VOLUME-9, ISSUE-2, FEBRUARY-2020 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper

Nephrology

EVALUATION OF VASCULAR AGING AND ARTERIAL STIFFNESS IN PATIENTS WITH CHRONIC KIDNEY DISEASE AND ASSOCIATED HYPERTENSION

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ABSTRACT

BACKGROUND: Patients with chronic kidney disease (CKD) on dialysis have high risk of cardiac diseases. Vascular aging (VA) and arterial stiffness (AS) are the major determinants of cardiovascular events. The present study assessed the parameters of VA and AS by oscillometric device in patients with CKD and associated hypertension.

MATERIALS AND METHODS: A prospective study was conducted in patients with CKD on dialysis with associated hypertension. Central blood pressure (BP) and AS were measured using the Mobil-O-Graph® PWA. It provides information about peripheral BP, vascular age, augmentation index and PWV. This validated device is a commercially available branchial oscillometric ambulatory BP monitor. Statistical analysis was performed using Chi-square, sample t and Mann Whitney U test.

RESULTS: A total of 303 patients with a mean age of 50.70 years were included in this study. The mean age was significantly higher in patients with large arteries of abnormal AS (64.05 years) ($p<0.001$). The mean VA was significantly higher in patients with average large arteries than normal large arteries ($p<0.001$). A significant association was observed between large normal, average and abnormal AS in peripheral systolic BP, pulse pressure, mean arterial BP and pulse wave velocity (PWV, [$p<0.001$]). Significant increase in trend in VA and PWV were observed with increasing age ($p<0.001$). A significant association was observed between PWV and body mass index, VA, AS and peripheral and central BP ($p<0.001$).

CONCLUSION: The overall observation suggests an increasing trend in oscillometric measurement of PWV, VA, AI with increase in the severity of AS. Theses parameters are indicative of cardiac events associated with CKD.

KEYWORDS : Augmentation Index, Blood Pressure, Cardiovascular, Oscillometric, Pulse Wave.

INTRODUCTION

Current lifestyle and stress factors have continued to increase the burden of chronic kidney diseases (CKD) ascribed to hypertension, diabetes, genetic factors and infections. Progressive CKD is associated with a wide range of complications including cardiovascular (CV) diseases, hypertension, anemia, bone disorders and dyslipidemia [1]. Association of hypertension and CKD is a vicious cycle, interlinked with each other. It damages the arteries with loss of arterial elasticity, resulting in arterial stiffness (AS), vascular dysfunction and finally CV events [2,3]. Its treatment involves a combination of antihypertensive drugs belonging to different classes that reduce BP [4,5], thus discharging the stiff arterial components causing a decrease in AS resulting a drop-in pulse wave velocity (PWV) [6,7]. Thus, AS is measured in terms of PWV.

Vascular aging (VA) and AS are prominent features of patients with CKD [8,9]. Scientific studies report stiffer arteries in dialysis patients than non-uremic [10]. The major causative factor of AS in these patients is BP rather than renal function. Mechanisms involved in AS in CKD patients is complex and still under research, however, studies suggest that dialysis stimulates chronic inflammation and oxidative stress, adversely affecting the arterial wall resulting in arterial stiffening and vascular impairment [11-13].

Oscillometric technique is used currently to detect AS and central hemodynamics. It is reliable, reproducible and inexpensive; suitable for community-based intervention programs. It measures aortic pressure, BP, PWV and augmentation index (AI). It is an important diagnostic means supporting the management of hypertensive patients with improved compliance. Research suggest greater than 40% patients on dialysis die due to CV diseases. Covic et al. [14] demonstrated that PWV and AI increase as the coronary vessels are affected adversely suggesting it to be an independent prognostic factor for CV morbidity and mortality. The vascular measurements guide to initiate the specific therapy through individual risk classification and hemody namics data [15].

Literature reports a strong association between PWV and AS with hypertension especially in elderly. Evaluating AS is a well-established diagnostic tool, hence, endorsed by Hypertension guidelines. Studies suggest, early treatment measures can reverse AS that could help in preventing hypertension and accompanying clinical conditions [16-18].

Limited studies are conducted in Indian population to determine the occurrence and profile of AS and VA in patients with CKD on dialysis with associated hypertension. This study is aimed to investigate the severity of AS and VA by measuring PWV in these patients using oscillometric device to determine the trend in Indian population. This study can help establish the CKD stage at which AS and VA become apparent in renal patients and their role in CV events.

METHODS AND MATERIALS

This was prospective study conducted at a tertiary care center. Patients of either sex with a diagnosis of CKD on dialysis and with associated hypertension were included in the study. The detailed medical history and demographic details [age, sex, body mass index (BMI), BP] were collected for each patient.

Central blood pressure (cBP) and AS were measured using the Mobil-O-Graph® PWA (I.E.M. GmbH, Stolberg, Germany). This device is a commercially available branchial oscillo metric ambulatory BP monitor and has been validated according to British Hypertension Society and European Society of Hypertension recommendations [19]. A common cuff was centered to the left upper arm. Cuff size was chosen according to the circumference of the mid upper arm. Mobil-O-Graph® PWA provides information about peripheral BP, vascular age, AI and PWV.

The primary outcomes of this study were PWV, AI, AS of large

and small arteries and VA and secondary outcomes were central and peripheral BP.

STATISTICAL ANALYSIS

Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 23.0. Analysis of categorical variables using Chi-square test and continuous variables using independent sample t-test and One-way ANOVA were done. Correlation analysis between AS and VA were done using Spearman's correlation coefficient (Non-parametric test was used because data were not normally distributed). Comparative analysis of quantitative parameters in patients with AS was performed using Mann Whitney U test (not normally distributed data) or independent sample t-test (normally distributed data).

RESULTS

A total of 303 patients diagnosed with CKD on dialysis associated with hypertension were included in this study. The mean age was 50.70 years and there was a prevalence of men (n=203; 67%). Demographic and clinical characteristics are summarized in Table 1

Table 1. Demographic and clinical characteristics of partic ipants

Characteristics	Total (N=303)
Age (years)	50.70 (14.23)
Sex, n (%)	
Men	203 (67)
Women	100 (33)
BMI (kg/m2)	23.39 (4.66)
Peripheral blood pressure (mmHg)	
Systole	128.58 (20.50)
Diastole	86.70 (16.09)
Pulse pressure (mmHg)	43.18 (12.23)
Heart rate per minute (bpm)	83.44 (16.92)
Mean arterial BP (mmHg)	105.58 (17.44)
Augmentation index (%)	25.98 (12.49)
Pulse wave velocity (m/s)	7.64 (1.72)
Vascular age	52.74 (14.06)
Central blood pressure (mmHg)	
Systole	118.57 (19.49)
Diastole	87.46 (18.48)
Arterial stiffness	
Small arteries	25.76 (12.64)
Large arteries	7.64 (1.72)
Data represented as median (SD), unless otherwise specified. BMI, body mass index; BP, blood pressure.	

ARTERIAL STIFFNESS

Small and large arteries were categorized into normal (<27 and <6.9), average (28-40 and 7-8.2) and abnormal (>40 and >8.3) AS (Table 2).

Table 2. Arterial stiffness wise analysis

Parameters	Arterial Stiffness						p-value	
	Normal		Average		Abnormal			
	Small	Large	Small	Large	Small	Large	Small	Large
Age (years)	35.5 (11-69)	36.33 (10.44)	52 (28-61)	51.74 (6.10)	64.00 (45-81)	64.05 (7.12)	>0.05[a, b,c]	0.001[a, b, c]
Sex, n (%) Men Women	77 (72.6) 29 (27.4)	48 (53.3) 42 (46.7)	78 (72.9) 29 (27.1)	-				
BMI (kg/m^2)	23.51 (4.91)	22.45 (11.72-67.21)	22.98 (4.07)	23.93 (16.53-33.30)	23.94 (4.99)	23.23 (16.44-37.83)	0.518	0.012[a], 0.562[b] ,0.042[c]
Vascular age (years)	51.66 (14.06)	37.00 (22.00-75.00)	53.22 (13.85)	53.00 (37.00-61.00)	51.60 (15.54)	62.00 (0.00-86.00)	>0.05[a, b,c]	<0.001[a] 0.013[b], 0.024[c]
Peripheral BP								
Systole (mm Hg)	124.93 (18.05)	119.00 (16.57)	133.91 (21.16)	129.83 (16.81)	131.5 (26.35)	137.02 (22.86)	<0.001[a, b,c]	0.001[a, b] 0.027[c]
Diastole (mm Hg)	84 (52-143)	80 (52-125)	88 (58-126)	85.00 (58.00-143)	81 (63-164)	88.00 (60.00-164.00)	0.005[a], 0.130[b], 0.871[c]	<0.001[a,c] 0.099 [b]
Pulse Pressure (mmHg)	41.2 (12.39)	38.5 (11-127)	45.08 (10.69)	42 (24-67)	47.4 (14.07)	46 (24-87)	>0.05[a, b,c]	<0.001[a, b,c]
Heart rate (bpm)	77.5 (13.98)	86.06 (19.02)	88.57 (15.45)	82.34 (16.31)	98.76 (20.50)	81.74 (14.91)	<0.001[a, b,c]	>0.05[a, b,c]
Mean arterial BP (mmHg)	97 (59-142)	97 (59-142)	105(65-163)	105 (65-163)	110 (43-172)	110 (43-172)	0.002[a], 0.264[b], 0.525[c]	<0.001[a, b] 0.028[c]
Augmentation Index (%)	19 (-10-27)	24.74 (14.01)	33 (28-40)	26.35 (11.17)	45 (41-90)	26.90 (11.95)	<0.001[a, b,c]	>0.05[a, b,c]
PWV (m/s)	7.47 (1.68)	5.85 (4.10-6.90)	7.91(1.71)	7.55 (7-8.20)	7.64 (1.89)	9.3 (8.3-12.4)	>0.05[a, b,c]	<0.001[a, b,c]
Central BP (mmHg)								
Systole	109 (63-152)	110.12 (15.51)	119(84-171)	120.52 (15.20)	123(18-197)	125.30 (23.00)	<0.001[a], >0.05[b,c]	<0.001[a, c], 0.212[b]

Diastole	80 (52-125)	81.00 (84-127)	85 (58-143)	88.83 (59-198)	88 (60-164)	89.00 (62-150)	0.005[a], >0.05 [b,c]	0.002[a], 0.001[b], 0.137[c]

Data represented as mean (SD), unless otherwise specified.
Statistical analysis: One-way ANOVA (For normally distributed data- independent sample t-test, For not normally distributed data- Mann Whitney U test).
a, normal vs. average; b, average vs. abnormal; c, normal vs. abnormal.
BMI, body mass index; BP, blood pressure; PWV, pulse wave velocity.

Mean age was significantly higher in patients with large arteries of abnormal AS (64.05 years) compared to normal (36.33 years) and average AS (51.74 years) ($p<0.001$). In abnormal large AS, VA was higher compared to normal and average large AS ($p<0.024$). Also, the mean VA was significantly higher in patients with average large arteries than normal large arteries ($p<0.001$). A significant association was observed between large normal, average and abnormal AS in peripheral systolic blood pressure (SBP), pulse pressure, mean arterial BP and PWV ($p<0.001$). Increase in severity of small and large AS showed a significant increase in PWV. As the severity of AS increased in small arteries, there was a significant increase in heart rate and AI ($p<0.001$).

AGE GROUP WISE ANALYSIS

Mean BMI was higher in patients with age group of 31-60 years. Patients with age more than 60 years had BMI between the patients with age group of 10-30 years and 31-60 years ($p=0.005$). Significant increase in trend in VA and PWV were observed with increasing age ($p<0.001$). Arterial stiffness was comparable between normal, average and abnormal small arteries among age groups (Table 3). A significant association was observed between large AS and age ($p<0.001$).

Table 3. Age group wise analysis

Parameters	Group I (10-30 years) (n=38)	Group II (31-60 years) (n=186)	Group III (>60 years) (n=79)	P value
Sex, n (%) Men Women	33 (86.8) 5 (13.2)	116 (62.4) 70 (37.6)	54 (68.4) 25 (31.6)	-
BMI (kg/m^2)	21.97 (11.72-29.52)	23.36 (15.06-67.21)	23.15 (16.90-36.65)	0.005
Vascular age (years)	27 (22-37)	51 (0-75)	67 (46-86)	<0.001
Normal	12 (35.30)	82 (44.10)	26 (32.90)	0.200
Average	9 (26.50)	54 (29.00)	32 (40.50)	
Abnormal	13 (38.20)	50 (36.90)	21 (26.60)	
Arterial stiffness				
Small Arterial stiffness, n (%)				0.677
Normal	18 (47.4)	109 (58.6)	44 (55.70)	
Average	15 (39.5)	56 (30.10)	28 (35.4)	
Abnormal	5 (13.20)	21 (11.30)	7 (8.90)	
Large Arterial stiffness, n (%)				
Normal	37 (97.4)	68 (36.6)	1 (1.3)	<0.001
Average	1 (2.6)	86 (46.2)	3 (3.8)	
Abnormal	-	32 (17.2)	75 (94.9)	
Peripheral BP				
Systole (mmHg)	122.5 (97-175)	50 (31-60)	66 (61-81)	0.304[a], 0.983[b], 0.305[c]
Diastole (mmHg)	83.5 (52-120)	85 (54-164)	85 (60-126)	0.209[a], 0.465[b], 0.522[c]
Pulse pressure (mmHg)	43 (14-127)	41 (11-77)	41 (24-87)	0.608[a], 0.288[b], 0.907[c]
Heart rate (bpm)	87.89 (23.16)	84.33 (16.18)	79.17 (14.23)	0.698[a], 0.068[b], 0.026[c]
Mean arterial BP (mmHg)	102 (73-145)	104 (59-172)	119 (63-197)	
PWV (m/s)	5.28 (0.69)	7.26 (1.13)	9.63 (1.06)	<0.001[a, b,c]
Central BP (mmHg)				
Systole	113.00 (85.00-158.00)	119.00 (63.00-197.00)	117.00 (18.00-177.00)	0.176
Diastole	84.94 (16.75)	88.29 (20.70)	86.69 (12.92)	0.933, 1.000[b,c]

Data represented as mean (SD), unless otherwise specified.
Statistical analysis: One-way ANOVA (For normally distributed data- independent sample t-test, For not normally distributed data- Mann Whitney U test)a, Group I vs. Group II; b, Group II vs. Group III; c, Group I vs. Group III.
BMI, body mass index; BP, blood pressure; PWV, pulse wave velocity.

Mean peripheral SBP was lower in 31-60 years (50 mmHg) and more than 60 years (66 mmHg) age group of patients compared to 10-30 years (122.5 mmHg) age group of patients. Whereas, peripheral diastolic blood pressure, pulse pressure, cBP and drug treatment were comparable among all age groups. Heart rate per minute was significantly lower in patients with more than 60 years of age (79.17 per min) compared to patients with age group 10-30 years (87.89 per min) ($p=0.026$).

A positive correlation was observed between age and PWV, VA and larger AS ($p<0.001$). PWV was positively correlated with age, VA, pulse pressure ($p<0.001$). Augmentation index and VA were directly related to VA and large AS, respectively (Table 4).

Table 4. Correlation analysis between arterial stiffness and vascular age

Parameter 1	Parameter 2	Correlation coefficient	P value
Age (years)	PWV	0.911	<0.001
	Vascular age	0.942	
	Large arterial stiffness	0.911	
Peripheral systole BP (mmHg)	Peripheral diastole BP	0.742	<0.001
	Pulse pressure	0.611	
	Mean arterial BP	0.917	
	PWV	0.401	
	Central systole BP	0.931	
	Central diastole BP	0.771	
	Large arterial stiffness	0.401	

Peripheral diastole BP (mmHg)	Peripheral systole BP	0.742	<0.001
	Mean arterial BP	0.918	
	PWV	0.313	
	Central systole BP	0.817	
	Central diastole BP	0.980	
	Large arterial stiffness	0.313	
Pulse pressure (mmHg)	Peripheral systole BP	0.611	<0.001
	Mean arterial BP	0.409	
	PWV	0.314	
	Central systole BP	0.543	
	Large arterial stiffness	0.314	
HRT (bpm)	Augmentation index	0.532	<0.001
	Small arterial stiffness	0.538	
Mean arterial BP (mmHg)	PWV	0.392	<0.001
	Central systole BP	0.941	
	Central diastole BP	0.928	
	Large arterial stiffness	0.392	
PWV (m/s)	Vascular age	0.935	<0.001
	Central Systole BP	0.382	
	Central diastole BP	0.311	
Augmentation index (%)	Vascular age	0.934	<0.001
Vascular age (years)	Large arterial stiffness	0.935	<0.001
Central systole BP (mmHg)	Large arterial stiffness	0.369	<0.001

Statistical analysis: Spearman's correlation coefficient.
BP, blood pressure; HRT, heart rate, PWV, pulse wave velocity.

PULSE WAVE ANALYSIS

A significant increase in PWV was observed as the age increased ($p<0.001$). A significant association was observed between PWV and BMI, VA, AS and peripheral BP and cBP ($p<0.001$). A significantly higher PWV (9.7-12 m/s) was observed in patients with abnormal VA (48.60%) (Table 5).

Table 5. Pulse wave velocity wise analysis

Parameters	Pulse wave velocity (m/s)			P value
	Normal (<7)	Average (7-9.7)	Abnormal (9.7-12)	
Age (years)	36.33 (10.44)	55.85 (7.45)	70.34 (5.73)	<0.001
Sex, n (%)				0.026
Men	77 (72.6)	98 (60.5)	28 (80.0)	
Women	29 (27.4)	64 (39.5)	7 (20.00)	
BMI (kg/m^2), median (range)	22.45 (11.72-67.21)	23.90 (16.53-37.83)	22.51 (16.44-35.25)	0.003[a], 0.063[b], 0.850[c]
Vascular age (years)	38.36 (10.84)	57.67 (6.88)	73.52 (4.81)	<0.001
Normal	61 (59.80)	59 (36.40)	-	<0.001
Average	22 (21.60)	55 (34.00)	18 (51.40)	
Abnormal	19 (18.60)	48 (29.60)	17 (48.60)	
Small Arterial stiffness, n (%)				
Normal	70 (66.00)	86 (53.10)	15 (42.90)	
Average	24 (22.60)	59 (36.40)	16 (45.70)	0.060
Abnormal	12 (11.30)	17 (10.50)	4 (11.40)	
Large Arterial stiffness, n (%)				<0.001
Normal	106 (100.0)	-	-	
Average	-	90 (55.6)	-	
Abnormal	-	72 (44.4)	35 (100.0)	
Augmentation Index	24.74 (14.01)	26.36 (11.33)	27.97 (12.71)	0.357
Peripheral BP				
Systole (mmHg)	116 (65.16)	130.5 (87-202)	137 (112-201)	<0.001
Diastole (mmHg)	80.73 (13.47)	89.74 (10.95)	90.73 (14.4)	<0.001
Pulse Pressure (mmHg), median (range)	38.50 (11.00-127.00)	43.50 (24.00-69.00)	48.00 (33.00-87.00)	<0.001
Heart rate (bpm)	86.06 (19.02)	81.87 (15.31)	82.71 (16.73)	0.142[a], 1.000[b], 0.926[c]
Mean arterial BP (mmHg), median (range)	97.00 (59.00-142.00)	107.00 (43.00-172.00)	111.00 (87.00-159.00)	<0.001
Central BP (mmHg), median (range)				
Systole	109.00 (63.00-152.00)	120.50 (18.00-197.00)	124.00 (102.00-177.00)	<0.001
Diastole	81.00 (-84.00-127.00)	88.00 (59.00-150.00)	91.00 (67.00-128.00)	<0.001

Data represented as mean (SD), unless otherwise specified.
Statistical analysis: One-way ANOVA (For normally distributed data- independent sample t-test, For not normally distributed data- Mann Whitney U test).
a, normal vs. average; b, average vs. abnormal; c, normal vs. abnormal.
BMI, body mass index; BP; blood pressure.

VASCULAR AGE

Patients with average and abnormal VA showed a significantly higher PWV as compared to patients with normal VA ($p<0.001$). Augmentation index was significantly higher in patients with abnormal VA than with normal and average VA ($p<0.031$). There is a significant correlation of large AS with VA. Patients with abnormal VA displayed a significantly higher cBP and peripheral BP (Table 6).

Table 6. Vascular age wise analysis

Parameters	Vascular age			P value
	Normal (n= 120)	Average (n=95)	Abnormal (n=84)	
Age (years)	52.00 (23.00-70.00)	53.00 (24.00-81.00)	52.50 (20.00-81.00)	0.050
Sex, n (%)				
Men	77 (72.6)	98 (60.50)	28 (80.00)	0.437
Women	29 (27.4)	64 (39.5)	7 (20.00)	
BMI (kg/m^2)	22.67 (15.06-33.30)	23.51 (15.23-34.85)	22.96 (16.44-67.21)	0.120

Small Arterial stiffness, n (%)				
Normal	70 (66.00)	86 (53.1)	15 (42.9)	
Average	24 (22.6)	59 (36.4)	16 (45.7)	0.060
Abnormal	12 (11.3)	17 (10.5)	4 (11.4)	
Large Arterial stiffness, n (%)				
Normal	106 (100)	-	-	
Average	-	90 (100)	-	<0.001
Abnormal	-	72 (44.4)	35 (100)	
PWV (m/s)	6.90 (1.38)	8.01 (1.67)	8.40 (1.68)	<0.001[a,c]
Augmentation index (%)	23.94 (13.47)	24.91 (11.63)	29.68 (11.1)	0.004[a] 0.031[b,c]
Peripheral BP				
Systole (mmHg)	113.00 (65.00-133.00)	130.00 (97.00-144.00)	150.00 (87.00-202.00)	<0.001
Diastole (mmHg)	77.00 (52.00-99.00)	86.00 (65.00-126.00)	100.00 (71.00-164.00)	<0.001
Pulse pressure (mmHg)	36.00 (11.00-127.00)	41.00 (30.00-67.00)	50.50 (35.00-87.00)	<0.001
Heart rate	79.50 (5.10-121.00)	83.00 (47.00-161.00)	86.00 (52.00-124.00)	0.282
Mean arterial BP (mmHg)	93.00 (43.00-114.00)	106.00 (87.00-123.00)	122.00 (100.00-172.00)	<0.001
Central BP (mmHg)				
Systole	104.50 (63.00-127.00)	120.00 (102.00-133.00)	137.00 (18.00-197.00)	<0.001
Diastole	76.20 (17.52)	87.78 (8.80)	103.97 (15.22)	<0.001

Data represented as median (SD), unless otherwise specified.
Statistical analysis: One-way ANOVA (For normally distributed data- independent sample t-test, For not normally distributed data- Mann Whitney U test).
a, normal vs. average; b, average vs. abnormal; c, normal vs. abnormal.
BMI, body mass index; BP; blood pressure.

DISCUSSION

Prevalence of CKD in India is an emerging cause of morbidity and mortality due to the accompanying complications. Hypertension is another rampant health issue, the incidence of which increases with age and is also associated with CKD. The characteristic risk factors of CKD including VA and AS are being emphasized in medical science due to the prognostic value in early detection and prevention of cardiac diseases associated with CKD. The standard method used to assess AS is PWV that in turn predicts VA. It is strongly associated with age and BP wherein arterial elasticity is reduced, subsequently increasing the vascular stiffness [20,21]. Apart from CKD, arterial stiffness is a predictor of cardiovascular diseases [22] and also associated with type I diabetes along with its complications such as renal, cardiovascular, retinal diseases and autonomic neuropathy. Managing PWV using antihypertensives reduces associated mortality [23].

Evidences reveal that aortic stiffness is significantly higher in patients with CKD than in hypertensives, regardless of analogous age and BP. Several investigators have conducted studies determining an increase in aortic stiffness in haemodialysis patients suggesting it to occur due to a rise in calcium levels of the arterial wall [24,25]. Townsend et al. conducted a study to determine whether AS has an impact on CKD progression and concluded that AS increases in patients with CKD and impaired renal function than the healthy population, thus helping to identify the high-risk patients and implement early intervention to prevent death [26,27].

This study represents a population with a very wide age range of 11-81 years and men preponderance. The present study revealed higher AS in patients with a higher mean age. The mean VA was higher in patients with average large AS. Increase in severity of large and small AS showed a significant increase in PWV. The 2013 European guidelines for the management of hypertension and CV disease prevention in clinical practice recommended that aortic PWV be used to assess target organ damage [28]. Nevertheless, the main drawback of PWV measurement is the difficulty to accurately record in peripheral artery disease and obese patients. In the present study a positive correlation was observed between pulse pressure, mean arterial BP, PWV and AS which is in accordance with the reported literature [29].

Age and BP have a greater impact on AS than GFR, however, AS is strongly associated with altered renal function. A similar investigation by Wang et al. assessed the severity of AS in 102 patients with CKD by using PWV to evaluate associated risk factors. PWV values in patients with CKD stages 1 to 2 and the age-matched control group were similar and an increasing trend was observed in PWV corresponding to progression in CKD stage ($p<0.0001$) [30,31]. Sigrist et al. conducted a study comprising, a total of 134 patients, of which 60 were on haemodialysis, 28 on peritoneal dialysis, and 46 with stage 4 CKD. It was observed that patients with stages 4 and 5 CKD showed a significant calcification over 24 months which is associated with AS and mortality [32].

Lilitkarntakul et al. determined that PWV increased linearly as renal function deteriorated, however, age and mean arterial BP are the strongest factors of AS in patients with CKD. Similarly, the present study showed a significant association between age and large AS with a significant increase in VA and PWV ($p<0.001$) as the age progressed [33].

Takenaka et al. [34] reported that AI showed a positive correlation with age and weight, and negatively to height and heart rate and suggested AI to be a risk factor of progression of non-diabetic CKDs. However, in this study heart rate showed a strong positive correlation with AI as well as a significant increase occurred in AI as the small AS and VA increased.

In the present study, Mobil-O-Graph was employed to determine the profile of AS and VA in terms of PWV that was in accordance with the studies conducted by Salvade et al. and Solanki et al. [35,36] demonstrating the instrument usage to assess PWV in patients with renal impairment and hypertension. In dialysis population, Mobil-O-Graph was used to determine PWV and test its sensitivity for VA and pulse pressure. It was observed to be more sensitive for VA than pulse pressure.

The present study showed a significant association between PWV with age, BMI, VA, AS and peripheral and cBP. Previous investigations reveal that PWV predicts early CV aging in young first-degree relatives of hypertensives. It is dependent on age, strongly associated with brachial BP and foresees upcoming cardiac diseases including hypertension [37].

This technique aids to identify the progression of disease, detection of co-morbidities and shape up the treatment with

new medical interventions for enhanced results.

LIMITATIONS OF THE STUDY

One potential limitation of this study is the confinement to patients with CKD; thus, these findings might not be applicable to the general population or those with other chronic conditions. This is a single center study with moderate sample size. Another limitation is absence of biochemical investigation.

CONCLUSION

The overall observation suggests an increasing trend in oscillometric measurement of PWV, VA, AI with an increase in the severity of AS. Further a positive association of PWV, VA and AS with aging indicates the role of these parameters to detect and improve CV risk prediction associated with CKD.

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