Alexandria Journal of Medicine (2014) 50, 345–358

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Alexandria Journal of Medicine

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Diagnostic value of delayed washout rate of contrast-enhanced multi-detector computed tomography in adrenal incidentalomas

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Received 24 September 2013; accepted 21 November 2013
Available online 18 December 2013

KEYWORDS

Washout;
Multi-detector computed tomography;
Adrenal incidentalomas

Abstract *Introduction:* Most adrenal incidentalomas are benign non-hyperfunctioning adenomas which can be categorized as lipid-rich or lipid-poor. An adrenal CT post-contrast delayed washout study may differentiate adenomas from other adrenal neoplasms.
Aim of the work: To evaluate the role of MDCT in detecting adrenal incidentalomas with assessment of the diagnostic value of 15-min delayed washout rate in the differentiation of these incidentally detected adrenal lesions.
Materials and methods: Sixty-four patients with adrenal incidentaloma were enrolled in this study that was carried out in the period from January 2010 to January 2013. The mean attenuation values of adrenal masses were measured in the pre-contrast, post-contrast venous and delayed enhanced phases in addition to estimation of 15-min delayed washout rate. The relative percentage washout (RPW) and absolute percentage washout (APW) values were calculated. The receiver operating characteristic (ROC) curve analysis was performed to evaluate the accuracy of different MDCT phases at optimal cut-off values for diagnosis of adrenal incidentalomas.
Results: The detected incidentalomas included 46 adenomas and 18 non-adenomas. The accuracy of the RPW at a washout threshold of $\geqslant 40\%$ was 98.9%, and the accuracy of APW at a washout threshold of $\geqslant 60\%$ was 99%.

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Peer review under responsibility of Alexandria University Faculty of Medicine.

http://dx.doi.org/10.1016/j.ajme.2013.11.005

Conclusion: The 15-min delayed washout MDCT could be a valuable diagnostic tool in adrenal incidentalomas. At APW $\geqslant$60% and RPW $\geqslant$40%, it is significantly accurate in differentiating adrenal adenomatous lesions.

1. Introduction

The adrenal glands are routinely visualized on computed tomography (CT) scans of the abdomen and on most CT scans of the chest. Nowadays, owing to the improved quality of CT images and the important role played by the multi-detector CT (MDCT) in medical care, there has been an increased frequency of detecting incidental findings.[1]

An incidental adrenal mass, often referred to as an adrenal incidentaloma, is defined as an adrenal mass discovered incidentally on a cross-sectional imaging examination performed for another reason. Incidental adrenal masses are common, estimated to occur in approximately 3–7% of the adult population.[2] Although the adrenal gland is involved by a range of diseases, adrenal adenomas are common, with a prevalence of up to 9% in the general population in autopsy series. Most adrenal incidentalomas are benign non-hyperfunctioning adenomas.[3] They represent 80% of all adrenal neoplasms.[4]

Accurate radiological evaluation is essential for appropriate diagnosis and differentiation of benign from malignant

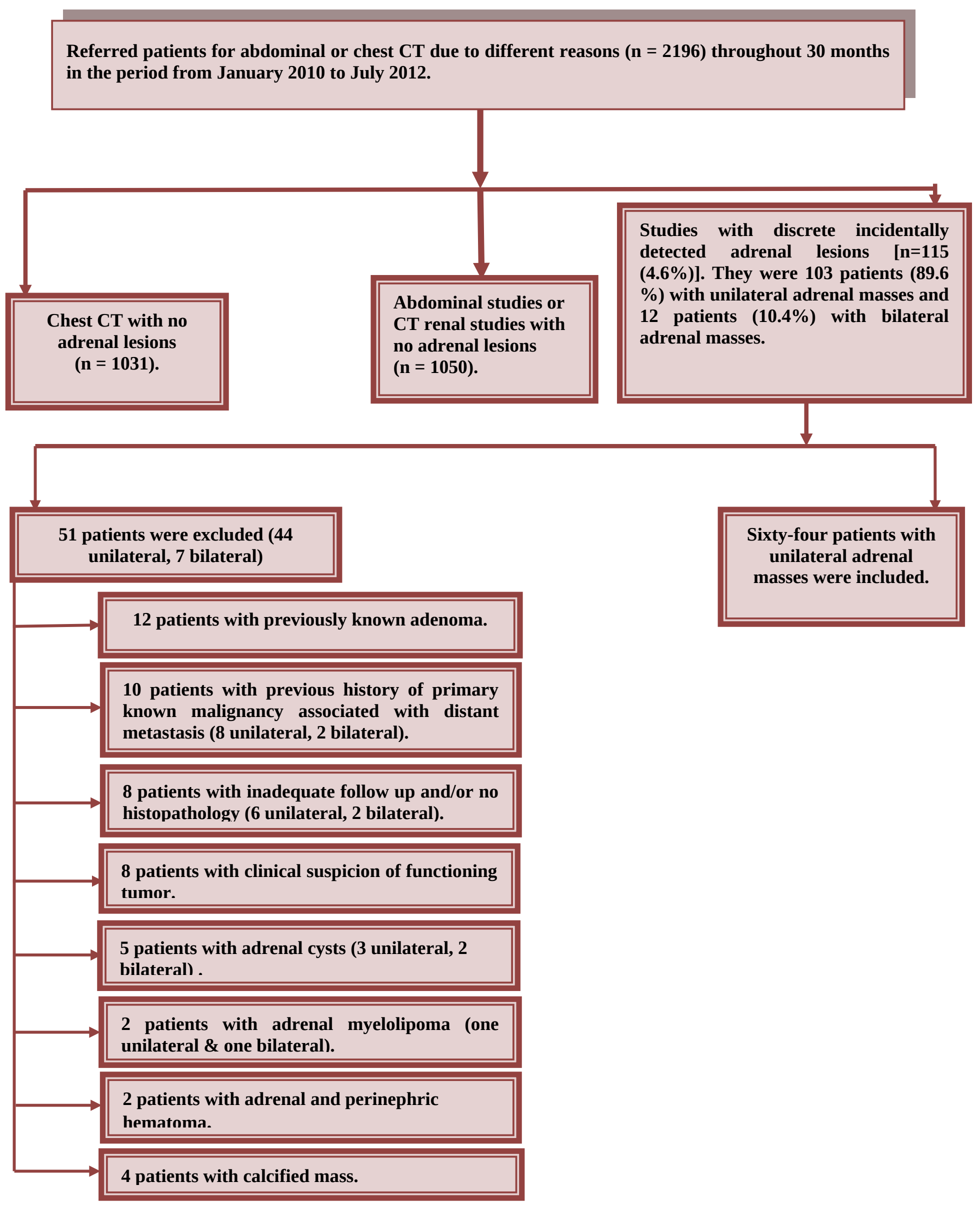

Figure 1 Schematic representation of patients in the present study.

neoplasms.[5,6] Adenomas typically show low attenuation on unenhanced CT and may be categorized as lipid-rich (70%) or lipid-poor (30%) depending on the intracytoplasmic fat content.[7–9] Lipid-sensitive imaging techniques such as unenhanced MDCT enable detection of lipid-rich adenomas, while in indeterminate cases; an adrenal CT washout study may differentiate adenomas from other adrenal neoplasms.[9,10] Washout refers to the reduction of attenuation values in the adrenal lesions at CT, during a variable period of time following intravenous bolus injection of contrast material.[11]

The aim of this work was to evaluate the role of MDCT in detection of adrenal incidentalomas with assessment of the diagnostic value of 15-min delayed washout rate in the differentiation of these incidentally detected adrenal lesions.

2. Materials and methods

Sixty-four patients with adrenal incidentaloma, 59 patients (92.2%) with unilateral and 5 patients (7.8%) with bilateral adrenal masses, were enrolled in this study that was carried out in the period from January 2010 to January 2013 (Fig. 1). They were referred to the Radiology Department of Tanta University Hospitals for chest or abdominal CT due to different reasons. The exclusion criteria included the following: adrenal masses smaller than 1 cm in diameter, clinically suspected functioning adrenal lesions, known adrenal masses on prior imaging studies and another specific imaging diagnosis such as adrenal cysts, hematoma, calcification, lipoma and myelolipoma, as diagnosis could be made on initial pre-contrast CT. Also, patients with a history of previously known malignancy were excluded as we considered such patients to be at risk of adrenal metastasis. However, patients with first ever diagnosed malignancy associated with adrenal incidentaloma on initial pre-contrast scan were included in this study to differentiate between adrenal adenoma and metastasis. An official permission to carry out the study was obtained from the responsible authorities and the administrative staff. Patient consent to participate in the study was obtained.

Pre-contrast and post-contrast images were obtained by using a 16-slice CT scanner (Toshiba Aquilion scanner; Toshiba Medical Systems, Tokyo, Japan). The patients lied supine and scans were obtained during breath hold. Images were obtained for all patients through the following phases: pre-contrast phase, venous phase, and 15-min delayed enhancement phase in addition to estimation of the 15-min delayed washout rate. Pre-contrast images were done to measure the Hounsfield unit (HU) of incidentally detected adrenal lesions and to identify scan range for contrast enhanced images. The following parameters were used: tube current of 150 milliampere (mA), tube voltage of 120 kilovolt (kV), gantry tilt of 0, detector collimation of 16×0.6, gantry rotation time of 0.4 s, slice thickness of 3 mm (mm), pitch of 1 and matrix of 512. To obtain post-contrast images, a 22-gauge catheter was fixed in an antecubital vein and a non ionic contrast medium with 300 milligram (mg) iodine/milliliter (ml) (100–120 ml Ipoamidol) was injected at a rate of 4 ml/s using automatic injector with a maximal injection time of 30 s. Early enhanced CT scans were obtained for all cases 65 s after contrast material injection (venous phase). Delayed time images were obtained 15 min after the end of injection of contrast media by using the same imaging parameters in the same patient and without changing the patient position on the scanning table.

Table 1 Demographic and radiological data of patients with incidentalomas ($n = 64$).

Data		Adenoma group ($n = 46$)		Non-adenoma group ($n = 18$)		*P*-value
Age (year)		29–70 (49.5 ± 6.2)		24–68 (46 ± 9.3)		0.554
Gender	Male	$n = 19$	0.7:1	$n = 11$	1:0.6	0.360
	Female	$n = 27$		$n = 7$		
Laterality	Right	$n = 16$	0.53:1	$n = 13$	1:0.4	0.258
	Left	$n = 30$		$n = 5$		
Size of the mass (cm)		2.5 ± 1.2		3.5 ± 2.3		0.083
Pre-contrast phase (HU)		12.9 ± 1.2		35 ± 7.2		<0.001*
Venous phase (HU)		62.1 ± 12.2		64.9 ± 11.1		0.401
Delayed enhanced phase (HU)		40.2 ± 5.5		78.9 ± 10.3		<0.001*
15-min Delayed washout rate	APW	72.5 ± 8.2		22.8 ± 30		<0.001*
	RPW	58.5 ± 6		13.8 ± 7		<0.001*

cm, centimeter; HU, Hounsfield unit; APW, absolute percentage washout; RPW, relative percentage washout.
* Significant ($P < 0.05$).

Table 2 True positive, false negative, true negative and false positive values of different MDCT phases and the delayed washout rate in diagnosis of adrenal adenoma ($n = 64$).

MDCT sequences		TP	FN	TN	FP
Pre contrast phase		44	2	16	2
Venous phase		20	26	14	4
Delayed enhanced phase		45	1	18	0
15-min Delayed washout rate	APW	46	0	18	0
	RPW	46	0	18	0

TP, true positive; FN, false negative; TN, true negative; FP, false positive.

Table 3 Statistical values of the MDCT phases and 15-min delayed washout rate with determination of the cut-off attenuation values and maximal AUC in adrenal adenomas (n = 46).

MDCT sequences		AUC	Cut-off	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	Accuracy (%)
Pre contrast phase		0.937	⩽10.2	95.65	88.89	95.65	88.89	93.75
Venous phase		0.531	⩽55	43.48	77.78	83.33	35.00	53.13
Delayed enhanced phase		0.984	⩽34	97.83	100.00	100.00	94.74	98.44
15-min Delayed washout rate	APW	0.990	⩾60	100.00	100.00	100.00	100.00	99.0
	RPW	0.988	⩾40	100.00	100.00	100.00	100.00	98.9

AUC, area under curve; PPV, positive predictive value; NPV, negative predictive value; APW, absolute percent washout; RPW, relative percent washout.

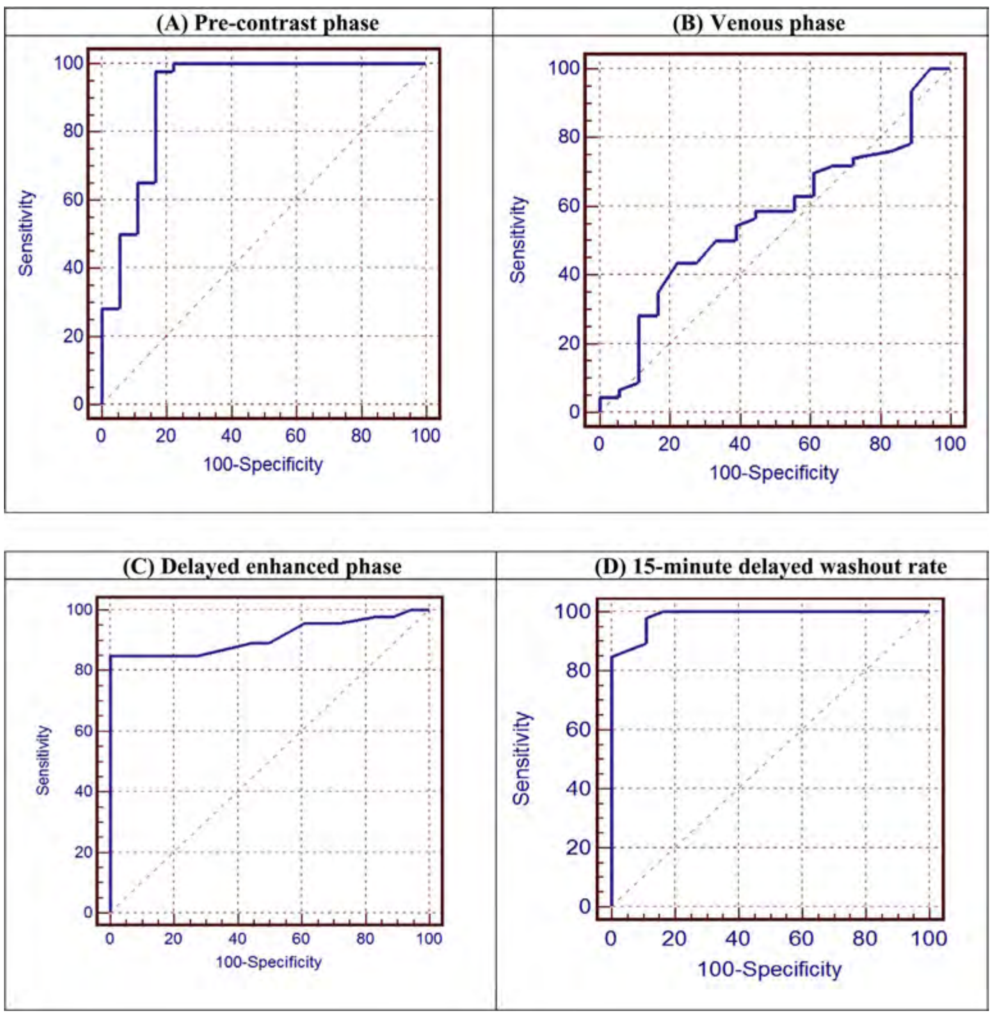

Figure 2 (A–D): ROC curve analysis of the attenuation values of pre-contrast (A), venous (B) and delayed enhanced (C) phases as well as 15-min delayed washout rate (D) in adrenal adenomas (n = 46).

Table 4 Comparison between the accuracy of different MDCT phases and the delayed washout rate in differentiation of adrenal incidentalomas (n = 64).

Parameter	Difference between areas	SE	95% CI	P-value
15-min Delayed washout rate versus pre-contrast	0.076	0.049	0.019–0.171	0.048*
15-min Delayed washout rate versus venous phase	0.420	0.082	0.260–0.580	0.000*
15-min Delayed washout rate versus delayed enhanced phase	0.077	0.036	0.006–0.148	0.034*

SE, standard error; CI, confidence interval.
* Significant (P < 0.05).

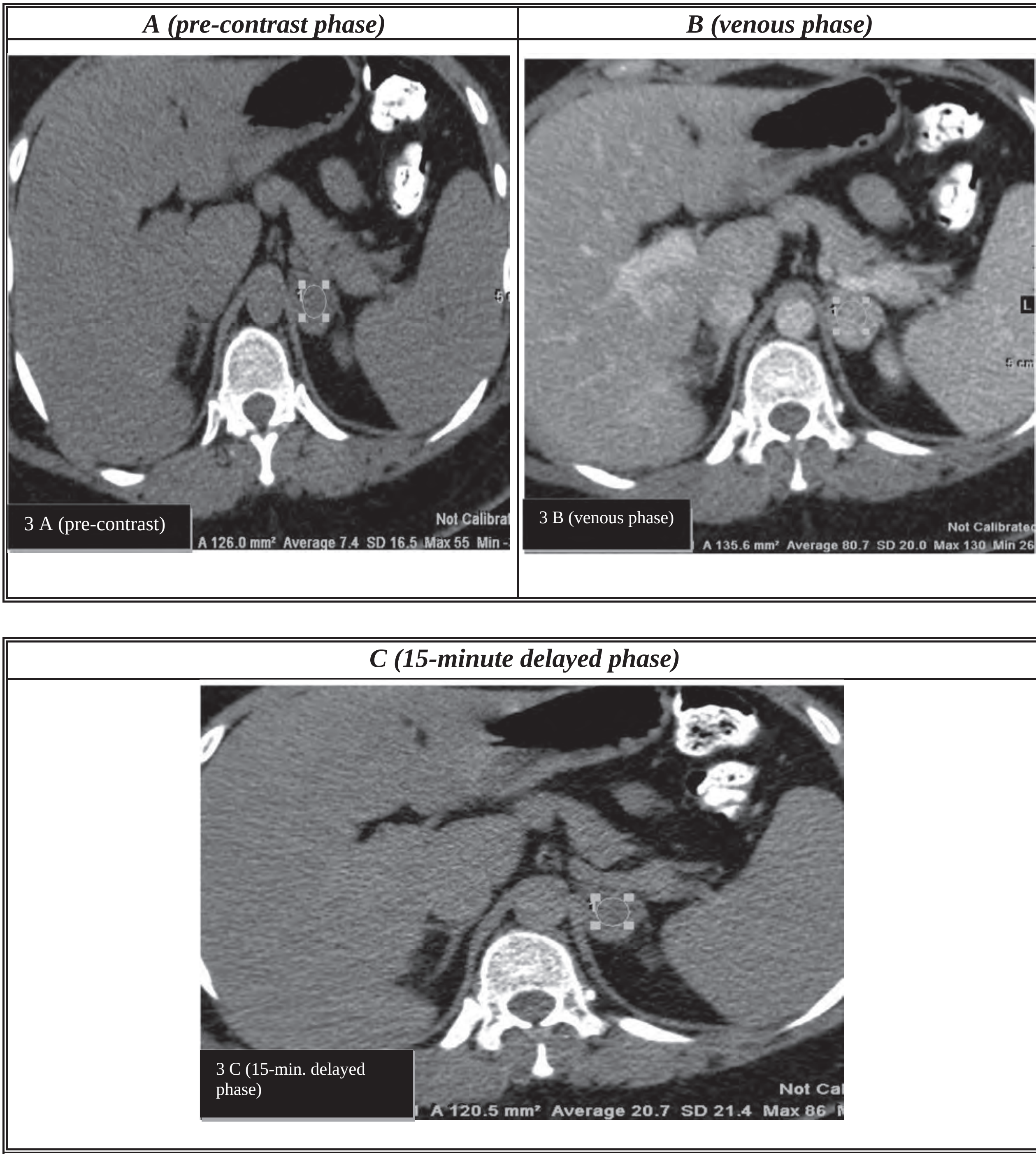

Figure 3 (A–C): Thirty year-old female with left adrenal incidentaloma discovered incidentally during abdominal CT examination for suspected renal stones. Pre-contrast axial image (A) showed a well-defined, hypodense, homogenous left supra-renal mass (2×2 cm) with attenuation value of 7 HU. There are no associated areas of cystic degeneration or calcification. It displayed attenuation value of 80 HU at venous phase (B) and 20 HU at delayed phase (C). The APW was 82% and RPW was 75%. It was diagnosed as left lipid-rich adrenal adenoma.

Imaging analysis and post processing were then performed. The CT images were retrieved from our institutional picture archiving and communication system (Millenmed Company, FDA approved for PACS). The attenuation values of the adrenal lesions were measured by placing a round or ovoid manually controllable region of interest (ROI) in the center of the adrenal mass to occupy more than half of the lesion. The peripheral areas of adrenal mass were avoided to reduce the effect of noise and to avoid the partial volume effect of the adjacent fat. Also, the calcified, necrotic, cystic and

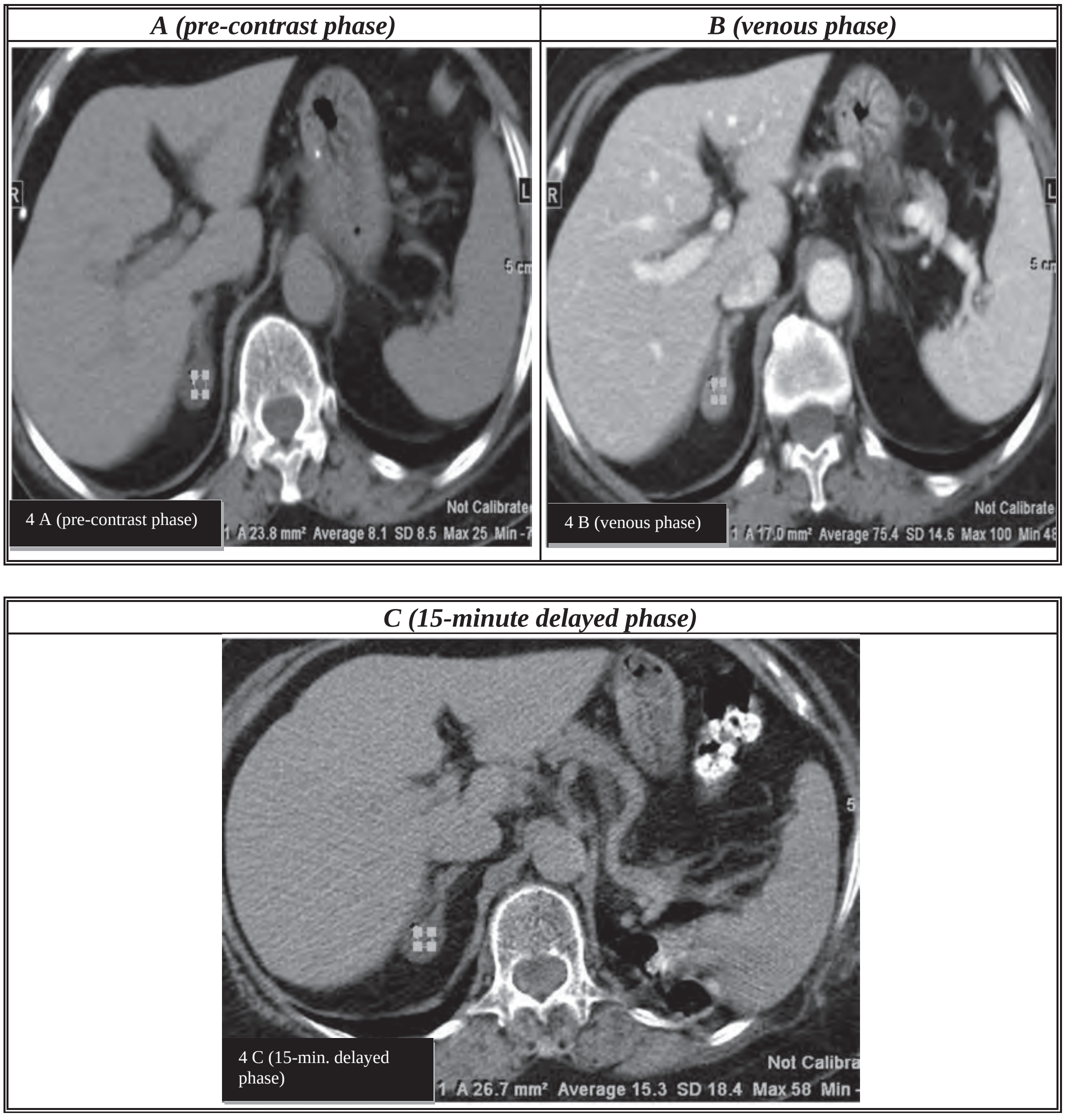

Figure 4 (A–C): Forty-nine year-old male with right adrenal mass discovered incidentally during first time abdominal CT examination for hematuria. Pre-contrast axial image (A) showed a well-defined right supra-renal mass (1.5×1.5 cm) with heterogeneous density (attenuation value of 8 HU) and no associated areas of cystic degeneration or calcification. It displayed attenuation value of 75 HU at venous phase (B) and 15 HU at delayed phase (C). The APW was 89% and RPW was 80%. It was diagnosed as right lipid-rich adrenal adenoma.

hemorrhagic areas were excluded from the region of interest. The obtained raw data of the multi-phasic studies were transferred to the attached workstation (Vitrea 4.1.2, Toshiba Medical Systems, Tokyo, Japan), then coronal and sagittal multi-planner reformatted (MPR) images were done for more diagnostic evaluation. The transferred data including pre-contrast, venous phase and 15-min delayed phase images were recorded and the absolute percentage of washout (APW) as well as relative percentage of washout (RPW) were calculated by means of the following formulas[10]:

$$\begin{aligned} \text{APW} = {} & 100 \times (\text{venous attenuation} - \text{delayed attenuation}/ \\ & \text{venous attenuation} - \text{pre} - \text{contrast attenuation}) \\ & \text{i.e.} 100 \times (\text{VA} - \text{DA})/(\text{VA} - \text{PCA}). \end{aligned}$$

$$\begin{aligned} \text{RPW} = {} & 100 \times (\text{venous attenuation} - \text{delayed attenuation}/ \\ & \text{venous attenuation}) \text{ i.e.} 100 \times (\text{VA} - \text{DA})/\text{VA}. \end{aligned}$$

where VA = venous attenuation, DA = delayed attenuation, PCA = pre-contrast attenuation.

Follow up with non-contrast adrenal MDCT for at least 6 months and/or histopathological diagnosis were performed to confirm the results of our study.

2.1. Statistical analysis

The SPSS for Windows version 18.0 software package (SPSS Inc., Chicago, IL) was used for statistical data analysis. Data were expressed as mean ± standard deviation (SD). Receiver operating characteristic (ROC) curve analysis was used to determine the optimal cut-off values and maximal area under curve (AUC) of different sequences with evaluation of the diagnostic sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of each sequence. $P < 0.05$ was considered statistically significant.

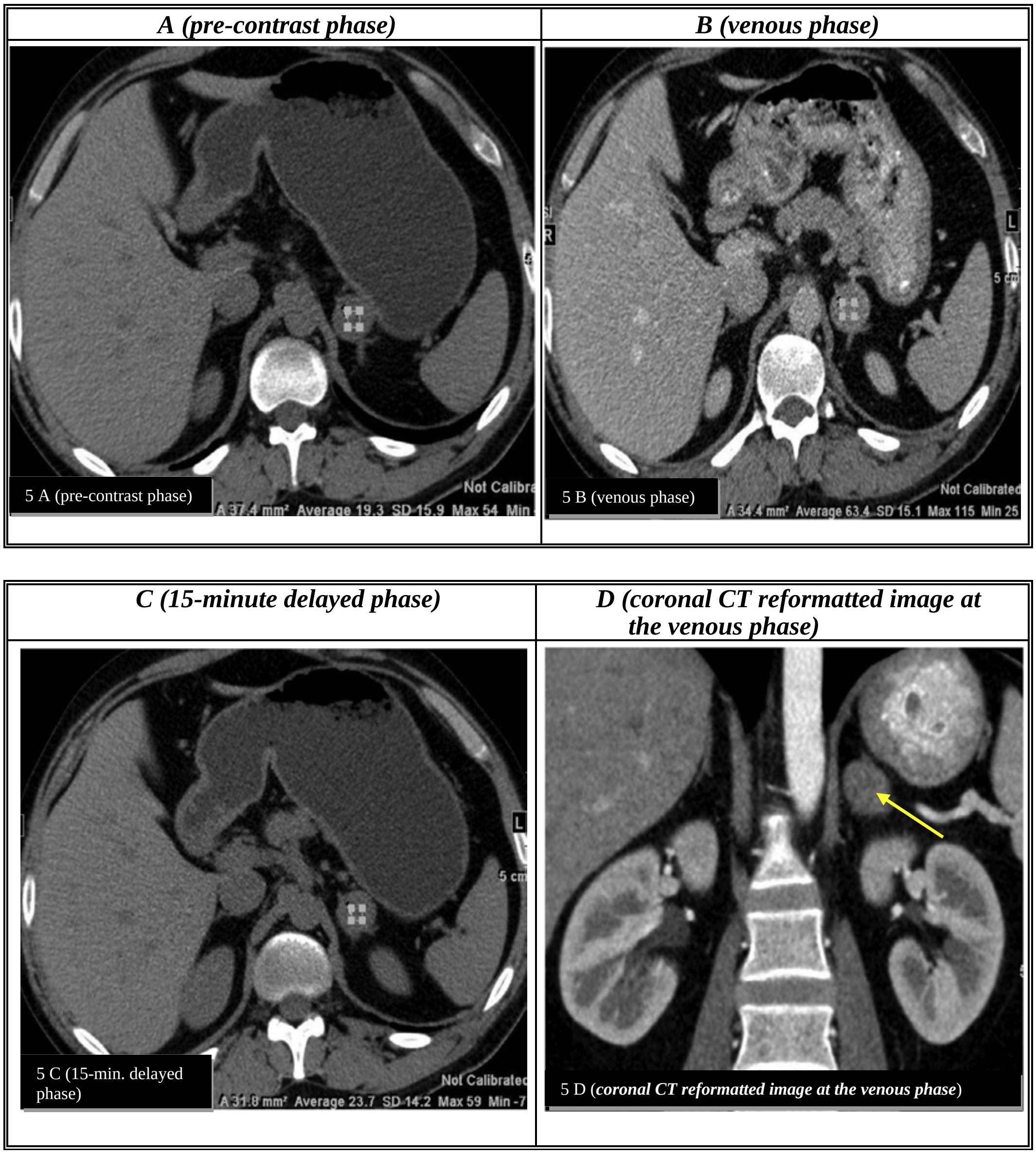

Figure 5 (A–D): Thirty-nine year old male with left adrenal incidentaloma discovered during abdominal CT examination for left loin pain. Pre-contrast axial image (A) showed a well-defined mass at the anatomical site of the left adrenal gland measuring 2.2 × 2.3 cm with homogenous intermediate density and attenuation value of 19 HU. At venous phase (B), the mass displayed attenuation value of 63 HU while at delayed phase (C), it displayed attenuation value of 23 HU. Coronal CT reformatted image (D) revealed that the mass is absolutely separable from the upper pole of the left kidney as well as the surrounding structures (yellow arrow). The APW was 90% and RPW was 63%. It was diagnosed as left lipid-poor adrenal adenoma. During the period of follow up the mass developed clinical manifestations of functioning tumor with increased size. So, it was surgically removed and the histopathology confirmed the diagnosis of lipid poor adenoma.

3. Results

This study included 64 patients with single solid adrenal incidentalomas. Forty-six (71.9%) masses were diagnosed as adrenal adenoma and 18 (28.1%) as non-adenoma. Final diagnosis was reached after at least 6 month follow up by non-contrast adrenal MDCT and/or histopathology. Patients with adrenal adenoma included 33 patients (71.7%) with lipid-rich and 13 patients (28.3%) with lipid-poor adenoma. Non-adenoma masses (n = 18) were histopathologically diagnosed as: 5 patients (27.8%) with pheochromocytoma, 4 patients (22.2%) with adrenocortical carcinoma, 4 patients (22.2%) with metastasis (2 cases from bronchogenic carcinoma, one from cancer breast and one from hepatocellular carcinoma), 4 patients (22.2%) with ganglioneuroma and one patient (5.6%) with lymphoma.

Table 1 shows the demographic and radiological data of patients with adrenal incidentalomas. Their ages ranged from 24 to 70 years. There was no significant difference between adenoma and non-adenoma groups regarding the age, gender, laterality and size of the mass (P = 0.554, 0.360, 0.258 and 0.083, respectively). The mean attenuation values of

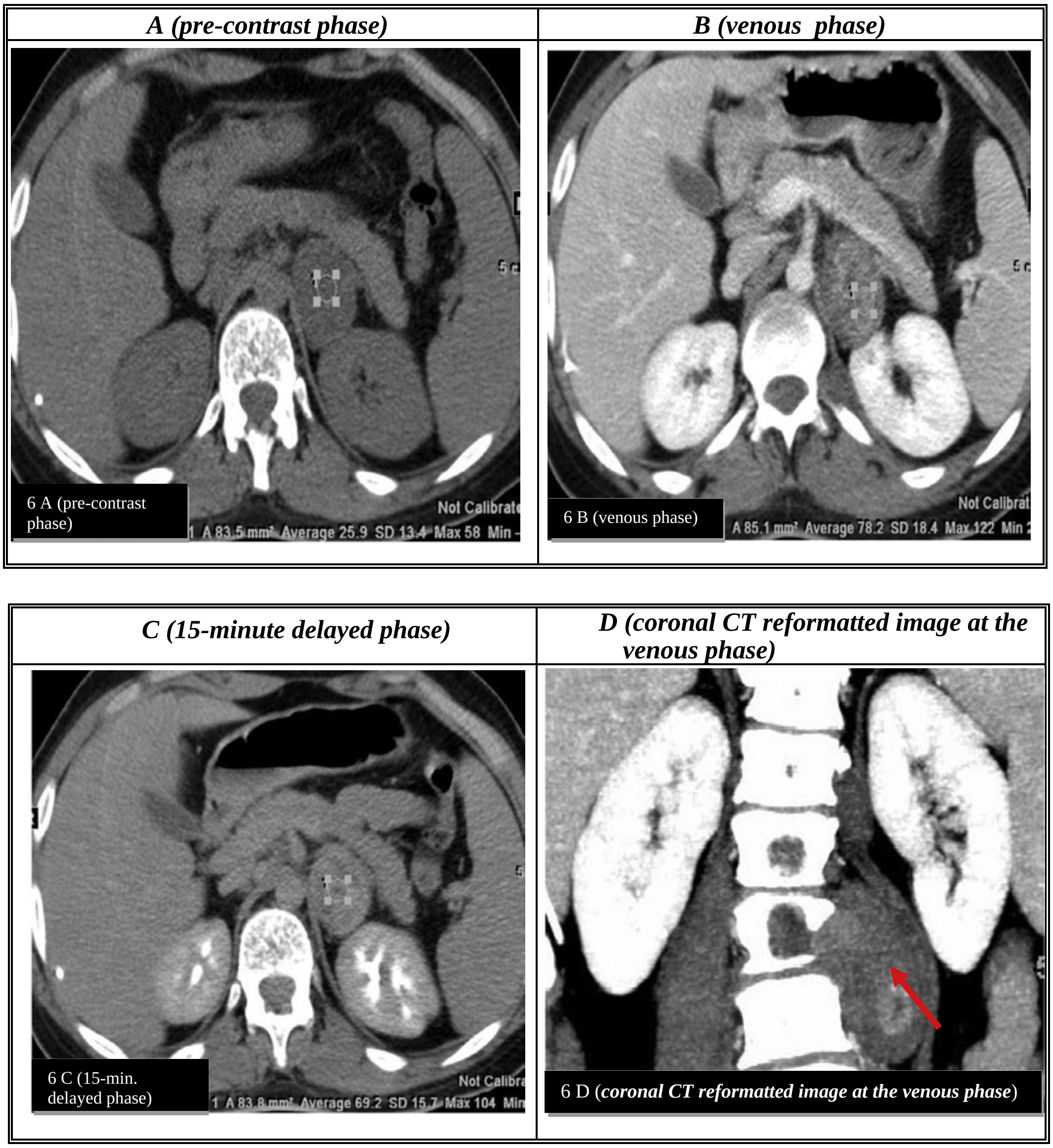

Figure 6 (A–D): Twenty-five year old male with left adrenal incidentaloma (3 × 4.2 cm) discovered during abdominal CT examination for investigating his hypertensive disease. It displayed 25 HU at the pre-contrast phase (A). At venous phase (B), the attenuation value of the mass was 78 HU associated with heterogenously enhancing left paravertebral soft tissue mass (red arrow), seen on coronal reformatted image at venous phase (D). At delayed phase (C), the attenuation value of the adrenal mass was 69 HU with APW of 16% and RPW of 11%. It was diagnosed radiologically as left adrenal non-adenomatous lesion with neurofibromatosis type II. Laparoscopic adrenalectomy and histopathology proved the diagnosis of pheochromocytoma.

pre-contrast and delayed enhanced phase images as well as the 15-min delayed washout rate showed significant differences between the two groups ($P < 0.001$). However, the mean attenuation value of the venous phase enhancement showed no significant difference between the two groups ($P = 0.401$).

Table 2 shows the true positive (TP), false negative (FN), true negative (TN) and false positive (FP) values of different MDCT phases and the delayed washout rate in the diagnosis of adrenal adenoma. Table 3 and Fig. 2 show the diagnostic sensitivity, specificity, PPV, NPV and accuracy in adrenal adenomas ($n = 46$) with determination of the optimal cut-off values and maximal AUC by using ROC curve analysis for all MDCT phases as well as the 15-min delayed washout rate.

Table 4 demonstrates that, in adrenal incidentalomas ($n = 64$), the 15-min delayed washout rate of MDCT was significantly accurate in differentiation between adenoma and non-adenoma than each of the pre-contrast attenuation ($P = 0.048$; 95% confidence interval: 0.019–0.171), venous phase attenuation ($P = 0.000$; 95% confidence interval: 0.260–0.580), and delayed enhanced phase attenuation ($P = 0.034$; 95% confidence interval: 0.006–0.148).

Final diagnosis of the studied patients was achieved through only follow up by non contrast MDCT in 44 (68.8%) patients, histopathology in 18 (28.1%) patients and histopathology after a follow up period of at least 6 months in 2 (3.1%) patients.

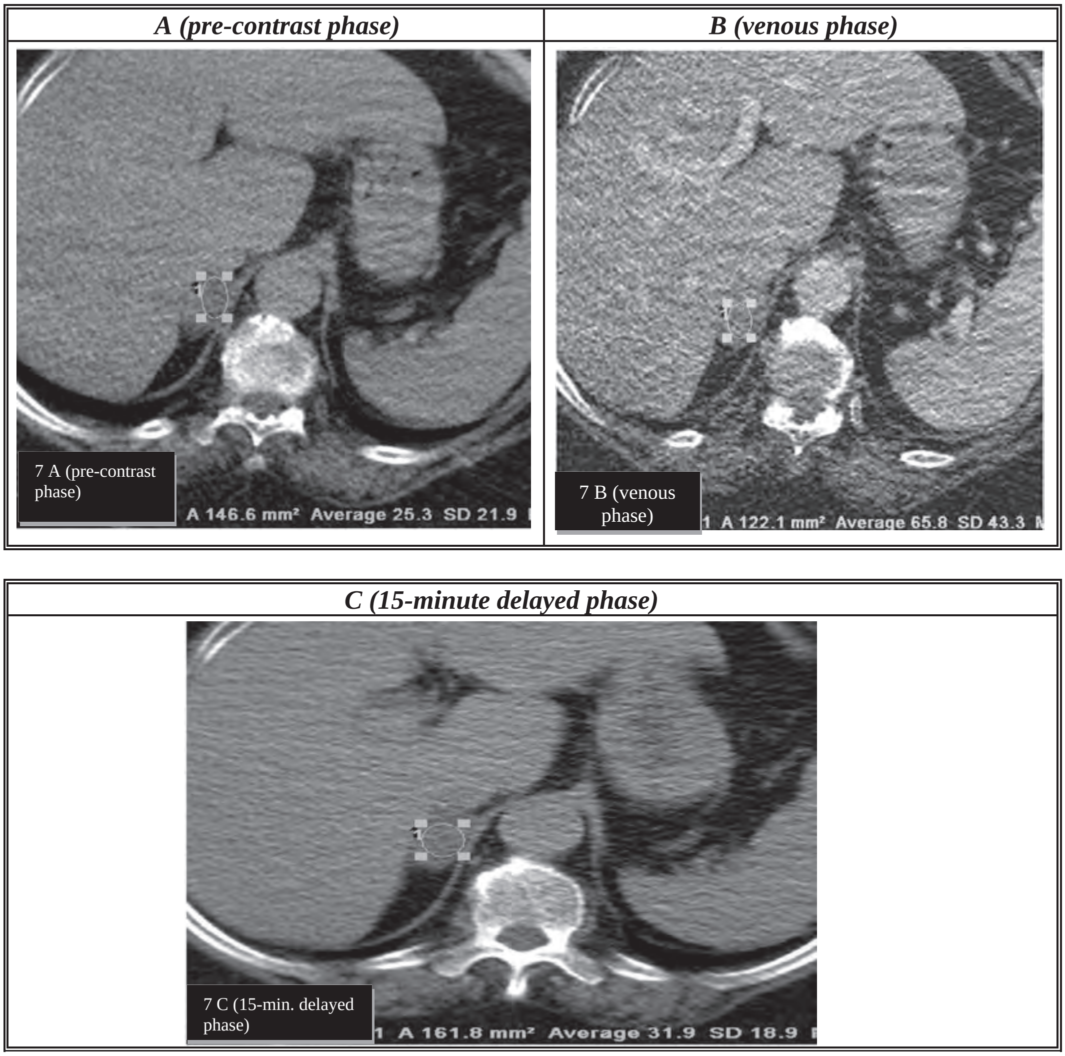

Figure 7 (A–C): Sixty-four year old female with right adrenal incidentaloma discovered during abdominal CT examination for biliary colic. Pre-contrast axial image (A) showed a well-defined mass at the anatomical site of the right adrenal gland measuring 1.4×1.5 cm with intermediate density and attenuation value of 25 HU. At venous phase (B), the mass displayed attenuation value of 65 HU while at delayed phase (C), it displayed attenuation value of 31 HU. The APW was 85% and RPW was 52%. It was diagnosed as right lipid-poor adrenal adenoma and the histopathology confirmed the diagnosis of lipid poor adenoma.

4. Cases

The figures from Figs. 3–10 demonstrate a sample of selected cases of our study, each figure outlines one case.

5. Discussion

The adrenal gland is involved by a range of neoplasms, including primary and metastatic malignant tumors; however, the most common tumor detected is the incidental benign adenoma.

With the current high resolution MDCT scanners, the prevalence of adrenal incidentalomas on imaging has increased approaching that of autopsy series.[1,4,7] Many studies have now confirmed the usefulness of attenuation measurements, at both non-enhanced and delayed contrast-enhanced CT, in the differentiation of adenoma from non-adenomas.[13]

Previous non-enhanced CT studies indicate the sensitivity for differentiating adenomas from non-adenomas is approximately 70% because as many as 30% of adenomatous lesions are considered lipid-poor.[4] Although the non-enhanced CT sequence is useful, its sensitivity is generally considered low because further tests are required to characterize lipid-poor lesions. On the other hand, CT contrast washout rate tests are more useful because they are highly sensitive, with a reported range of 96–100%.[11,12,14–16] However, the exact sensitivity or specificity threshold that has been used varies from study to study because of the variable time delayed scan among the different studies.

Our study revealed that, at both the pre-contrast MDCT and the delayed enhanced images, the mean attenuation value of adenoma is significantly lower than that of non-adenoma ($P < 0.001$). However, no significant difference is found between the mean attenuation values of both adrenal adenoma and non-adenoma at the venous phase. So,

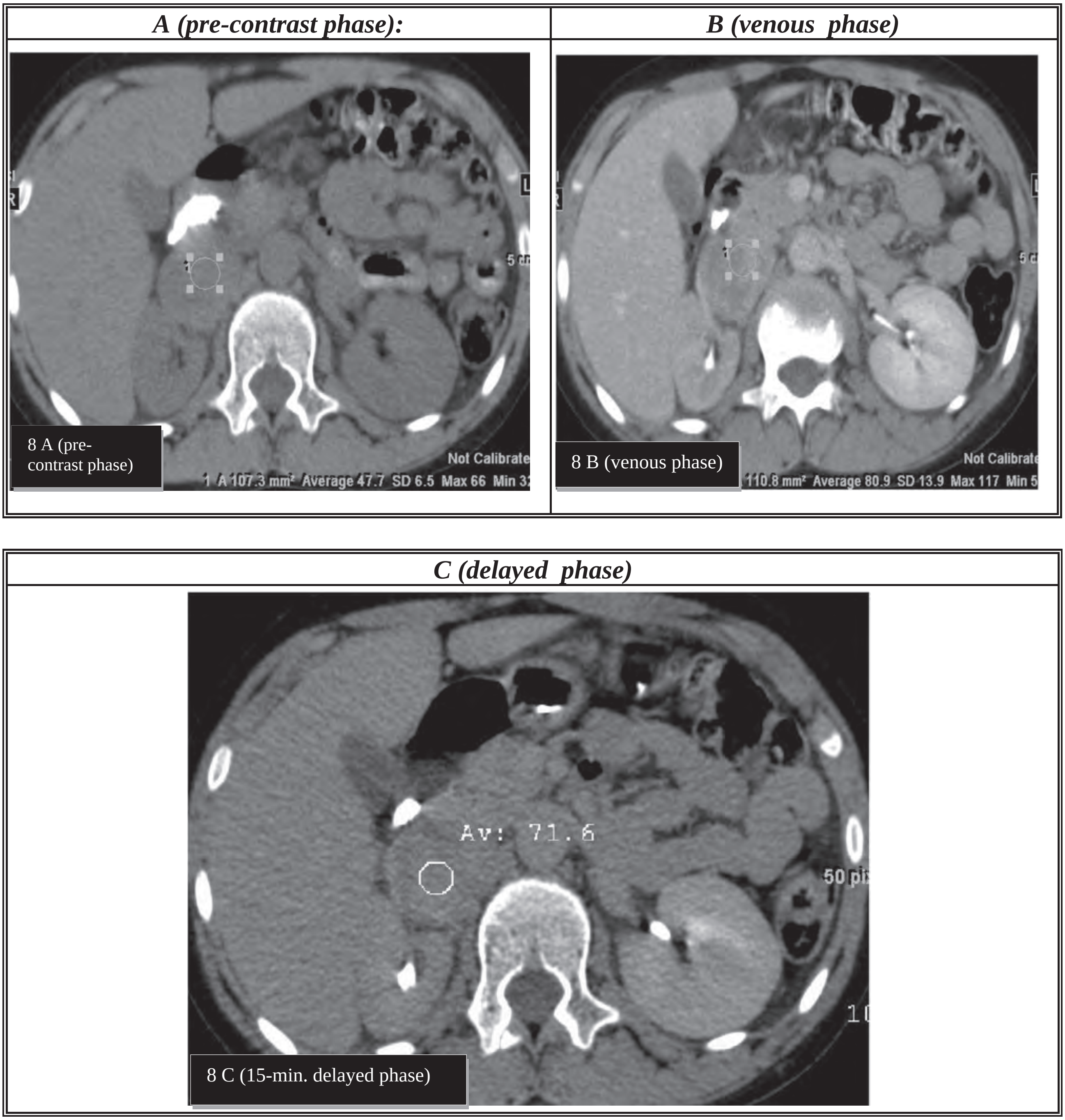

Figure 8 (A–C): Twenty-four year old male with right adrenal incidentaloma discovered incidentally during abdominal CT examination for right loin pain. Pre-contrast axial image (A) showed a well-defined mass at the anatomical site of the right adrenal gland measuring 4.2×3 cm with attenuation value of 47 HU associated with areas of cystic degeneration but with no calcification within the mass. At venous phase (B), the mass displayed attenuation value of 80 HU while at delayed phase (C), it displayed attenuation value of 71 HU. The APW was 27% and RPW was 11%. It was diagnosed as right non adenomatous adrenal lesion. Right laparoscopic adrenalectomy and histopathology proved the diagnosis of ganglioneuroma.

measuring the attenuation value of the mass at the venous phase is insufficient to allow accurate differentiation between the two groups of adrenal incidentalomas as it has the sensitivity of 43.48%, specificity of 77.8%, PPV of 83.3%, NPV of 35.0% and an accuracy of 53.1%. This was in agreement with previous studies[9,10,13,17,18] which stated that the attenuation values of adenomas are significantly lower than non-adenoma at pre-contrast and delayed enhanced MDCT images. Moreover, they stated that the venous enhanced phase showed too much overlap between the adrenal adenoma and non-adenoma with resultant inaccurate differentiation between the two groups.

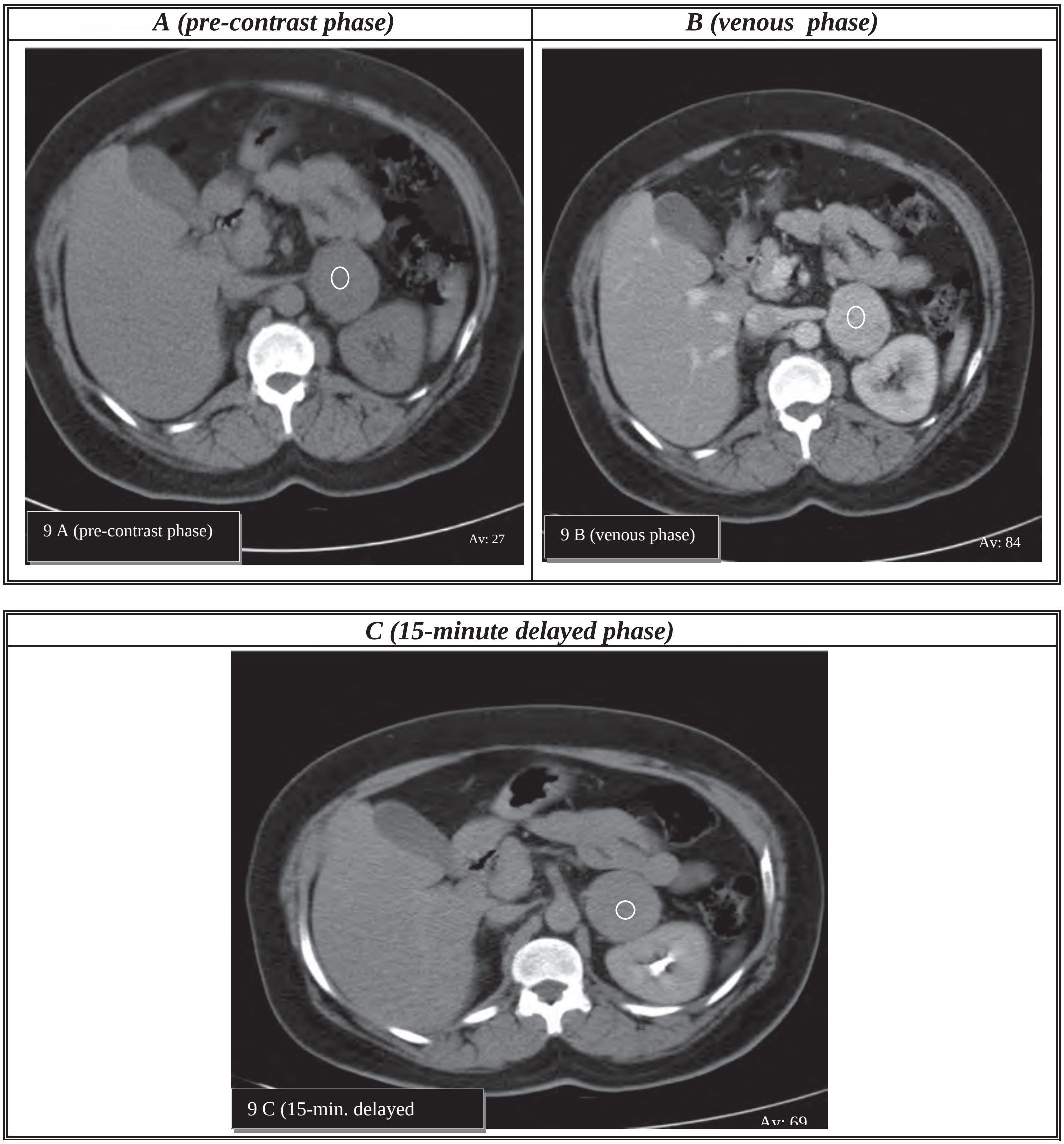

Figure 9 (A–C): Sixty-five year old male with left adrenal incidentaloma discovered during abdominal CT examination for left loin pain. Pre-contrast axial image (A) showed a well-defined left adrenal mass measuring 3.6×3.8 cm with attenuation value of 27 HU. At venous phase (B) the mass displayed attenuation value of 84 HU while at delayed phase (C) the attenuation value was 69 HU with the APW of 26% and RPW of 14%. It was diagnosed radiologically as left adrenal non-adenomatous lesion. Open adrenalectomy and histopathology proved adrenocortical carcinoma.

In the current study, the use of pre-contrast MDCT at a threshold of $\leqslant$10.2 HU for the diagnosis of adrenal adenoma has the sensitivity of 95.7%, specificity of 88.9%, PPV of 95.7%, NPV of 88.9% and accuracy of 93.8%. Also, the use of 15-min delayed enhanced images at a threshold $\leqslant$34 HU has the sensitivity of 97.8%, specificity of 100%, PPV of 100%, NPV of 94.7% and an accuracy of 98.4%. In another study done by Park et al.[10] they demonstrated that the sensitivity and specificity of pre-contrast CT at a threshold of $<$10 HU were 45.7% and 97.1%, respectively but the sensitivity and specificity of 15-min delayed enhanced CT at a threshold $<$35 HU for the diagnosis of adrenal adenoma were 67.6% and 100% respectively. This difference may be attributed to differences in selection criteria, number of patients, procedures used and different MDCT machines as well as the difference of the cut-off values. Also, it may be due to differences in the type, total dose and injection rate of contrast media which caused difference of the optimal threshold attenuation.

Adrenal adenomas of more than 10 HU on non-enhanced CT can be classified as lipid-poor adenomas which show enhancement washout features similar to those of lipid-rich adenomas. Therefore, differentiation of lipid poor adenoma from non-adenoma is possible even by using their increased percentage washout of the contrast material.[11] In the present study, 2 (3.1%) patients were initially diagnosed as non-adenoma on the pre-contrast phase, but by estimating the 15-min delayed washout rate, they were diagnosed as lipid-poor adenoma. During the period of follow up, these two cases developed clinical manifestations of functioning tumor with

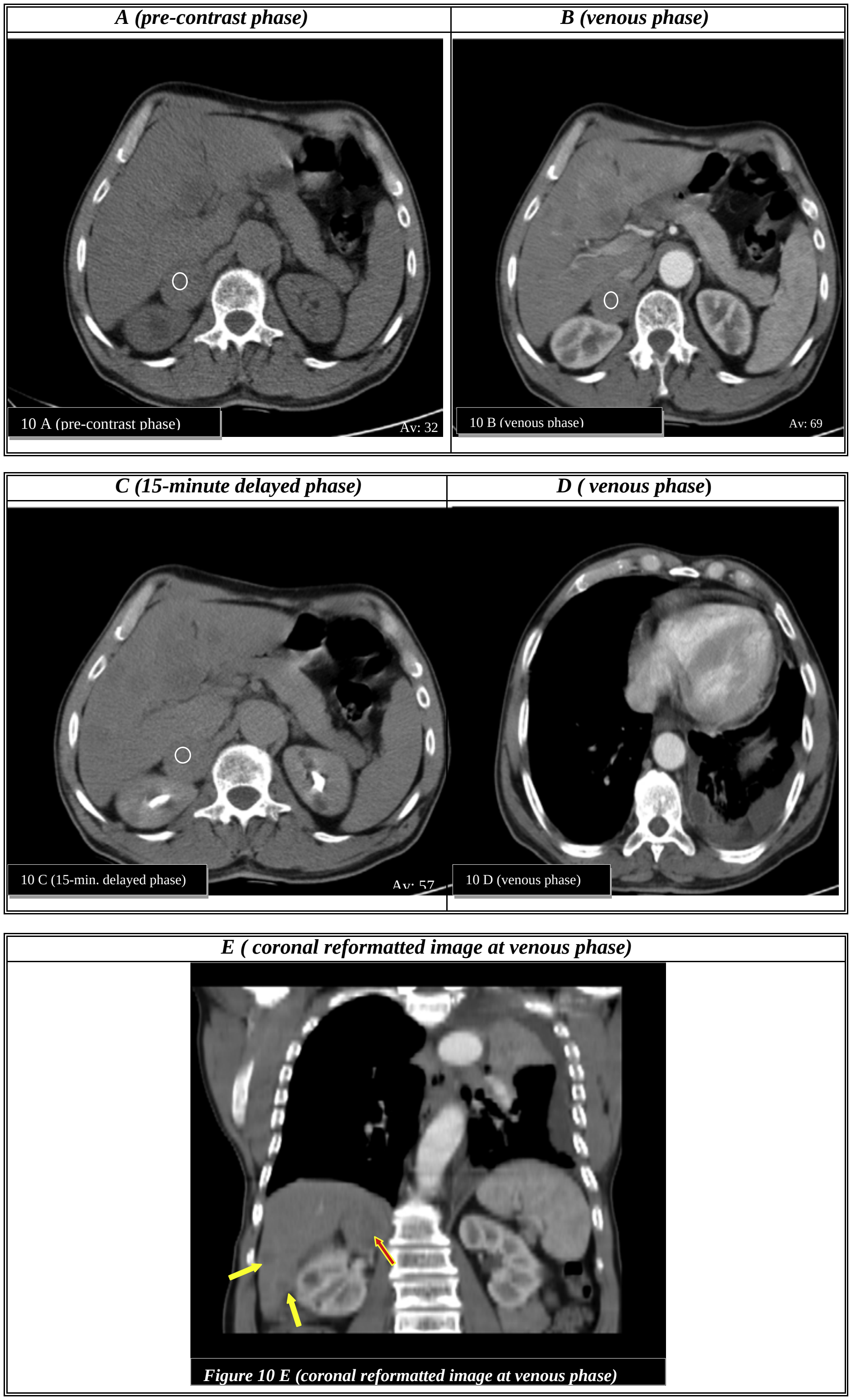

Figure 10 (A–E): Sixty-two year old female with right adrenal incidentaloma discovered during CT Chest examination for haemoptysis. Pre-contrast axial image (A) showed a well-defined right adrenal mass measuring 3×3.2 cm with attenuation value of 32 HU. At venous phase (B), the mass displayed attenuation value of 74 HU. At delayed phase (C), the adrenal mass displayed the attenuation value of 57 HU with APW of 48% and RPW of 34%. It was radiologically diagnosed as right adrenal non-adenomatous lesion. Axial CT chest (D) and coronal reformatted image at venous phase (E) showed left lung upper lobe collapse with left pleural effusion associated with the right supra renal incidentaloma (red arrow) as well as incidentally discovered multiple hepatic focal lesions (yellow arrows) which are likely to be metastatic. Laparoscopic adrenalectomy and histopathology revealed right adrenal metastasis from bronchogenic carcinoma.

increased size. So, they were surgically removed and the histopathology confirmed the diagnosis of lipid poor adenoma.

Despite the differences between techniques and results in the previous studies[2,9,13,17] and our study, the findings are similar enough to signify that adrenal adenomas show more rapid washout of MDCT enhancement compared with non-adenomas. In the present study, we found that all incidental adenomas (lipid-rich and-lipid poor) had APW $\geqslant 60\%$ (sensitivity was 100%, specificity was 100%, PPV was 100%, NPV was 100% and the accuracy was 99%) and RPW $\geqslant 40\%$ (sensitivity was 100%, specificity was 100%, PPV was 100%, NPV was 100% and the accuracy was 98.9%) while lesions with APW $< 60\%$ and RPW $< 40\%$ were non-adenomas. In the study of Park et al.[10], the sensitivity and specificity with a threshold of 55% washout rate at 15-min were 93.9% and 95.8%, respectively. These differences may be attributed to the differences in the cut-off values as well as number of patients and selection criteria. The anatomical or physiological mechanisms underlying the differences in response to contrast material enhancement have not yet been elucidated. However, some authors have suggested that non-adenomas elicit disturbed capillary permeability with prolonged retention of the contrast material in the effective extracellular space. In fact, controversy exists as to not only what scanning delay to use but also what washout sensitivity threshold should be used for differentiating adenomas from non-adenomas properly.[19]

Previous studies of different timing of the post-contrast washout rate showed variable results. Sangwaiya et al.[9] concluded that the 10-min contrast-enhanced delayed adrenal washout at MDCT offered no advantage over the non-enhanced CT attenuation measurements to characterize adenomatous disease. Furthermore, they demonstrated that lowering the RPW threshold to 40%, as recommended when using 15-min delayed protocols, improved the sensitivity to 76.9% which is still not sufficiently useful in clinical practice. They concluded that the 10-min delayed imaging protocol is not sufficiently sensitive to be routinely useful in clinical practice and the earlier post-contrast washout imaging does not appear to permit sufficient washout time for adenomatous lesions to fully show. In the current study, we found that the sensitivity of 15-min delayed washout rate at RPW threshold of 40% and APW threshold of 60% is 100%, which, in our opinion, is sufficiently useful in clinical practice to characterize adenomatous lesions.

Pheochromocytoma may be associated with other syndromes as neurofibromatosis type II as well as multiple endocrinal neoplasm (MEN) syndrome.[20] Our study revealed 5 cases of pheochromocytoma; one appears with neurofibromatosis type II and another one with MEN syndrome. The most common neoplasms that metastasize to the adrenal glands are carcinomas of the lung and breast which may be bilateral or unilateral.[17] The present study revealed four patients diagnosed as non-adenoma with APW < 60 and RPW < 40. Their diagnosis was confirmed after adrenalectomy by histopathology to be metastasis; from bronchogenic carcinoma (2 cases), from cancer breast (one case) and from hepatocellular carcinoma (one case).

The limitations of our study included some selection criteria that led to a relatively smaller number of patients. So, further studies with a larger number of patients are needed for more accurate statistics. Also, non use of the pixel analysis method (a far more sensitive than the mean CT attenuation analysis) because of the technical difficulties regarding the software art capable of displaying a pixel map in the form of a histogram. Further limitation was missing of the follow up and/or histopathology of some patients with unknown outcome.

In conclusion, washout rate of 15-min delayed MDCT images could be a valuable diagnostic tool for adrenal adenoma. Using the 15-min washout rate with APW $\geqslant 60$ (sensitivity was 100%, specificity was 100%, PPV was 100%, NPV was 100% and the accuracy was 99%) and/or RPW $\geqslant 40$ (sensitivity was 100%, specificity was 100%, PPV was 100%, NPV was 100% and the accuracy was 98.9%) is significantly accurate in the diagnosis of adrenal incidentalomas and differentiation between adenoma (regardless its lipid content) and non-adenoma lesions.

Conflict of interest

None.

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