

# Incidental Adrenal Lesions: Accuracy of Characterization with Contrast-enhanced Washout Multidetector CT—10-minute Delayed Imaging Protocol Revisited in a Large Patient Cohort<sup>1</sup>

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## Purpose:

To reassess the accuracy of the 10-minute delayed scan to differentiate both lipid-rich and lipid-poor lesions in a large cohort of patients.

## Materials and Methods:

This HIPAA-compliant retrospective study had institutional review board approval; the need for informed consent was waived. A multidetector computed tomography (CT) adrenal protocol (unenhanced, dynamic contrast material-enhanced, and 10-minute delayed CT) was used in 314 consecutive patients (201 women, 113 men; mean age, 63.6 years) for the period from January 2006 through February 2009. The mean adrenal attenuation during all three CT phases was measured by two readers, and the relative percentage washout (RPW) and absolute percentage washout (APW) values were calculated. APW and RPW receiver operating characteristic (ROC) analysis was performed to evaluate the strength of the tests.

## Results:

There were 323 adrenal lesions (213 left, 110 right) consisting of 307 adenomas and 16 nonadenomas. The sensitivity, specificity, and accuracy for the RPW test at a washout threshold of 50% were 55.7%, 100%, and 57.9%, respectively; at 40% were 76.9%, 93.7%, and 77.7%; and at 35% were 81.4%, 93.7%, and 82.0%. The sensitivity, specificity, and accuracy for the APW test at a 60% threshold were 52.1%, 93.3%, and 54.0%, respectively; at 55% were 62.5%, 93.3%, and 64.0%; and at 50% were 71.3%, 80.0%, and 71.7%. Areas under the ROC curve were 0.85 (95% confidence interval: 0.75, 0.95) and 0.91 (95% confidence interval: 0.85, 0.97) for the APW and RPW tests, respectively, to detect adenomatous disease.

## Conclusion:

The 10-minute delayed adrenal enhancement washout test has reduced sensitivity for the characterization of adrenal adenomas compared with results from prior studies.

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**A**drenal lesions commonly are depicted at computed tomography (CT)—approximately 5% in most series (1). CT is effective at characterizing many of these lesions, which is particularly important in patients with an underlying malignancy, to exclude or identify metastatic disease. Although unenhanced CT is useful for differentiating lipid-rich benign lesions from lipid-poor lesions (2,10), most lipid-poor lesions remain indeterminate, and further tests are required to characterize this lesion subset. More recent interest has focused on the use of delayed contrast material-enhanced washout tests that appear to be highly accurate in characterizing both lipid-rich and lipid-poor lesions (3–8). For purposes of an adrenal washout analysis, three sets of images are acquired. The unenhanced series is followed by administration of intravenous contrast material, and a dynamic series (or contrast-enhanced series) is then acquired. After a finite delay period, a final series of delayed images are acquired. From these three series, the absolute percentage washout (APW) and relative percentage washout (RPW) can be derived by using a set formula (3). Both unenhanced and delayed contrast-enhanced washout CT images have been used with variable accuracy for the characterization of incidentally detected adrenal lesions (3–5,8), with adenomas exhibiting rapid contrast material washout, whereas nonadenomas

tend to wash out more slowly. However, controversy exists as to whether to use 10- or 15-minute contrast-enhanced delayed imaging to calculate the washout fraction.

Korobkin et al (8) initially studied a variety of delay times, from 5 to 15 minutes, finally choosing 15-minute delayed imaging as most appropriate, on the basis of the results of their study, for the differentiation of adenomas from nonadenomas. By using a similar protocol, Caoili et al (3), also using a 15-minute delay, went one step further and reported high test sensitivity and specificity for the characterization of both lipid-poor and lipid-rich adenomas from nonadenomatous disease. In an attempt to modify the delayed contrast-enhanced CT protocol to address busy CT schedules, Peña et al (7) used a 10-minute delayed imaging protocol and also reported high test sensitivity and specificity for differentiation of adenomatous from nonadenomatous disease. However, they used a 50% RPW threshold rather than the 40% as recommended in previous studies in which 15-minute delayed protocols were used. In a similar study, Blake et al (4), using a multidetector CT scanner, also studied a 10-minute delayed imaging protocol and confirmed high test accuracy by using this reduced imaging delay, but at an RPW threshold of 37.5%.

However, some authors believe that 10-minute delayed imaging may not give sufficient time for contrast material to wash out from benign adrenal lesions, a necessary prerequisite for characterizing adenomatous disease (3,5,8). Others believe 10-minute, or even 5-minute, delayed imaging is accurate and more convenient for busy CT schedules (4,7,9). Given the controversy, the purpose of this study, therefore, was to reassess

the accuracy of the 10-minute delayed scan to differentiate both lipid-rich and lipid-poor lesions in a large cohort of patients.

## Materials and Methods

This retrospective study was approved by our institutional review board. The requirement for informed consent from study patients was waived. This study also complies with the Health Insurance Portability and Accountability Act.

## Patients

We performed an electronic search by using our picture archiving and communication system (Impax; Agfa-Gevaert, Mortsel, Belgium) to determine all patients who had undergone dedicated adrenal unenhanced, dynamic contrast-enhanced, and 10-minute delayed CT in an attempt to characterize adrenal lesions that were detected incidentally at CT performed for other clinical reasons during the period from January 2006 through February 2009. All patients who undergo dedicated renal and/or adrenal washout CT in our institution have their results coded on our picture archiving and communication system as “CTAB&,” which was therefore used to perform the database search. Patients with studies coded as “CTAB&” within the recruitment period numbered 849. Patients with renal studies ( $n = 473$ ) and

## Advances in Knowledge

- Ten-minute delayed multidetector CT adrenal washout tests have reduced accuracy compared with results from prior studies; overall test accuracy at 40% threshold was 77.7% (251 of 323) according to our study results.
- Test sensitivity of 76.8% (236 of 307) is insufficient to be useful in routine clinical practice.
- Test specificity of 93.7% (15 of 16) remains acceptable, confirming that washout tests can be useful for differentiating nonadenomatous from adenomatous disease.

## Implication for Patient Care

- The 10-minute delayed imaging multidetector CT adrenal protocol demonstrates inferior sensitivity compared with results from previous studies in which 10- or 15-minute delayed imaging of the adrenal gland was used.

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## Abbreviations:

APW = absolute percentage washout  
ROC = receiver operating characteristic  
RPW = relative percentage washout

## Author contributions:

Guarantors of integrity of entire study, M.J.S., G.W.L.B.; study concepts/study design or data acquisition or data analysis/interpretation, all authors; manuscript drafting or manuscript revision for important intellectual content, all authors; manuscript final version approval, all authors; literature research, M.J.S., G.W.L.B., M.A.B.; clinical studies, G.W.L.B.; statistical analysis, M.J.S., G.W.L.B., E.F.H.; and manuscript editing, M.J.S., G.W.L.B., M.A.B., P.F.H.

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adrenal studies with no reference standard ( $n = 25$ ) were excluded (Fig 1). A multidetector CT adrenal protocol was used in 314 consecutive patients (201 women, 113 men; mean age for men, 63.1 years  $\pm$  13.5 [standard deviation]; age range, 27–88 years; mean age for women, 63.9 years  $\pm$  12.8; age range, 32–95 years; mean overall age, 63.6 years  $\pm$  13.1; overall age range, 25–95 years) during the study.

### Reference Standard

Adenomas were confirmed if they were less than 10 HU at unenhanced CT or demonstrated stability in size for 6 months or longer according to the multiple previous studies in which these criteria were used as the standard of reference (2–5,7,8). Similarly, the well-reported criteria for determination of nonadenomatous disease were used and defined by means of interval growth at serial CT (2–5,7,8) or were confirmed by means of histopathologic results (surgery or percutaneous biopsy). Myelolipomas and cysts were excluded from this study according to previously published diagnostic criteria (11).

Proof of diagnosis was adrenal attenuation less than 10 HU at unenhanced CT (173 lesions), follow-up imaging results (131 lesions: 126 adenomas, five nonadenomas), or by means of histologic findings (19 lesions: eight adenomas, 11 nonadenomas). Nonadenomas included 13 metastases, with eight proved by means of histopathologic findings (lung cancer [ $n = 3$ ], breast cancer [ $n = 1$ ], colon cancer [ $n = 1$ ], malignant melanoma [ $n = 1$ ], lymphoma [ $n = 1$ ], and unknown primary tumor [ $n = 1$ ]) and five other metastases proved at follow-up imaging (lung cancer [ $n = 2$ ], breast cancer [ $n = 1$ ], lymphoma [ $n = 1$ ], and unknown primary tumor [ $n = 1$ ]). Of these, three patients had bilateral disease (lymphoma, metastatic breast cancer, and unknown primary tumor). There were also three other nonadenomas—two pheochromocytomas and one ganglioneuroma—with all three confirmed by means of histopathologic findings.

### CT Technique

Multidetector CT images were obtained with one of four CT scanners; 43 patients

underwent imaging with an eight-section scanner (LightSpeed Ultra; GE Healthcare, Milwaukee, Wis), 224 patients underwent imaging with a 16-section scanner (LightSpeed 16; GE Healthcare), 39 patients underwent imaging with a 64-section scanner (LightSpeed VCT; GE Healthcare), and eight patients underwent imaging with a 64-section scanner (Somatom Definition; Siemens Medical Solutions, Ann Arbor, Mich). Unenhanced and contrast-enhanced images were obtained by using variable tube current (150 mA maximum of scanner depending on patient size) and 120 kVp. Scans were performed with a pitch of 1 to 1.5, rotation time of 0.5 to 0.8 second, section thickness of 2.5 mm, and standard reconstruction algorithm. Dynamic scanning was performed after a 75-second delay from the beginning of the bolus administration of the intravenous contrast agent. Each patient received 100 mL of a contrast agent with 370 mg of iodine per milliliter (iopamidol 76%, Isovue 370; Bracco Diagnostics, Princeton, NJ) at a rate of 3 mL/sec with a power injector (MEDRAD, Warrendale, Pa). Delayed imaging was restricted to the upper abdomen and was performed 10 minutes after the initial administration of the bolus by using the same imaging parameters and without moving the patient's position on the scanning table.

### Imaging Analysis

For adrenal lesion attenuation measurements, a circular or elliptical region of interest was placed centrally over the lesion to occupy at least two-thirds of the adrenal gland on the transverse image to reduce the effect of noise, and the mean of two attenuation values was recorded by two readers by means of consensus (G.W.L.B., with 18 years of adrenal imaging experience and M.J.S., with 2 years of adrenal imaging experience) on two separate occasions 6 weeks apart. Similar regions of interest were placed over the same region on both the dynamic and delayed images at the same sitting to determine any increase in attenuation (wash-in) and the absolute and relative percentage loss of enhancement (washout) for each lesion.

Figure 1

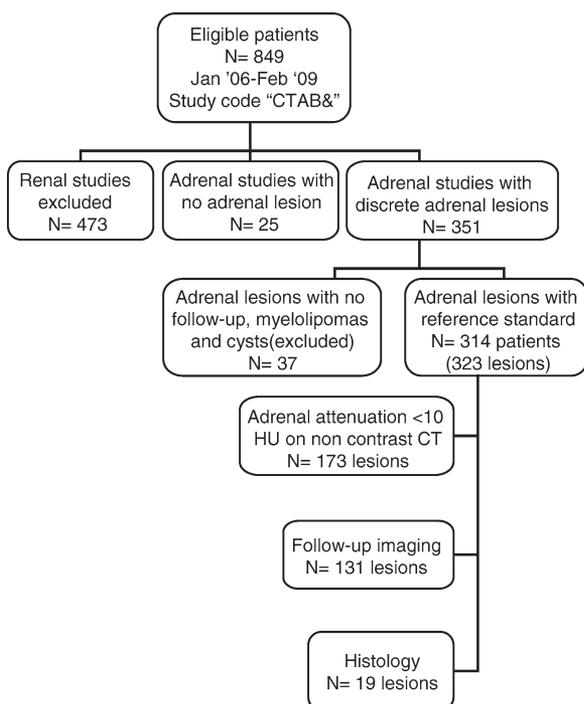


Figure 1: Flowchart shows the inclusion and exclusion criteria adopted for our study.

If identified, cystic, calcified, necrotic, and hemorrhagic areas were excluded from the region of interest. Lesion size was calculated along its long axis on the transverse data set. Average lesion size was determined separately for adenomas and nonadenomas.

From the attenuation values recorded on the unenhanced, dynamic, and delayed images, APW and RPW were calculated by means of the following formulas (3):  $APW = (\text{enhanced} - \text{delayed}) / (\text{enhanced} - \text{unenhanced}) \times 100\%$  and  $RPW = (\text{enhanced} - \text{delayed}) / \text{enhanced} \times 100\%$ .

### Statistical Analysis

Sensitivity, specificity, and accuracy were calculated at 50%, 40%, 37.5%, 35%, and 30% washout thresholds for RPW and 60%, 55%, and 50% washout thresholds for APW. Binormal receiver operating characteristic (ROC) analysis for calculating the area under the ROC curve was performed for the APW and RPW tests by using statistical software (DBM MRMC 2; University of Iowa, Iowa City, Iowa). Subsequently, sensitivity and specificity also were calculated separately for lipid-rich and lipid-poor adenomatous lesions.

For purposes of the ROC, one non-adenoma was excluded from the analysis because it did not enhance at contrast-enhanced CT, so the APW value was not calculable. This was a metastatic adrenal lesion from an unknown primary lesion, determined by means of a sudden rapid increase in size at follow-up CT.

### Results

In the 314 patients, 323 adrenal lesions (213 left, 110 right) were detected. Three hundred seven lesions were adenomas (mean size, 2.0 cm  $\pm$  0.8; size range, 0.9–5.1 cm), and 16 were non-adenomas (mean size, 3.1 cm  $\pm$  1.2; size range, 2.8–5.8 cm). The mean attenuation for all adenomas (lipid rich and lipid poor) at unenhanced CT was 10 HU (range, –22.5 to 47 HU). The mean unenhanced CT attenuation for nonadenomatous disease was 31 HU (range, 11–43 HU). One hundred

seventy-three of all 323 lesions were lipid rich at unenhanced CT, and 150 were lipid poor. Therefore, of the 307 adenomas, 173 (56.4%) were lipid rich, and 134 (43.6%) were lipid poor.

The sensitivity and specificity of the RPW test to detect both lipid-rich and lipid-poor adenomas are listed in Table 1. Test sensitivity and specificity at a washout threshold of 50% were 55.7% (171 of 307) and 100% (16 of 16), respectively, and at 30% were 86.9% (267 of 307) and 87.5% (14 of 16), respectively (Table 1). The APW test sensitivity and specificity with a washout threshold of 60% were 52.1% (160 of 307) and 93.3% (14 of 15), respectively, and at 50% APW threshold were 71.3% (219 of 307) and 80.0% (12 of 15), respectively (Table 2). Binormal ROC analysis revealed areas under the ROC curve for the APW and RPW tests to characterize adenomatous disease as 0.85 (95% confidence interval: 0.75, 0.95) and 0.91 (95% confidence interval: 0.85, 0.97), respectively (Figs 2, 3).

If adenomatous lesions were to be differentiated according to their lipid content, the sensitivity and specificity for detecting lipid-rich lesions at an APW of 60% were 62.4% and 93.3%, respectively, whereas for lipid-poor lesions they were 38.8% and 93.3%, respectively (Table 3). For a 50% RPW threshold, the sensitivity and specificity to detect lipid-rich lesions were 75.1% and 100%, respectively, whereas for lipid-poor lesions they were 26.7% and 100%, respectively. At a 40% RPW threshold, the test demonstrated a sensitivity and specificity for detecting lipid-rich lesions of 90.9% and 93.7%,

respectively, whereas corresponding values for lipid-poor lesions were 59.0% and 93.7%, respectively. The APW and RPW values for lesions imaged with eight-, 16-, and 64-section scanners are demonstrated in Tables E1–E6 (online).

### Discussion

To our knowledge, Krestin et al (12) were the first to notice on contrast-enhanced magnetic resonance images that adenomatous and nonadenomatous adrenal lesions might be differentiated on the basis of their contrast-enhanced washout characteristics. Korobkin et al (8) noticed a similar phenomenon at CT and observed that nonadenomatous adrenal lesions, for a relatively short period (5–15 minutes), tended to retain a greater proportion of injected intravenous contrast material within the adrenal glands compared with that in adenomatous lesions. In other words, the injected intravenous contrast material washes out less rapidly from non-adenomatous lesions than from benign adenomatous lesions, at least for a limited time. Since the study by Korobkin et al (8), results from multiple studies (3–5,7) indicate the ability of CT washout tests to be used for differentiating adrenal adenomas from nonadenomas. This washout is either expressed as relative—the ratio of the attenuation of the adrenal gland at delayed CT to the attenuation at dynamic CT—or absolute by taking into account the attenuation of the adrenal gland at unenhanced CT. Applying a percentage washout threshold to the data set makes it possible to determine an optimal level that permits

**Table 1**

#### Sensitivity, Specificity, and Accuracy of the Washout Test for Adenomas at the RPW Threshold Values

Threshold RPW (%)	Sensitivity (%)	95% CI for		Accuracy (%)
		Sensitivity	Specificity (%)	
50	55.7 (171/307)	49, 61	100 (16/16)	57.9 (187/323)
40	76.8 (236/307)	71, 81	93.7 (15/16)	77.7 (251/323)
37.5	79.1 (243/307)	74, 83	93.7 (15/16)	79.8 (258/323)
35	81.4 (250/307)	76, 85	93.7 (15/16)	82.0 (265/323)
30	86.9 (267/307)	82, 90	87.5 (14/16)	86.9 (281/323)

Note.—Numbers in parentheses are raw data. CI = confidence interval.

sufficient sensitivity and specificity for the test to be useful (8).

Any imaging test used to help differentiate adenomas from nonadenomatous disease needs to be highly specific in order not to make a diagnosis of benignity in error. On the other hand, although high test sensitivity for detection of adenomatous disease is less critical, it still needs to be sufficiently high for the test to be useful. Results from previous unenhanced CT studies indicated the sensitivity for differentiating

adenomas from nonadenomas was approximately 70% because as many as 30% of adenomatous lesions were considered lipid poor (2). Although this test was useful, its sensitivity generally was considered too low because further tests were required to characterize lipid-poor lesions. On the other hand, CT washout tests are more useful because they are highly sensitive, with a reported range of 96% to 100% (3–5,7,8).

However, the exact sensitivity or specificity threshold that has been used

varies from study to study primarily because of the variable time delay used for the delayed scan across studies. Most investigators used a 15-minute delayed imaging protocol with an RPW of 40% and reported sensitivity and specificity of 83% and 93%, respectively, to detect adenomatous disease and an APW of 60% with a reported sensitivity and specificity of 88% and 96%, respectively (3,5,7). In other words, this test can be used to discriminate adenomas from nonadenomas effectively. However, other investigators used 10-minute delayed imaging, believing that this work-flow modification is more conducive to busy CT schedules (4,6,7). Results from a study by Peña et al (7), with 61 adenomatous and 40 nonadenomatous lesions, demonstrated sensitivity and specificity of 98% and 100%, respectively, for this test for differentiating adenomatous from nonadenomatous disease, but at a 50% RPW threshold. This 50% washout threshold at 10-minute imaging seems counterintuitive compared with the established 40% level at 15-minute imaging. If

**Table 2**

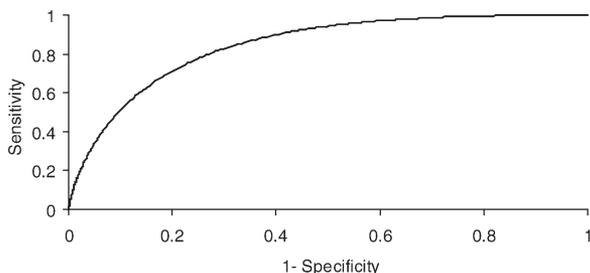
**Sensitivity, Specificity, and Accuracy of the Washout Test for Adenomas at the APW Threshold Values**

Threshold APW (%)	Sensitivity (%)	95% CI for		95% CI for Specificity	Accuracy (%)
		Sensitivity	Specificity (%)		
60	52.1 (160/307)	46, 57	93.3 (14/15)*	68.0, 99.8	54.0 (174/322)
55	62.5 (192/307)	56, 67	93.3 (14/15)*	68.0, 99.8	64.0 (206/322)
50	71.3 (219/307)	65, 76	80.0 (12/15)*	51.9, 95.7	71.7 (231/322)

Note.—Numbers in parentheses are raw data. CI = confidence interval.

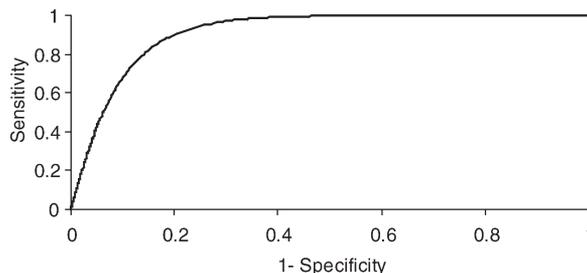
\* APW for one lesion was not calculable because the lesion did not enhance at contrast-enhanced CT, so this lesion was excluded from analysis.

**Figure 2**



**Figure 2:** ROC curve for APW values (area under the curve = 0.85) for detecting adenomatous disease.

**Figure 3**



**Figure 3:** ROC curve for RPW values (area under the curve = 0.91) for detecting adenomatous disease.

**Table 3**

**Sensitivity and Specificity of the Washout Test for Lipid-rich and Lipid-poor Adenomas**

Threshold Value	Lipid-rich Adenomas				Lipid-poor Adenomas			
	Sensitivity (%)	95% CI for Sensitivity	Specificity (%)	95% CI for Specificity	Sensitivity (%)	95% CI for Sensitivity	Specificity (%)	95% CI for Specificity
60% APW	62.4 (108/173)	40, 55	93.3 (14/15)*	68, 99	38.8 (52/134)	43, 60	93.3 (14/15)*	68, 99
50% RPW	75.1 (130/173)	64, 78	100 (16/16)	79, 99	30.6 (41/134)	19, 35	100 (16/16)	79, 99
40% RPW	90.8 (157/173)	85, 94	93.7 (15/16)	69, 99	59.0 (79/134)	49, 66	93.7 (15/16)	69, 99

Note.—Numbers in parentheses are raw data. CI = confidence interval.

\* APW for one lesion was not calculable because the lesion did not enhance at contrast-enhanced CT, so this lesion was excluded from analysis.

anything, the washout threshold for discriminating adenomatous from nonadenomatous disease should be lower because the test allows for less time on the delayed images for indeterminate adrenal lesions to indicate that they are adenomatous or nonadenomatous. This fact was emphasized by Blake et al (4), reporting on a smaller cohort of patients who underwent multidetector CT, who documented lower RPW and APW washout thresholds at 37.5% RPW and 52% APW thresholds on 10-minute delayed images. Controversy exists, therefore, as to not only what scanning delay to use but also what washout sensitivity threshold should be used for differentiating adenomatous from nonadenomatous disease effectively.

Our study results demonstrated that the 10-minute contrast-enhanced delayed adrenal protocol at multidetector CT provides poor test sensitivity (55.7%) for the detection of adenomas at the previously established RPW threshold of 50% by Peña et al (7). At this threshold, therefore, the test offered no advantages over unenhanced CT attenuation measurements, which, in this study, demonstrated a sensitivity of 56.4% to characterize adenomatous disease. Lowering the RPW threshold to 40% (as recommended when using 15-minute delayed protocols) improves the sensitivity to 76.9%, as might be expected, but is still likely too low to be sufficiently useful in clinical practice. Compared with the 37.5% threshold established by Blake et al (4), also using a similar 10-minute delayed multidetector CT protocol, the sensitivity for adenoma detection improved to 79.1% but was still far less than the 95% quoted in that study. When compared with the optimal 37.5% threshold as established by Blake et al, also using a similar 10-minute delayed multidetector CT protocol (4), the sensitivity and specificity for adenoma detection improved to 79.1% and 93.7%, respectively, but was still far less than the 95% sensitivity and 100% specificity quoted in that study. The reasons for this discrepancy are unclear but might be explained by the much larger number of patients in this series.

Washout tests also have been used to determine whether lipid-rich adenomas differ from lipid-poor adenomas with respect to their washout patterns. Caoili et al (3), using a 15-minute delayed imaging protocol, initially noted that there were similar APW washout patterns between lipid-rich and lipid-poor lesions. We also found no substantial APW differences between lipid-rich and lipid-poor adenomas, but test sensitivity for the 10-minute delayed study was significantly inferior to that of the 15-minute delayed study used by Caoili et al (3). These authors demonstrated an optimal APW threshold for both lipid-rich and lipid-poor adrenal adenomas of 60%, with corresponding sensitivity and specificity of 89% and 95%, respectively, for lipid-poor adenomas and of 79% and 95%, respectively, for lipid-rich adenomas. This finding is in contrast to our corresponding values of 64.2% and 93.3%, respectively, for lipid-rich adenomas and 38.8% and 93.3%, respectively, for lipid-poor adenomas at the same 60% threshold.

However, Caoili et al (3) reported that the RPW of lipid-rich lesions was significantly higher than that observed for lipid-poor lesions, an expected finding given that the RPW does not include the unenhanced adrenal attenuation in its calculation. This finding was confirmed in our study. At an RPW threshold of 40%, the sensitivity for detecting lipid-rich lesions was 90.8%, but only 59.0% for lipid-poor lesions. Caoili et al (3), however, described an optimal RPW value of 50% (rather than the usual 40%) for characterization of lipid-rich adenomas, demonstrating sensitivity of 93% and specificity of 98% with this threshold. The corresponding sensitivity for characterization of lipid-rich lesions calculated in our study was much lower at 75.1%, although specificity was high at 100%. At this RPW threshold, the sensitivity for lipid-poor lesion characterization was a dismal 30.6%, further emphasizing the different washout patterns previously observed between lipid-rich and lipid-poor adenomas. This finding also underlines the poor sensitivity findings from this study for differentiating adenomatous

from nonadenomatous disease. The lower sensitivity found in this study might be expected, however, given that the adrenal glands were imaged on average 5 minutes earlier compared with methods used in the previous studies in which the 15-minute delayed protocol was used. The earlier delayed imaging does not appear to permit sufficient washout time for adenomatous lesions to fully show. In short, we believe that the 10-minute delayed imaging protocol is not sufficiently sensitive to be routinely useful in clinical practice.

However, a 5-minute delayed imaging protocol was recommended more recently. Kamiyama et al (9) demonstrated that a combination of diagnostic parameters of the CT protocol yields diagnostic results comparable with those of longer scanning delays. The diagnostic parameters used by this group were tumor size, unenhanced attenuation, 35-second and 5-minute delayed enhanced attenuation, wash-in (the percentage increase in adrenal enhancement during early scanning) and washout attenuation, percentage enhancement washout ratio, and relative percentage enhancement washout. This group diagnosed adrenal adenomas with a sensitivity of 94% and accuracy of 96% by comparing the diagnostic values of these parameters.

Although our washout study is the largest, to our knowledge, performed to date, it has some limitations. First, patients underwent imaging with different multidetector CT scanners (Tables E1–E6 [online]). However, the adrenal CT protocol for each scanner was similar, and it has been demonstrated previously that attenuation measurements from different scanners demonstrate only minimal, nonclinically important, differences (13). Second, although it may be surmised that the 15-minute delay is more sensitive and accurate than the 10-minute delay, we could not compare the same lesions on 15-minute delayed images, which was considered impractical due to the additional radiation exposure to patients. Third, the sample size for nonadenomatous lesions was small, and further prospective data with more nonadenomatous lesions may be

required to reevaluate the specificity of the test. However, a previous relatively large study also had small numbers of nonadenomatous lesions (4). Furthermore, the prevalence of malignancy in incidental adrenal lesions in patients with no known malignancy is low, as demonstrated in a recent large study (1). Also, our study was designed primarily to confirm the sensitivity, rather than the specificity, of the 10-minute delayed washout studies to characterize adrenal adenomas. Although there was clustering of multiple lesions in some patients, the number was so small that we could not account for it in the modeling. As a result, our estimates of the sensitivity and specificity may be only approximate. It was not possible to perform a post hoc analysis to determine if the number of detectors (or scanner types) affected the ability to evaluate adrenal lesions because of underpowering (Tables E1–E6 [online]).

A further limitation was that serial growth or stability of lesions at follow-up imaging was considered characteristic of adenomas or nonadenomatous disease. Also, a mean attenuation less than 10 HU at unenhanced CT was used to characterize lipid-rich benign disease from indeterminate disease (including lipid-poor adenomas). However, the use of these criteria is now well established clinically and has been used routinely in multiple previous imaging studies to characterize adrenal lesions (2–5,7,8,14–21). Finally, different concentrations and volumes of intravenous contrast material were used in this study compared with those used in some prior studies. However, investigators in most of these previous studies used variable iodine concentrations and volumes, so it is therefore unlikely that our use of 100 mL of 370 mg of iodine per milliliter had any substantial effect on the results.

In conclusion, the 10-minute delayed adrenal enhancement washout tests have reduced sensitivity for the detection of adenomas compared with

results from prior studies, and the test sensitivity appears to be clinically suboptimal. This finding might be explained by insufficient time for the intravenous contrast material to wash out from benign lesions.

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