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Usefulness of power Doppler and contrast-enhanced sonography in the differentiation of hyperechoic renal masses

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Abstract
Background: In a prospective study, we compared power Doppler with and without contrast medium in the depiction of vascularity for the characterization of hyperechoic renal lesions.
Methods: Forty-one hyperechoic renal expansive lesions (29 benign, 12 malignant) in 32 patients were studied with power-Doppler ultrasonography before and after administration of an echo-enhancing agent (Levovist Schering AG, Berlin, Germany). Vascular architecture of the lesions was categorized into five different patterns.
Results: Power Doppler ultrasonography showed vascular structures in 25 lesions. The study enhanced with Levovist showed vascularity in eight of 16 lesions not seen on the unenhanced study. The characterization of vascular patterns with unenhanced power Doppler ultrasonography improved diagnostic accuracy compared with gray-scale ultrasonography (59% vs. 32%). The combination of B mode and power Doppler produced even greater diagnostic accuracy (78%), independent of the administration of echo-enhancing agent. Levovist administration was useful in the differential diagnosis between pseudotumor and neoplasm.
Conclusion: The use of songraphic contrast agent did not increase the diagnostic accuracy of power Doppler in the differential diagnosis of hyperechoic renal lesions but was advantageous for the characterization of suspected pseudomasses.

Key words: Contrast-enhanced power Doppler sonography, hyperechoic renal masses—Contrast-enhanced power Doppler sonography, kidney, neoplasms.

The routine clinical application of ultrasonography (US) has significantly increased the incidental detection of renal focal lesions, but their characterization remains unclear. The early distinction between a small renal cell carcinoma (RCC) and a lesion that does not need to be treated surgically is a critical point in view of the progressive extension of nephron-sparing surgery, particularly in patients with diminished renal function, solitary kidney, or bilateral renal malignancy [1, 2].

On gray-scale US, differential diagnosis of a renal hyperechoic mass can be particularly difficult. A benign tumor such as angiomyolipoma (AML) and a small RCC, which are the most frequently encountered solid renal tumors, can appear as hyperechoic nodules [3–9]. The low specificity of US in the characterization of hyperechoic renal lesions has been widely reported in literature; for this reason, the differential diagnosis of these lesions relies on computed tomography (CT) and magnetic resonance imaging (MRI) [4, 10–12]. An increase in the diagnostic accuracy of US for the characterization of small renal masses has been acheived, thanks to power Doppler [6, 13, 14]. Further, use of the echo-contrast agent Levovist has improved the evaluation of vessels within the lesion, thus adding important information [14–16].

To our knowledge, the usefulness of US contrast medium in the differential diagnosis of hyperechoic renal masses has not been evaluated in a large number of patients. We report the results of a prospective study in which the depiction of vascularity for the characterization of hyperechoic renal lesions was compared using power Doppler with and without contrast medium.

Materials and methods

Between January 1998 and February 2000, we prospectively studied 41 hyperechoic renal lesions (diameter

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range = 0.6–6 cm, mean diameter = 2.4 cm) in 32 subjects (15 male, 17 female; age range = 10–79 years; mean age = 57 years) with the use of gray-scale and power Doppler US before and after the administration of echo-enhancing contrast agent (Levovist Schering AG, Berlin, Germany). All US examinations were performed with an ATL HDI 3000 scanner (Advanced Technology Laboratories, Bothell, WA, USA) equipped with a broadband 2–4-Mhz convex transducer.

Lesions were classified as markedly hyperechoic when they appeared iso- or hyperechoic in relation to renal sinus fat and as slightly hyperechoic when they appeared hyperechoic in relation to adjacent renal parenchyma but were not as echogenic as renal sinus fat.

On gray-scale US, criteria for the diagnosis of RCC were an anechoic rim completely surrounding the lesion and small cystic areas within the lesion [7, 8, 13]. Shadowing (no visualization of the posterior wall of the lesion or reduced echogenicity of distal tissues) was considered a diagnostic criterion for AML [5, 13].

Power Doppler scan, before and after echo-enhancing agent administration, was performed using 1000-Hz PRF and wall filter medium. The color gain was turned up until color noise appeared and then reduced until noise was no longer present in the region of interest on the scans.

After informed consent was obtained, a single bolus of Levovist, a contrast agent commercially available in our country, was injected manually into an antecubital fossa vein at a concentration of 300 mg/mL and a rate of 1 mL/s.

Vascular architecture of the lesion, before and after echo contrast administration, was categorized into five different patterns based on the classification of Jinzaki et al.: pattern 0 = no signal pattern, indicating no detectable vessels; pattern 1 = intratumoral focal pattern, indicating persistent focal color flow signal (spotty or linear) reproducibly detected within the lesion and not extending to the margins; pattern 2 = penetrating pattern, indicating that blood vessels arose outside the lesion and coursed toward the center; pattern 3 = peripheral pattern, indicating that blood vessels arose outside the lesion and surrounded it; and pattern 4 = mixed penetrating and peripheral patterns (patterns 2 and 3) [13].

Hyperechoic lesions with patterns 0–2 were diagnosed as AML; those with patterns 3 and 4 were diagnosed as indeterminate lesions; pseudotumor was diagnosed when the distribution of vascular signal was the same as that for the surrounding renal parenchyma before and after echo-enhancing contrast administration.

CT examination was performed with 5-mm collimation and 7.5-mm table feed in all patients. In 10 patients (11 cases of AML and one of RCC), no contrast medium was used; in the remaining 22 patients, CT was performed before and after the administration of nonionic iodinate contrast medium, infused at a rate of 3 mL/s with an automatic mechanical injector; two contrast-enhanced spiral acquisitions were made in each patient. The first scan was initiated 25 s after the start of contrast material infusion for the corticomedullary phase, and the second was done after 60–80 s to obtain tubular nephrogram images (parenchymal phase).

We diagnosed 11 RCCs, one metastasis from colon carcinoma, 26 AMLs, and three pseudotumors. Definitive diagnoses were obtained by surgery in 10 cases (10 RCCs) and fine-needle biopsy in two (one RCC, one metastasis). In the other cases, diagnoses were made on the basis of fat content within the lesions on CT and/or US follow-up examinations demonstrating the stability of the lesions for at least 12 months (26 AMLs, three pseudotumors).

Statistical evaluation was done with the McNemar test. $P < 0.05$ was considered statistically significant.

Results

Twenty-nine patients had one lesion; three had multiple AMLs (two, four, and six lesions, respectively). Of the 41 nodular lesions, 31 showed a markedly hyperechoic structure (26 AMLs, four RCCs, one metastasis) and 10 were moderately hyperechoic (seven RCCs, three pseudotumors). Three RCCs had an anechoic rim, two an intratumoral cyst, and two had both. Shadowing was present in six AMLs.

On the basis of these criteria, gray-scale US diagnoses were correct for 13 of 41 nodules (32%; seven RCCs, six AMLs) and indeterminate for 28 of 41 (68%; four RCCs, one metastasis, 20 AMLs, three pseudotumors). Power Doppler visualized vascular structures in 25 lesions (18 markedly and seven moderately hyperechoic) but not in 16 lesions (all markedly hyperechoic). The administration of Levovist enhanced vascularity in eight of 16 lesions not visible on the unenhanced study. In all 25 vascularized lesions studied, an increase in color signal was observed, allowing for a better definition of vascular patterns.

Tables 1 and 2 present the vascular patterns on unenhanced and enhanced US, according to the classification by Jinzaki et al. [13]. On the unenhanced studies, diagnoses were correct for 24 of 41 lesions (59%; 23 AMLs, one pseudotumor) and indeterminate for 17 of 41 (41%; three AMLs, two pseudotumors, 12 malignancies; Figs. 1–3). After Levovist administration, diagnoses were correct for 23 of 41 lesions (56%; 20 AMLs, three pseudotumors; Fig. 4) and indeterminate for 18 of 41 (44%; six AMLs, 12 malignancies).

The combination of B-mode and unenhanced power Doppler findings produced greater diagnostic accuracy, with correct diagnoses for 32 of 41 cases (78%) and indeterminate diagnoses for nine of 41 (22%). The combination of B mode and power Doppler with Levovist administration produced correct diagnoses for 31 of 41

Table 1. Vascular patterns with power Doppler before echocontrast medium administration

Diagnosis	*n*	P0	P1	P2	P3	P4
AML	26	16	3	4	3	—
RCC	11	—	—	—	4	7
Pseudotumor	3			Not applicable		
Metastasis	1	—	—	—	—	1

AML, angiomyolipoma; RCC, renal cell carcinoma; P0, no signal pattern, indicating no detectable vessels; P1, intratumoral focal pattern, indicating persistent focal color flow signal (spotty or linear) reproducibly detected within the lesion, not extended to the margins; P2, penetrating pattern, indicating that blood vessels arose outside the lesion and coursed toward the center; P3, peripheral pattern, indicating that blood vessels arose outside the lesion and surrounded it; P4, mixed penetrating and peripheral patterns (P2 + P3)

Table 2. Vascular patterns with power Doppler after echocontrast medium administration

Diagnosis	*n*	P0	P1	P2	P3	P4
AML	26	8	9	3	—	6
RCC	11	—	—	—	2	9
Pseudotumor	3			Not applicable		
Metastasis	—	—	—	—	—	1

AML, angiomyolipoma; RCC, renal cell carcinoma; P0, no signal pattern, indicating no detectable vessels; P1, intratumoral focal pattern, indicating persistent focal color flow signal (spotty or linear) reproducibly detected within the lesion, not extended to the margins; P2, penetrating pattern, indicating that blood vessels arose outside the lesion and coursed toward the center; P3, peripheral pattern, indicating that blood vessels arose outside the lesion and surrounded it; P4, mixed penetrating and peripheral patterns (P2 + P3)

cases (76%) and indeterminate diagnoses for 10 of 41 (24%; Table 3). The combination of gray-scale and unenhanced power Doppler US findings allowed for the correct diagnoses in 24 of 26 AMLs (23 with power Doppler, one with B-mode, five with power Doppler and B mode combined), seven of 11 RCCs (with B mode), and one of three pseudotumors (with power Doppler). We found a significant difference between the diagnostic accuracy of gray-scale US and that of gray-scale and power Doppler US combined ($p < 0.05$).

The use of echo-enhancing contrast medium allowed for correct diagnoses in 21 AMLs (20 with power Doppler, one with B mode, five with power Doppler and B mode combined), seven RCCs (with B mode), and three pseudotumors (with power Doppler).

Discussion

US is sensitive but not specific enough for the identification of renal nodular lesions. Its echogenicity has not been adequate to show definitive tissue characterization [1, 2, 7, 10]. Although hypoechoic and isoechoic lesions are found to be malignant in a high percentage of cases, thus requiring further CT examination, even hyperechoic solid lesions, typically considered AMLs in the past, need further evaluation to exclude a small RCC. Forman et al. showed that 77% of small RCCs present variable degrees of echogenicity, whereas 32% are hyperechoic so as to mimic AMLs [5]. Conversely, Jinzaki et al. reported that AMLs containing a small amount of fat often appear as iso- or moderately hyperechoic on US [3].

Several gray-scale US features have been advocated for the differential diagnosis of solid renal lesions. Some investigators have reported that an anechoic rim, intratumoral cyst, or shadowing on an hyperechoic renal mass are important findings that might to distinguish RCC from AML. However, the usefulness of these findings for differential diagnosis is not well established [7, 8]. Our series confirms those observations: those characteristics were found in only 13 of 41 hyperechoic nodules, so the percentage of correct diagnoses was extremely small (32%).

The low specificity of gray-scale US has been improved considerably with the use of power Doppler, a recent technique based on total integrated power rather than the direction and velocity of the color Doppler signal [17, 18]. This technique has improved the sensitivity of US to low flow and, because of its dynamic range and relative angle independence, provided better delineation of tortuous vessels, thus increasing its accuracy in predicting the likelihood of benign versus malignant small renal nodules. However, US power Doppler detection of parenchymal blood flow in deep organs, in the presence of abdominal gas or motion artifacts, remains difficult.

Ultrasound contrast agents have further improved the ability of power Doppler to distinguish intrarenal vascularity from interlobar vascularity up to the interlobular arteries and veins. Levovist is a suspension of galactose microparticles stabilized with palmitic acid. The microbubbles measure 2–8 μm in diameter, can traverse the pulmonary capillary bed, and are nontoxic and biodegradable. It increases the amplitude of the echo by about 10^{10}-fold compared with the echo rising from a red cell [6,14,16].

In our series, angiopatterns 0–2 were typical of AML, thereby confirming the observations of Jinzaki et al. [13]. This vascular model is therefore characteristic of benign lesions. The high percentage of avascular AMLs in our series (pattern 0: 16 on basal power Doppler, eight on enhanced power Doppler) versus the series of Jinzaki et al. is probably due to the higher number of lesions smaller than 1 cm, in which vascularity is not easily detectable. On power Doppler, all malignant lesions showed patterns 3 and 4; however,

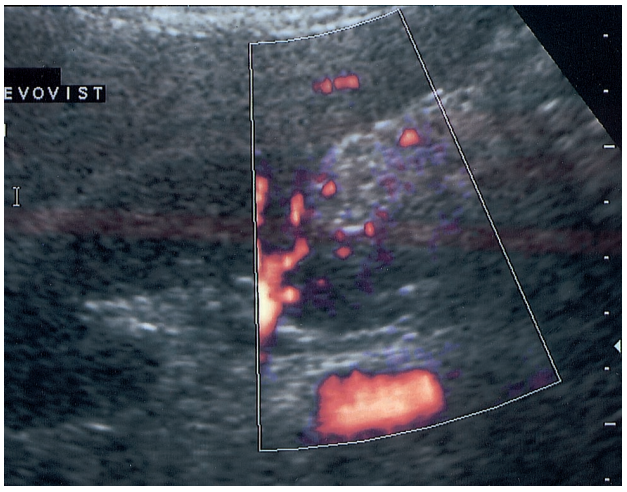

Fig. 1. A 42-year-old woman with angiomyolipoma. US power Doppler sagittal scan of the right kidney after Levovist administration shows a 2-cm hyperechoic lesion containing some colored spots (pattern 1).

these patterns cannot be considered specific for malignancy because they characterized a small percentage of highly vascularized AMLs (21%). Combining gray-scale and power Doppler findings significantly increased our diagnostic accuracy, with 78% correct diagnoses versus 32% when using only gray-scale US.

In our study, the use of US contrast agent did not increase the diagnostic accuracy of power Doppler; in fact, the characterization of two pseudotumors not sufficiently distinguished on unenhanced power Doppler was counterbalanced by the characterization of three AMLs with peripheral and afferent vascularity that were considered indeterminate after administration of echo-enhancing contrast medium. Contrast medium in the evaluation of renal focal lesions was useful for the differential diagnosis between pseudotumor and neoplasm.

Renal pseudotumors caused by hypertrophic column of Bertin, fetal lobulation, or dromedary or splenic humps

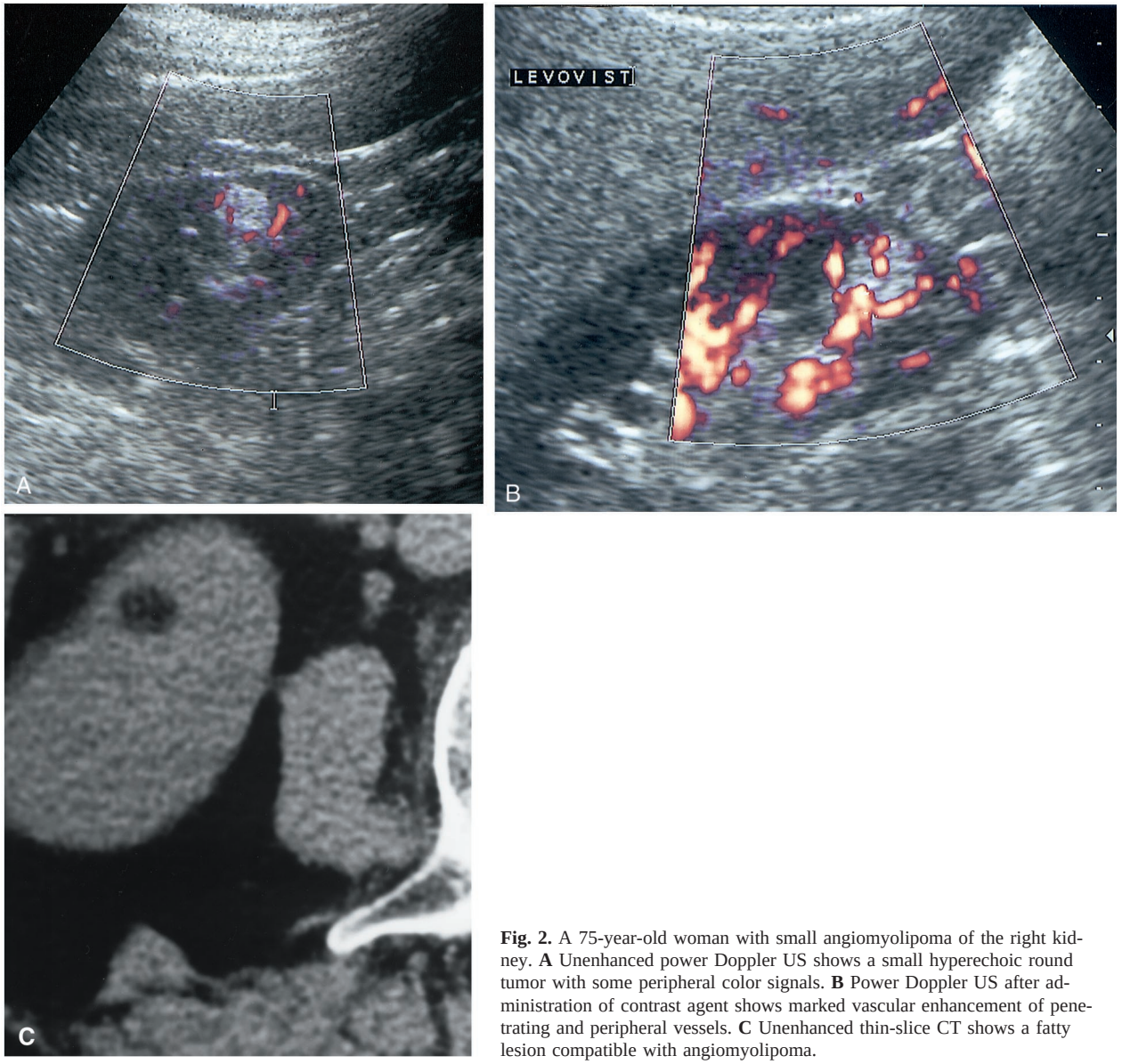

Fig. 2. A 75-year-old woman with small angiomyolipoma of the right kidney. **A** Unenhanced power Doppler US shows a small hyperechoic round tumor with some peripheral color signals. **B** Power Doppler US after administration of contrast agent shows marked vascular enhancement of penetrating and peripheral vessels. **C** Unenhanced thin-slice CT shows a fatty lesion compatible with angiomyolipoma.

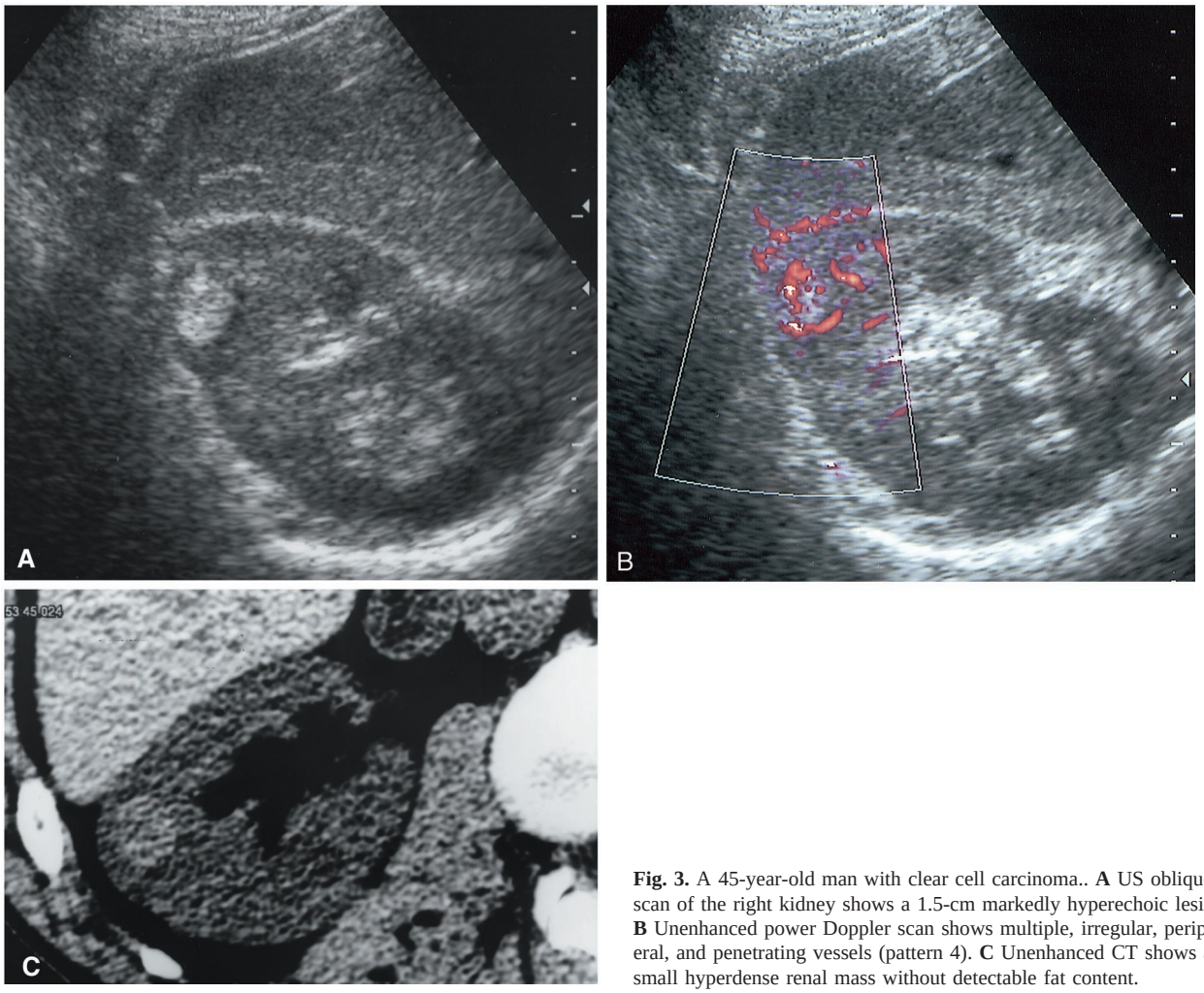

Fig. 3. A 45-year-old man with clear cell carcinoma.. **A** US oblique scan of the right kidney shows a 1.5-cm markedly hyperechoic lesion. **B** Unenhanced power Doppler scan shows multiple, irregular, peripheral, and penetrating vessels (pattern 4). **C** Unenhanced CT shows a small hyperdense renal mass without detectable fat content.

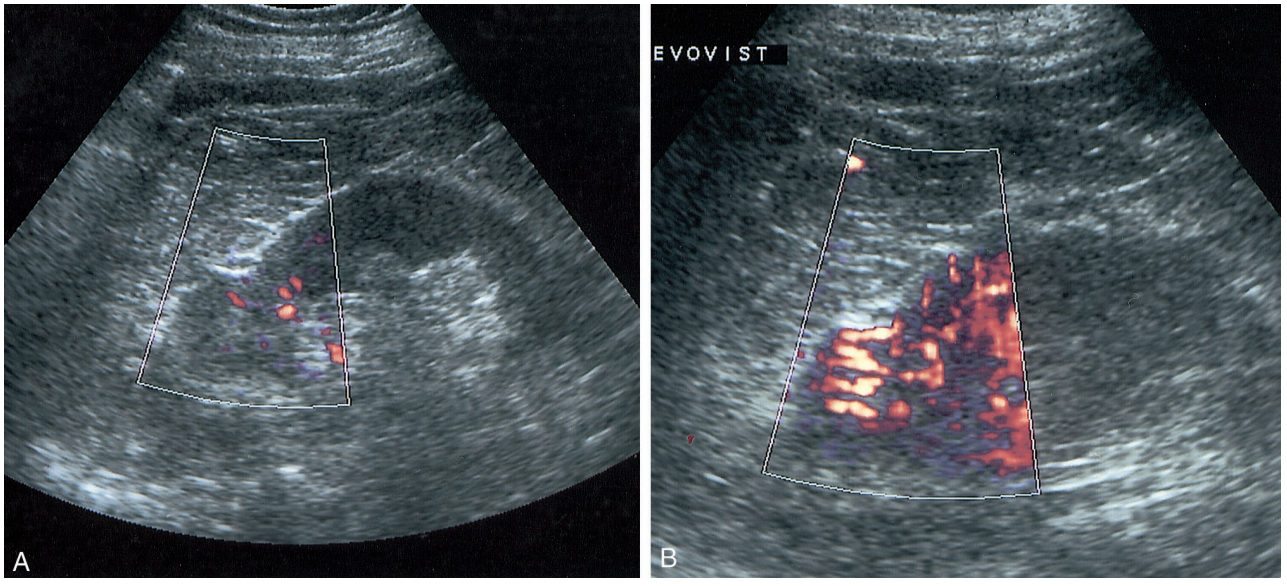

Fig. 4. A 51-year-old man with persistent fetal lobulation. US longitudinal scan of the left kidney shows a slightly hyperechoic nodule in the upper pole. **A** The poor vascularity depicted on basal power Doppler is not sufficient to confidently exclude a neoplasm. **B** Power Doppler study after infusion of Levovist shows smooth and homogeneous branching vessels throughout the mass, for a diagnosis of persistent fetal lobulation (confirmed by successive CT examinations, not shown).

Table 3. Hyperechoic lesions: percentage of diagnostic accuracy

Hyperechoic renal lesions	B mode	Power Doppler	Power Doppler MDC	B mode + power Doppler	B mode + power Doppler MDC
Correct diagnosis	32%	59%	56%	78%	76%
Indeterminate diagnosis	68%	41%	44%	22%	24%

are frequent anatomic variations that can simulate an expanding lesion as an RCC [19]. Echo-enhancing contrast agent clarifies the appearance of normal intraparenchymal vascularity, which is the basis of a diagnosis of renal pseudotumor on power Doppler [6, 13, 14].

In the three pseudotumors of our series (one persistent fetal lobation, two hypertrophic column of Bertin), we observed a characteristic vascular pattern not comparable to that of nodular lesions. Pseudotumors presented the same vascularity of normal surrounding parenchyma, without features of penetrating or peripheral vessels. In two cases, this was evident only on enhanced power Doppler because of the poor vascularity visible on unenhanced power Doppler.

Most investigators agree that CT should be used in all cases of renal nodular hyperechoic lesions. However, in routine practice, this recommendation is questionable for small asymptomatic lesions [9]. Correct radiologic diagnosis of AML can be made by the identification of intralesional fat density on thin-slice CT or the depiction of adipous signal within the tumor on T1-weighted MRI. Cases of AML without evident adipous components and cases of RCC with foci of adipous degeneration have been described in the literature [20, 21]. Our experience suggests that power Doppler is very useful in the differential diagnosis between AML and RCC because it significantly increased diagnostic accuracy.

When hyperechoic homogeneous lesions are smaller than 3 cm, have no or poor vascularity, and appear as pattern 1 or 2, AML is a reasonable diagnosis and a follow-up can be arranged for the patient. Hyperechoic nodular lesions with extremely tortuous penetrating and/or peripheral vessels (patterns 3 and 4) are strongly suggestive of malignancy and, although rarely caused by hypervascularized AMLs, should always be confirmed with enhanced CT.

In our series, the use of contrast agent did not increase the diagnostic accuracy of unenhanced power Doppler in the differential diagnosis of hyperechoic renal lesions. However, our study evaluated only the vascular phase when comparing power Doppler findings before and after contrast agent administration for the differential diagnosis of hyperechoic renal lesions. Nonetheless, it seems likely that useful information can be derived from the use of pulse inversion with harmonics and pulse interval delay in the parenchymal phase.

In conclusion, our work confirms the results of Jinzaky et al. [13] by demonstrating that the combination of gray-scale and power Doppler US is the best diagnostic approach in the diagnosis of hyperechoic renal masses. Levovist may be useful in the characterization of suspicious pseudotumors in which the number of detectable vessels on unenhanced power Doppler cannot confidently exclude a neoplasm.

References

1. Bosniak M. Problematic renal masses. In: McClennan BL. *Syllabus: a categorical course in genitourinary radiology*. St. Louis: Mosby, 1994:183–191
2. Bosniak M, Rofsky NM. Problems in the detection and characterization of small renal masses. *Radiology* 1996;198:638–641
3. Jinzaki M, Tanimoto A, Narimatsu Y, et al. Angiomyolipoma: imaging findings in lesions with minimal fat. *Radiology* 1997;205: 497–502
4. Zagoria RJ, Dyer RB. The small renal mass: detection, characterization and management. *Abdom Imaging* 1998;23:256–265
5. Forman HP, Middleton WD, Melson GL, et al. Hyperechoic renal cell carcinoma: increase in detection at US. *Radiology* 1993;188: 431–434
6. Robbin ML. The promise of sonographic contrast agents in the kidney. In: Nanda NC, Schlief R, Goldber B, eds. *Advances in echo imaging using contrast enhancement*. Dubai: Kluwer Publishers, 1997:525–541
7. Siegel CL, Middleton WD, Teefey SA, et al. Angiomyolipoma and renal cell carcinoma: US differentiation. *Radiology* 1996;198:789–793
8. Yamashita Y, Ueno S, Makita O, et al. Hyperechoic renal tumors: anechoic rim and intratumoral cysts in US differentiation of renal cell carcinoma from angiomyolipoma. *Radiology* 1993;188:179–182
9. Mindell HJ. Question and answer. *AJR* 1996;167:1590
10. Curry NS. Small renal masses (lesions small than 3 cm): imaging evaluation and management. *AJR* 1995;164:355–362
11. Davidson AJ, Hartman DS, Choyke PL, et al. Radiologic assesment of renal masses: implications for patient care. *Radiology* 1997;302: 297–305
12. Smith SJ, Bosniak MA, Megibow AJ. Renal cell carcinoma: earlier discovery and increased detection. *Radiology* 1989;170: 699–703
13. Jinzaki M, Ohkuma K, Tanimoto A, et al. Small solid renal lesions: usefulness of power Doppler US. *Radiology* 1998;209: 543–550
14. Correas JM, Helenon O, Moreau JF. Contrast-enhanced ultrasonography of native and transplanted kidney diseases. *Eur Radiol* 1999; 9(suppl 3):394–400
15. Maresca G, Summaria V. De Gaetano A, et al. Masse renali. *Radiol Med* 1998;95:(suppl 1):59–63
16. Schwarz KQ, Bezante GP, Becher H, et al. Efficacy SH U 508 (Levovist) as blood pool enhancer in the Doppler evaluation of multiple vascular regions. *Radiol Med* 1994;87(suppl 1):3–14
17. Bude RO, Rubin JM, Adler RS. Power versus conventional color Doppler sonography: comparison in the depiction a normal intrarenal vasculature. *Radiology* 1994;192:777–780

18. Rubin JM. Power Doppler. *Eur Radiol* 1999;9(suppl 3):318–322
19. Lafortune M, Constantin A, Breton A, et al. Sonography of the hypertrophied column of Bertin. *AJR* 1986;146:53–56
20. Hammadeh MY, Thomas K, Philp T, Singh M. Renal cell carcinoma containing fat mimicking angiomyolipoma: demonstration with CT scan and histopathology. *Eur Radiol* 1998;8:228–229
21. Helenon O, Chretien Y, Paraf F, et al. Renal cell carcinoma containing fat: demonstration with CT. *Radiology* 1993;188:429–430