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Unenhanced velocity-selective MR angiography (VS-MRA): Initial clinical evaluation in patients with peripheral artery disease

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Abstract

Background: Safe and accurate imaging of the peripheral arterial system is important for diagnosis and treatment planning of patients with peripheral artery disease (PAD).

Purpose: To evaluate image quality and diagnostic performance of unenhanced magnetic resonance angiography (MRA) based on velocity-selective (VS) magnetization preparation (termed VS-MRA).

Study Type: Prospective

Population: 31 symptomatic PAD patients underwent VS-MRA. Twenty four of them underwent clinical digital subtraction angiography (DSA) examination, 18.8 ± 5.2 days after the MR scans.

Field Strength/Sequence: 1.5T MRI which included VS-MRA (home-made research sequence) and phase-contrast flow imaging (clinical sequence).

Assessment: Image quality (0: non-diagnostic – 3: excellent) and stenosis severity (0: normal – 3: occlusion) of VS-MRA images were assessed independently by three reviewers. Arterial signal-to-noise-ratio (SNR) and artery-to-muscle contrast-to-noise ratio (CNR) were calculated.

Statistical Tests: The sensitivity and specificity of VS-MRA were calculated for the detection of significant stenosis (>50%) with DSA as the reference standard. Inter-observer agreement among the three reviewers was evaluated by using Cohen κ -statistics.

Results: The image quality score of VS-MRA was 2.7 ± 0.5 for Reader 1, 2.8 ± 0.5 for Reader 2 and 2.8 ± 0.4 for Reader 3; SNR and CNR were 37.8 ± 12.5 and 30.5 ± 11.8, respectively. Segment-based analysis revealed that VS-MRA had sensitivities of 85.3 %, 74.5 % and 78.4 % respectively

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for the three reviewers, and specificities of 93.5 %, 96.8% and 95.2 %. The inter-observer agreement for the stenosis grading was good, as demonstrated by Cohen κ values of 0.76 (Reader 1 versus Reader 2), 0.82 (Reader 1 versus Reader 3) and 0.79 (Reader 2 versus Reader 3).

Data Conclusion: Unenhanced VS-MRA allows clear depiction of the peripheral arteries and accurate stenosis grading, as evidenced by high image quality scores and strong agreement with DSA.

Keywords

Unenhanced MRA; velocity-selective magnetization preparation; peripheral artery disease

Introduction

Catheter-based x-ray arteriography has long been the reference standard for depiction of the arterial circulation in patients with peripheral artery disease (PAD), but is invasive and expensive, and involves the risk of arterial complications (1,2). Non-invasive alternatives such as computerized tomography angiography (CTA) and contrast-enhanced magnetic resonance angiography (CE-MRA) have been increasingly used in clinical practice (3–8). They however suffer from limitations including the risks of adverse effects of ionizing radiation (CTA) and nephrogenic systemic fibrosis (CE-MRA) (9,10).

Unenhanced MRA is an ideal approach for safe imaging due to the absence of invasiveness, ionizing radiation and external contrast agents, and a variety of techniques have been developed in recent decades. Time-of-flight (TOF) is the most classical unenhanced approach, but suffers from the saturation of blood residing in the imaging volume, being barely used for peripheral applications (11). Flow-sensitive subtractive approaches enable excellent suppression of background tissues and 3D encoding, but need two acquisitions which increases scan time and motion sensitivity (12–16). Quiescent single shot imaging (QISS) is an inflow-based 2D multi-slice method employing slice-selective saturation preparation and delay period until the data acquisition, and has shown high diagnostic accuracy in a number of clinical studies (17–20). Potential limitations appear to be suppression of in-plane-oriented vessel segments and limited superior-inferior (S-I) resolution due to limited minimal thickness of slice excitation.

Another recently developed unenhanced MRA method relies on Fourier-based velocity-selective (VS) magnetization preparation to generate angiographic contrast (21,22). Designed based on the excitation k-space formalism (23,24), VS magnetization preparation selectively excites magnetic spins based on their velocities with flexible excitation profiles over the velocity, and has compelling advantages in its use in angiography. First, the spatially non-selective nature allows the use of 3D encoding which offers high signal-to-noise-ratio (SNR) and high spatial resolution in all three dimensions but is difficult to use in inflow-based methods. Second, by allocating the velocity passband and stopband to arterial blood and background tissues, respectively, positive angiographic image contrast can be obtained directly using a single acquisition without subtraction. This is superior to the subtractive 3D techniques which require subtraction between flow-suppressed and baseline images (12–16). Recent studies on this technique (hereafter termed VS-MRA) have shown

great promise for diverse arterial territories including renal, peripheral, cerebral and pedal arteries (21,22,25,26). This article aims to evaluate image quality and diagnostic performance of unenhanced VS-MRA in PAD patients.

Materials and Methods

Study population

This study was health insurance portability and accountability act (HIPAA) compliant with the study protocol approved by the Institutional Review Board (IRB). The purpose and procedure of the study was explained to all participants, and informed written consent was obtained before enrollment.

We prospectively recruited thirty one patients with known or suspected symptomatic PAD from the vascular clinic at the University of Maryland Medical Center (mean age = 60.9, 22 men aged 49 – 75 and 9 women aged 52 – 77). Exclusion criteria were general contraindications to MR examination (claustrophobia, pacemaker, and aneurysm clip) and all metallic implants which can cause severe image artifacts with balanced steady-state free precession (bSSFP) readout sequence used in VS-MRA. Twenty-four patients underwent both unenhanced VS-MRA and DSA (mean age = 59.8, 17 men aged 49 – 75 and 7 women aged 52 – 77), while 7 participants underwent only VS-MRA. The patients underwent DSA examinations 18.8 ± 5.2 days later than the MR examinations with no vascular intervention between the MR and DSA studies.

Imaging Protocols

Unenhanced VS-MRA was performed on a Siemens 1.5T clinical MR scanner (Avanto; Siemens Medical Solutions, Erlangen, Germany) equipped with maximum gradient amplitude of 45 mT/m and maximum slew rate of 200 mT/m/s. Three 6-channel body coils and a spine matrix coil were simultaneously used for signal reception from the pelvis through lower legs. Four stations were used for S-I coverage of $4 \times 24 = 96$ cm while the stations were numbered 1 and 4 for the most inferior and superior levels, respectively (Refer to Fig. 2). All subjects were placed in the supine, feet-first position.

Velocity-selective MRA pulse sequence was electrocardiographically triggered, and consisted of a VS preparation pulse, a fat saturation pulse and a segmented 3D bSSFP acquisition in each cardiac cycle (Fig. 1A). The VS preparation pulse consisted of five RF hard pulses for excitation (black) and four $90_x-180_y-90_x$ composite pulses for refocusing (blue), interleaved with a series of unipolar gradients for velocity encoding (Fig. 1B) (22). Figure 1C shows numerical simulations of resultant longitudinal magnetization as a function of spin's velocity in the S-I direction. Two different VS gradient waveforms were assumed in the simulation (solid and dotted). The nominal VS gradient waveform (solid lined) was first designed for a target velocity passband of [3, 54] cm/s for station 1 in the lower extremities. For other stations in more superior levels, the gradient waveform was scaled down incrementally, which stretched the excitation profile along the velocity axis and therefore widened the velocity passband at the same rate. The scaling factors for 3 superior stations were pre-set based on expected velocity ranges (Table 1). The dotted lines in Figs

1B and 1C represent the case of a scaling of 50% and were used for station 4 in the pelvis. The flip angle of VS excitation determines the longitudinal magnetization of stationary spins in the velocity stopband, and was set to 110° considering incomplete M_z recovery since the end of the acquisition in the previous cycle and post-prep delay time of 100 ms used for eliminating eddy current effects. The imaging parameters for the four stations are summarized in Table 1.

Phase-contrast (PC) flow MRI was performed to determine the cardiac trigger delay TD for the VS preparation pulse. The imaging parameters included $FOV = 36 \times 16 \text{ cm}^2 / 36 \times 24 \text{ cm}^2$ (station 2 / station 4), resolution = $1.4 \times 1.3 \text{ mm}^2 / 1.4 \times 1.9 \text{ mm}^2$, VENC = 60 cm/s / 90 cm/s, and scan time = 40 sec / 60 sec. Reconstructed phase images were loaded on a vendor-provided application tool “mean curve”, and two circular regions-of-interest (ROIs) were placed on major arteries of both legs (e.g. right and left iliac arteries for station 4). From the resultant two time curves, TD was determined as the mean of the times to peak flow in the right and left legs. Flow imaging and analysis were performed for stations 2 and 4 only, and the TDs for stations 1 and 3 were determined by adding 30 ms to the TDs for stations 2 and 4, respectively. Using the acquired flow data in stations 2 and 4, the efficacy of the VS excitation profile was investigated by calculating the percentage of measured arterial blood that is included in the velocity passband.

Image and Statistical Analysis

VS-MRA images were reconstructed from two-fold undersampled k-space data using self-consistent parallel imaging (SPIRiT) reconstruction which improves the reconstruction accuracy by maximally enforcing the coil calibration consistency throughout the entire k-space (27). Coronal partial maximum intensity projection (MIP) images were created with a projection width of 6 – 8 cm. The SPIRiT reconstruction and MIP generation were done off-line in matlab (Mathworks, Natick, MA).

The image quality of MIP formatted VS-MRA images was independently assessed by three readers with 15 years (S.R.), 12 years and 6 years (A.U.C.) of experience in vascular imaging, respectively. The MR images were anonymized (tagged by random numbers), and both readers were not involved in the clinical readings of the MR scans and were blinded to the corresponding patient's clinical history. Their evaluation was performed on a four-point scale (0- non-diagnostic due to severe arterial signal loss and/or poor background tissue suppression, 1- fair diagnostic arterial display with medium background tissue artifacts, 2- good diagnostic arterial display with minor background tissue artifacts, 3- excellent diagnostic arterial display with no background tissue artifact) after dividing the arterial tree into the following 18 segments: common iliac artery, external iliac artery, common femoral artery, superficial femoral artery, popliteal artery, tibiofibular trunk, anterior tibial artery, posterior tibial artery, and peroneal artery for each of the left and right limbs.

The SNR of the artery and the artery-to-background contrast-to-noise ratio (CNR) were calculated on 5 equally spaced axial slices for each of the 4 stations. On each slice, two bilateral polygonal ROIs were specified for each of arterial blood and nearby background region. The ROIs for background region enclosed venous blood and muscle adjacent to the arterial ROI. Also, four polygonal ROIs were specified in airspace free of image artifacts,

and the mean of four standard deviations was used as noise in calculating SNR and CNR values. Arterial SNR was defined as the signal intensity of arterial ROI divided by the noise. Artery-to-background CNR was defined as the difference between the arterial and background signal intensities divided by the noise.

The severity of arterial stenosis was evaluated on both MRA and DSA images, based on the 18 segment-model used for the MR image quality assessment. The evaluation of MRA images was done independently by the three readers who scored the MR image quality. DSA images were assessed in consensus by two vascular surgeons with 19 years (R. S.) and 10 years (R. S. C.) of experience in peripheral DSA examination. The stenosis severity of each segment was graded based on a 4-point scale: 0-normal, 1-less than 50% stenosis, 2-greater than 50% stenosis, 3- occlusion.

On the segments that were available on both MR and DSA images, sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV) and accuracy of VS-MRA were calculated for determination of nonsignificant (<50%) versus significant (50%–100%) stenosis, with DSA as the reference standard. All the diagnostic measures were calculated on per-segment and per-region bases. For the per-region calculation, each limb was divided into three regions and the score for the most severe stenosis in each region was used. The Cohen κ statistics was used to evaluate inter-observer agreement in the assessment of significant arterial stenosis in VS-MRA (28).

Results

For all 31 participants, clinical indications based on the Rutherford classification were mild claudication (class I) in 2 patients (6.5%), moderate claudication (class II) in 3 patients (9.7%), severe claudication (class III) in 20 patients (64.6%), rest pain (class IV) in 4 patients (12.9%) and ischemic ulceration (class V) in 2 patients (6.5%). Ankle-brachial index (ABI) was available in the 49 limbs in 26 patients, with normal ABI in 12 limbs (mean, 0.90; range, 0.9 – 1.17) and ABI of less than 0.9 in 37 limbs (mean, 0.75; range, 0.20 – 0.86). Diabetes (10 of 31 patients, 32.3%) and hypertension (22 of 31 patients, 71.0%) were relatively common conditions.

From VS-MRA images (which would ideally have yielded $31 \times 18 = 558$ arterial segments), 535 segments were available for analysis while 23 segments could not be obtained due to claustrophobia that disabled scanning at 1 or 2 superior stations, and/or sub-optimal localization of the imaging FOV which failed to capture common iliac arteries. From DSA performed in 24 patients, 306 arterial segments were available as a result of selective imaging at the vascular regions of clinical interest. Of the 306 DSA segments, 105 segments (34.3%) were classified as hemodynamically significant stenosis (< 50%), and 61 segments (19.9%) were classified as occlusion. Figures 2–4 illustrate representative VS-MRA and DSA images in three patients.

For the 535 arterial segments available in VS-MRA, the image quality score was 2.7 ± 0.5 (in the scale of 0–3) for Reader 1, 2.8 ± 0.5 for Reader 2, and 2.8 ± 0.4 for Reader 3. Four segments (0.9%) were rated as non-diagnostic (score 0) by at least one reviewer, and their

anatomical locations were iliac arteries (n=2) and femoral arteries (n=2). The retrospective analysis revealed that all the four non-diagnostic segments involved arterial signal loss presumably due to severe B_1 field inhomogeneity which distorts the excitation profile. One thousand fifty three ROIs were available for SNR and CNR calculations from 20 equally spaced axial slices for each subject. Collectively, arterial blood SNR and artery-to-muscle CNR were 37.8 ± 12.5 and 30.5 ± 11.8 , respectively. As seen in Fig. 5, CNR decreases significantly as the S-I spatial offset from isocenter increases in each station. This variation is likely due to larger B_0 and B_1 field variations at larger S-I offsets (29). The field errors cause decrease in arterial signal and increase in background tissue signal, which collectively contribute to the reduction of CNR.

The cardiac trigger delay for the VS preparation pulse was 192.6 ± 29.7 ms for station 4 (iliac artery) and 273.6 ± 35.7 ms for station 2 (popliteal artery). Deviation of the trigger delay from the actual time to peak flow in each of the right and left legs was 9.3 ± 8.7 ms (range, 0 – 30 ms) in station 4, and 20.7 ± 16.2 ms (range, 0 – 50 ms) in station 2, which shows larger difference of peak flow times between legs in distal arteries. Collectively over station 2 and station 4, Spearman correlation coefficient for the deviation from peak flow time versus arterial SNR was -0.06 ($P=0.55$), which implies very weak correlation between the two variables and therefore negligible effect of suboptimal trigger delay on depiction of the arteries. The measured arterial flow velocity ranged 9.2 cm/s to 118.3 cm/s (mean = 61.3 cm/s) in station 4, and ranged 1.7 cm/s to 40.5 cm/s (mean = 27.6 cm/s) in station 2. Across 31 patients, the percentage of arterial voxels that are included in the velocity passband was 96.8 % and 93.2% in station 4 and station 2, respectively.

Two hundred eighty eight arterial segments were available in both DSA and MRA images and were used for diagnostic testing. The sensitivity of VS-MRA for detecting significant stenosis for the three reviewers was 85.3 % (87/102), 74.5 % (76/102) and 78.4 % (80/102) when calculated on a per-segment basis, and 96.4 % (53/55), 89.1 % (49/55) and 90.9 % (50/55) when calculated on a per-region basis. The specificity was 93.5 % (174/186), 96.8 % (180/186) and 95.2 % (177/186) on a per-segment basis, and 92.0% (46/50), 96.0 % (48/50) and 94.0 % (47/50) on a per-region basis. Other diagnostic measurements are summarized in Table 2. Cohen κ values regarding inter-observer agreement were 0.76 between Reader 1 and Reader 2, 0.82 between Reader 1 and Reader 3, and 0.79 between Reader 2 and Reader 3. Excellent agreement between the two readers was observed regarding the stenosis evaluation, as demonstrated by Cohen κ values of 0.82 (on a per-segment basis) and 0.87 (on a per-region basis).

Discussion

Velocity-selective magnetization-prepared imaging is a new unenhanced MRA method, which generates angiographic contrast by suppressing stationary tissues while highlighting relatively fast-moving arterial blood based on their velocities. This technique uses a single acquisition without the need for subtraction of two images and allows high spatial resolution in all 3 dimensions. Other advantages include high SNR and high capacity for scan acceleration due to the use of 3D encoding, and robustness to cardiac arrhythmia due to the dependence only on systolic phase. The presented study is the first clinical testing of the VS-

MRA technique in the entire peripheral arterial trees of PAD patients with DSA as the reference.

The VS preparation pulse used in this study is robust to B_0 field error due to the use of refocusing pulses, but involves sensitivity to B_1 field inhomogeneity. The error of refocusing pulses (blue colored in Fig. 1B) prevents spins from being accurately dephased based on their velocities and might erroneously suppress arterial blood in the velocity passband. The error of hard pulses (black colored in Fig. 1B) causes inaccurate excitation flip angle in the velocity stopband and therefore suboptimal background suppression. B_1 error is typically larger at larger offset from the isocenter, which explains CNR distribution of parabolic shape along the S-I direction in each station. According to Bloch simulations using expected ranges of B_0 variation (± 50) and B_1 variation (20%) at 1.5T, the arterial signal calculated as the average of passband signal, can decrease by $0.18M_0$ and the stationary tissue signal can increase by $0.47M_0$. Overall, the B_1 error seemed to affect the diagnostic performance of VS-MRA only marginally in this study performed at 1.5T, but might be a serious issue at 3T or higher fields. Recently, advanced versions of VS excitation pulse sequences have been developed which reduced the B_1 sensitivity through the use of two or four refocusing pulses and may be good alternatives at high field (25,29).

The VS preparation pulse has 1D velocity selectivity in the S-I direction, which raises a concern that arterial segments oriented orthogonal to the S-I direction might be suppressed undesirably. However, we have found that most of horizontally oriented vessel segments were well visualized without noticeable signal loss. We presume that a significant portion, though not all, of arterial blood spins in horizontal vessel segments still has vertical velocity component due to the curvy nature of nearby vessels. In fact, the weak dependence of the direction of velocity selectivity has been observed in other independent studies which also use 1D velocity sensitivity. Velocity-selective arterial spin labeling was found to produce nearly the same perfusion measurements using any of three orthogonal directions only if the cut-off velocity is reasonably small (30). Very recently, application of VS-MRA for the cerebral arteries yielded only marginal difference in resultant angiograms obtained using VS preparations along each of three orthogonal directions (25). Nevertheless, it will be worthwhile to test VS preparation in R-L or anterior-posterior (A-P) direction and examine if the resultant angiograms improve delineation of any vessel segments compared to the S-I selective angiogram particularly in patients with advanced PAD.

The total scan time of the 4-station protocol ranged 15 – 20 min depending on heart rates. This appears to be long when compared with QISS technique which takes less than 10 min, but can be reduced relatively easily in the following ways. While the present study used coronal scan orientation with high in-plane resolution (S-I and R-L directions), we can use axial scan orientation with relaxed S-I resolution as in QISS protocols (e.g. 3 mm) under assumption that peripheral arteries are orientated primarily in the S-I direction. Furthermore, the rate-2 parallel imaging reconstruction used in this study can be easily combined with partial Fourier (as in QISS) and/or compressed sensing which looks promising due to “sparse” nature of VS-MRA images. In fact, the scan time would have been nearly same as QISS if scan orientation, spatial resolutions in 3 dimensions, scan acceleration factors were all same.

One issue in determining the trigger delay is that the timing of peak systolic flow varies between two legs particularly in the presence of stenosis. If the trigger delay is chosen from the flow data in open vessels in one leg, the VS preparation will not be optimal in the stenotic parts possibly in the other leg. We feel that even with sub-optimal trigger delays, arterial flow velocity is likely greater than the lower bound of the velocity pass-band if the deviation from the optimal value is not very large. Still, further investigation would be warranted to estimate the tolerance and effect of suboptimal trigger delays in a large cohort of subjects.

Despite the use of DSA as the reference standard, the lack of comparison with other MRA techniques is a limitation of this work. Gadolinium-based contrast-enhanced imaging is the most established MR approach for peripheral angiography. Among existing unenhanced MR approaches, QISS has shown the greatest promise in peripheral territories. QISS has little sensitivity to field errors and is easy to use, but is expected to allow lower S-I resolution and SNR (due to the use of 2D multi-slice acquisition) than VS-MRA. The clinical value of VS-MRA needs to be further verified through systematic comparisons with CE-MRA and QISS techniques in PAD patients.

In conclusion, unenhanced MRA with VS magnetization prepared imaging (VS-MRA) enables clear delineation of the entire peripheral arterial tree and accurate detection of arterial stenosis, as evidenced by high image quality scores and strong diagnostic agreement with DSA. While this initial clinical test demonstrates the potential of VS-MRA as a safe and accurate tool for the evaluation of PAD, comparisons with other MRA methods are warranted.

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Figure 1:

A: Timing diagram of velocity-selective (VS) magnetization-prepared MRA pulse sequence.

B: VS magnetization preparation pulse consists of hard RF pulses (black) and refocusing RF pulses (blue) interleaved with velocity-selective unipolar gradients played in the superior-inferior direction. C: Bloch simulation of resultant longitudinal magnetization (M_z) where positive velocity represents arterial flow direction. The M_z profile is scalable along the velocity dimension by scaling the gradient waveform (solid versus dotted lines).

Figure 2: Coronal maximum intensity projection (MIP) and selected axial images of VS-MRA, and DSA images in a 61-year-old male patient with mild right-sided claudication (Rutherford class I). The MR angiogram shows excellent agreement with the DSA image in identifying mild intermittent narrowings in the right femoral artery (arrowheads) and occlusion of the right anterior tibial artery (arrow). The plots on the right show flow velocity-time curves measured by phase-contrast MRI (on stations 2 and 4), based on which the cardiac trigger delays were determined.

Figure 3:

Coronal MIP and selected axial images of VS-MRA, and DSA images in a 56-year-old male patient with severe right sided claudication (Rutherford class III). Ankle brachial index (ABI) was 0.6 in the right leg and 1.0 in the left leg. Occlusion of the right superficial femoral artery and nearby collateral arteries are well visualized by VS-MRA with good agreement with DSA (arrows). Note that the arterial flow in the right popliteal artery measured by PC flow MRI in station 2, is substantially slowed down.

Figure 4:

VS-MRA and DSA images in a 56-year-old male patient with severe bilateral claudication (Rutherford class IV). ABI was measured as 0.2 in the right limb and 0.6 in the left limb. Despite small thickness and likely slow flow in the diseased regions, VS-MRA well depicts diffuse vasculature due to high velocity sensitivity and high 3D spatial resolution. Arterial flow could not be obtained on the right leg in station 2 due to the absence of vessels of measurable size.

Figure 5:

Artery-to-muscle CNR measured at equally-spaced 20 axial slices across the 4 stations. ‘S’ and ‘I’ represent superior and inferior directions, respectively and the subsequent number means spatial offset from isocenter in the unit of millimeters. Collectively over the entire ROIs, the average and standard deviation are 30.5 and 11.8, respectively. Within each station, a parabolic distribution is observed due to larger B_0 and B_1 field offsets at larger S-I offsets.

Table 1:

Imaging parameters of 4-station VS-MRA

Station	1	2	3	4
TR/TE (msec)	4.0/2.1	4.0/2.1	4.0/2.1	4.0/2.1
FOV (RL×SI×AP, cm ³)	36×24×9.6	36×24×13.6	36×24×17.6	36×24×23
Resolution (RL×SI×AP, mm ³)	1.1×1.1×1.2	1.1×1.1×1.7	1.1×1.1×2.0	1.1×1.1×2.4
Scaling factor for VS gradient	1.0	0.85	0.7	0.5
Parallel imaging factor	2	2	2	2
Views per segment	44	44	44	44
Scan time (cardiac cycles)	320	320	352	384

Table 2:

Diagnostic performance for detection of significant stenosis (>50%).

Test Characteristic	Reviewer 1		Reviewer 2		Reviewer 3	
	Per Segment	Per Region	Per Segment	Per Region	Per Segment	Per Region
Sensitivity (%)	85.3 (87/102)	96.4 (53/55)	74.5 (76/102)	89.1 (49/55)	78.4 (80/102)	90.9 (50/55)
Specificity (%)	93.5 (174/186)	92.0 (46/50)	96.8 (180/186)	96.0 (48/50)	95.2 (177/186)	94.0 (47/50)
PPV (%)	87.9 (87/99)	93.1 (54/58)	92.7 (76/82)	96.1 (49/51)	89.9 (80/89)	94.3 (50/53)
NPV (%)	92.1 (174/189)	97.9 (46/47)	87.4 (180/206)	88.9 (48/54)	88.9 (177/199)	90.4 (47/52)
Accuracy (%)	90.6 (261/288)	95.2 (100/105)	88.9 (256/288)	92.4 (97/105)	89.2 (257/288)	92.4 (97/105)