound examinations: initial experiences for hepatic tumors. *Eur J Radiol* 2016; **85**: 2090–5. doi: <https://doi.org/10.1016/j.ejrad.2016.09.026>
13. Bonacchi G, Becciolini M, Seghieri M. Superb microvascular imaging: a potential tool in the detection of FNH. *J Ultrasound* 2017; **20**: 179–80. doi: <https://doi.org/10.1007/s40477-017-0240-y>
14. Zhang H, Du J, Wang H, Wang H, Jiang J, Zhao J, et al. Comparison of diagnostic values of ultrasound micro-flow imaging and contrast-enhanced ultrasound for neovascularization in carotid plaques. *Exp Ther Med* 2017; **14**: 680–8. doi: <https://doi.org/10.3892/etm.2017.4525>