Original Article

Association of brachial and central hemodynamic parameters to eGFR and proteinuria in Gujarati diabetics with mild-to-moderate nephropathy

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Abstract

Introduction: Diabetes mellitus (DM) is a significant risk factor for nephropathy and cardiovascular morbidity. Pulse wave analysis (PWA) gives direct inference of brachial hemodynamics (BH) and central hemodynamics (CH). We studied relation of them with diabetic nephropathy (DN) among type-2 diabetics (T2D). **Methods:** We studied oscillometric PWA by a cross-sectional study in 160 T2Ds. Using Mobil-o-Graph (IEM, Germany), we derived BH (blood pressure, pulse pressure index, rate pressure product) and CH (aortic pressure, cardiac index, stroke volume index, stroke work). They were further compared and associated with DN in terms of creatinine, proteinuria, and estimated glomerular filtration rate (eGFR). **Results:** There were 89 males, mean age 56 years, mean duration 4.8 years, 80% hypertensive predominantly using ACE inhibitors, poor glycemic blood pressure (BP) control, mainly mild-to-moderate DN, mean eGFR 88.2, 34% prevalence of proteinuria. Arterial stiffness was high with female disadvantage. BH and CH parameters were not different with or without DN using proteinuria or eGFR (60 cutoff) criteria. BH, CH correlated insignificantly with creatinine and eGFR. Female disadvantage, correlation with bSBP and aSBP were only significant results. **Conclusions:** BH and CH are not related to eGFR and proteinuria in predominantly hypertensive, Gujarati diabetics with mild-to-moderate nephropathy suggesting need of other cardiovascular parameters.

Keywords: Blood pressure, diabetes, estimated GFR, hemodynamic, proteinuria

Introduction

The burden of diabetes mellitus (DM) has threatening trend in India.[1] DM itself is a cardiovascular risk[2] and in majority, hypertension develops as co-morbidity.[3] Brachial blood pressure (BP) is a routine in diabetics with/without hypertension but with limitations. Aortic BP and central hemodynamics are better, direct, discrete parameters about vascular ageing of diabetes that can be measured noninvasively by a pulse wave analysis (PWA).[4] PWA-based studies are recently published in normal, diabetic, and hypertensive population of our region.[4-6] Diabetic nephropathy (DN) is a common microvascular complication whose association with PWA parameters is not known in our population. In a recent study, we found that PWA-derived arterial stiffness (AS) parameters are related to estimated glomerular filtration rate (eGFR) but not proteinuria in our diabetics.[7] To extend further by this paper, we tested association of DN with hemodynamic parameters in same study sample.

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Materials and Methods

Study design and participants

We got study protocol approved by our institutional review board IRB committee approval number: IRB (HEC) 760/2018,

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Physiology 77/2018 dated 28/03/2018. Study protocol was approved by the institutional review board of our medical college and it was registered prospectively in clinical trial registry of India. We undertook a cross-sectional study on diabetic patients attending medicine outdoor patient department at a tertiary care teaching government hospital, attached to a government medical college.

Inclusion and exclusion criteria

We included ambulatory, nonathletic, type-2 diabetics (T2D) taking regular antidiabetics, with or without hypertension, with current reports of serum creatinine and proteinuria available, both males and females, nonalcoholic, nonsmoking, not known to have any acute/chronic systemic disease, willing for written informed consent. Apart from these criteria, we also excluded pregnant subjects, subjects with eGFR <15, subjects using any alternative system of medicines.

Study groups

Sample size was calculated by Raosoft software (Raosoft, Inc., free online software, Seattle, WA, USA). To have 95% confidence level, 5% precision, considering diabetes prevalence 7.4%, sample size of 148 was adequate for our population. We screened and enrolled 178 diabetics meeting inclusion criteria from general medicine outdoor patient department by simple random sampling. We excluded six subjects due to arm circumference beyond available cuff size, seven subjects due to poor quality of record, and one with irregular pulse wave rhythm. In previous publication of the same study, we had 164 subjects, of which, 4 subjects with age more than 75 years have been dropped in current paper. So, a case group finally had 160 cases.

Subject assessment and definitions

We noted demographic characteristics, risk factors, self-reported moderate physical activity, relevant disease history, and detailed history of pharmacotherapy of all subjects. Systolic BP (SBP) ≥140 mm of Hg and diastolic BP (DBP) ≥90 mm of Hg or use of antihypertensive medication was defined as hypertension. SBP <140 mm of Hg and DBP <90 mm of Hg was taken as BP control. Glycemic control was defined as per American Diabetes Association guidelines 2018[8] based on fasting plasma glucose (FPG <130 mg/dl) and 2 h plasma glucose (2 hPG <180 mg/dl). Current reports of proteinuria and serum creatinine were noted. eGFR was calculated using MDRD formula:[9] eGFR = 186 × Serum Cr $^{-1.154}$ × age $^{-0.203}$ × 1.212 (if patient is black) × 0.742 (if female). Using eGFR cutoff, 60 subjects were graded for DN.

Oscillometric PWA

We used portable, personal computer attached, calibrated[10] and validated[11] instrument Mobil-o-Graph (IEM GMBH, Stolberg, Germany) of Physiology department. It performs oscillometric PWA as per protocol designed by European Society of Hypertension. Pressure waves are generated by brachial arterial pulsation, which are transmitted to brachial BP cuff and measured by transducer that is fed into microprocessor. Computerized software records brachial pulse wave and by validated a generalized transfer factor, derives central aortic pulse wave. Using ARCSolver algorithm, it further undergoes point based and area-based analysis by computer software to derive various cardiovascular parameters. Based on measured left mid arm circumference, a BP cuff was chosen and applied to using standard protocol. All readings were taken after rest for 10 min, in postabsorptive phase in a calm room without external influences or avoiding arm movement.[10]

Parameters measured and derived

These are same as used in our previous Mobil-o-graph based studies.[12,13]

1) Heart rate (HR), body mass index (BMI), body surface area (BSA).
2) Brachial hemodynamics (BH) - blood pressure (bBP)- systolic (bSBP), diastolic (bDBP), pulse (bPP) and mean (bMBP), pulse pressure index (PP/SBP), rate pressure product (RPP = HR per minute × SBP × 10^{-2}).
3) Central hemodynamics (CH)- aortic blood pressure (aBP)- systolic (aSBP), diastolic (aDBP), pulse (aPP), cardiac index (CI = cardiac output/BSA), stroke volume index (SVI = stroke volume/BSA), stroke work (SW = pulse pressure × stroke volume × 0.0144).
4) It also gives AS parameters, which were described in another published paper.

Statistical analysis

Data were entered into and sorted by Excel spreadsheets. Numerical data were expressed as mean ± standard deviation and qualitative data were expressed as number. Statistical calculations were done by GraphPad InStat 3 software (demo version free software of GraphPad Software, Inc., California, USA). Normality test was done for all parameters to test for parametric distribution before choosing a test. A comparison of quantitative data was done by student's unpaired *t*-test or Mann–Whitney *U*-test. We compared difference in distribution of qualitative data by normality test or Chi-square test. Linear correlation was tested by Pearson's or Spearmen's test depending on parametric or nonparametric nature of variables. Statistical significance level was kept at P value < 0.05.

Results

Table 1 shows baseline and hemodynamic parameters of T2D in total and with respect to gender-based subgroups. Overall, there was mean age of 56 years, mean duration of diabetes is 4.76 years, representation of both genders, high mean BMI, low-percentage physical activity. There was 80% co-existence of hypertension in which all but three were using ACEI and there was 50% BP control and 40% glycemic control. DN parameters showed mean serum creatinine 1.09, mean eGFR 88.92, one-third prevalence of proteinuria and one-sixth prevalence of eGFR <60. Mean BH and CH were below cutoff. Male and female subgroups were comparable

Table 1: Baseline data of study group

Parameter, Unit	Males (*n*=89)	Females (*n*=71)	*P*	Total (*n*=160)
Age, years	57.21±8.85	54.21±9.64	**0.0461***	55.88±9.30
Height, cm	160.48±8.23	155.25±8.17	**<0.0001***	158.16±8.58
Weight, kg	66.72±10.29	65.87±12.34	0.64	66.34±11.22
BMI, kg/m^2	26.04±4.71	27.46±5.59	0.08	26.67±5.15
BSA, m^2	1.72±0.16	1.66±0.18	0.08	1.69±0.17
Physically active (number)	27/62	19/52	0.73	46/114
Duration, years	4.58±4.49	4.98±5.90	0.62	4.76±5.15
Hypertension (+/-)	74/15	55/16	0.42	129/31
BP control (+/-)	45/44	25/46	0.06	76/84
Proteinuria (+/-)	31/58	22/49	0.62	53/107
Serum Creatinine, mg/dL	1.13±0.44	1.05±0.37	0.26	1.09±0.41
eGFR, ml/min/1.73 m^2	97.66±31.43	77.97±25.15	**<0.0001***	88.92±30.35
eGFR (number)				
<60 ml/min/1.73 m^2	9	17	**0.0296***	26/134
≥60 ml/min/1.73 m^2	80	54		
Pharmacotherapy				
ACEI (+/-)	72/17	54/17	0.56	126/34
Beta blockers (+/-)	48/41	31/40	0.21	79/81
Statin (+/-)	51/38	30/41	0.08	83/81
Aspirin (+/-)	9/80	4/67	0.39	14/150
HR, bpm	86.92±15.86	90.76±13.21	0.10	88.63±14.82
BH				
SBP, mm Hg	130.28±17.81	141.30±20.94	**0.0051***	135.17±19.97
DBP, mm Hg	86.03±13.32	88.18±12.43	0.53	86.99±12.94
MBP, mm Hg	106.45±14.21	110.13±18.89	0.06	108.53±16.56
PP, mm Hg	44.27±12.59	53.11±16.95	**0.0005***	48.19±15.29
PPI	0.34±0.07	0.37±0.08	**0.0058***	0.35±0.08
RPP, mm Hg.bpm	113.70±27.50	128.48±27.65	**0.0009***	120.26±28.45
CH				
aSBP, mm Hg	119.69±16.24	130.66±19.64	**0.0021***	124.56±18.59
aDBP, mm Hg	87.63±13.63	90.31±12.82	0.46	88.82±13.30
aPP, mm Hg	32.06±9.60	40.35±15.03	**0.0002***	35.74±12.95
CI, ml/min/m^2	2.96±0.47	3.24±0.55	**0.001***	3.08±0.53
SVI, ml/min/m^2	35.53±8.31	36.20±7.69	0.37	35.83±8.03
SW, g m/beat	114.43±30.95	122.44±36.53	0.33	117.98±33.67

eGFR=estimated glomerular filtration rate, += present, −= absent, ACEI=Angiotensin converting enzyme inhibitor, HR=heart rate, BH=brachial hemodynamics, SBP=systolic blood pressure, DBP=diastolic blood pressure, MBP=mean blood pressure, PP=pulse pressure, PPI=pulse pressure index, RPP=rate pressure product, CH=central hemodynamics, aSBP=aortic SBP, aDBP=aortic DBP, aPP=aortic pulse pressure, CI=cardiac index, SVI=stroke volume index, SW=stroke work, * indicates statistical significance

for baseline data except low mean age, low mean height, and poor BP control in females than males. Females had significantly higher decline in eGFR than males. BH and CH parameters were higher in females than males. These differences were significant for most parameters except DBP, SVI, and stroke work.

Table 2 shows comparisons of diabetic proteinurics (n = 53) and nonproteinurics (n = 53, selected from remaining 107 subjects by matching of age and gender). Subgroups were comparable for most baseline and confounder parameters though glycemic control was poor and nephropathy parameters were augmented in proteinuric subgroup than nonproteinuric one. BH and CH parameters were not significantly different between these two subgroups.

Table 3 shows comparisons of subgroups of diabetics stratified by eGFR cutoff 60 into grades of DN. There were no statistically significant differences with respect to baseline parameters, BH or CH.

Table 4 shows correlation between hemodynamics and DN parameters (serum creatinine and eGFR). Most hemodynamic parameters correlated positively with serum creatinine and negatively with eGFR. However, most correlations were small and except for SBP and eGFR, all were insignificant statistically. eGFR showed better correlation with BH, CH than serum creatinine.

Discussion

We recently published cross-sectional studies of oscillometric PWA in our population-normal,[4] diabetic,[5] hypertensive;[6] showing utility of PWA for beyond brachial BP inference about cardiovascular ageing. Central hemodynamics (CH) were not completely dependent on brachial BP in these studies.[4-6] As per the literature, central BP is better related to cardiovascular morbidity and mortality.[14] So, we assumed CH to be better related to status of microvascular complication like DN, which prevails in nearly one-third[7] of our diabetics. In the previous

Table 2: Baseline and hemodynamic parameters is subgroups with proteinuria or without proteinuria (matched by total number, age, and gender)

Parameter, unit	Proteinuria + (*n*=53)	Proteinuria - (*n*=53)	*P*
Age, years	57.91±9.71	57.66±9.50	0.77
M/F (no)	31/22	31/22	1.00
Height, cm	158.21±8.40	157.11±8.78	0.51
Weight, kg	66.66±10.40	65.51±11.42	0.14
BMI, kg/m^2	26.75±4.62	26.25±5.27	0.61
BSA, m^2	1.68±0.19	1.68±0.16	0.76
Physically active (number)	24/29	11/42	**0.0126***
Duration, years	5.23±5.97	4.43±4.16	0.89
Hypertension (+/-)	48/05	41/12	0.11
BP control (+/-)	27/26	25/28	0.85
ACEI users (+/-)	45/8	42/11	0.61
Serum Creatinine, mg/dL	1.26±0.54	0.99±0.35	**<0.0001***
eGFR, ml/min/1.73 m^2	76.49±29.07	99.35±31.53	**0.0002***
eGFR (number)			
<60 ml/min/1.73 m^2	15	6	**0.0495***
≥60 ml/min/1.73 m^2	38	47	
HR, bpm	88.23±14.91	86.23±14.78	0.36
BH			
SBP, mm Hg	133.47±17.93	135.21±20.03	0.64
DBP, mm Hg	84.85±14.55	88.49±12.71	0.17
MBP, mm Hg	105.19±19.62	109.91±14.60	0.30
PP, mm Hg	48.62±13.62	46.75±14.54	0.40
PPI	0.36±0.08	0.34±0.07	0.15
RPP, mm Hg.bpm	119.11±26.91	117.60±30.70	0.79
CH			
aSBP, mm Hg	121.81±17.38	124.68±17.48	0.40
aDBP, mm Hg	86.51±15.09	90.43±12.99	0.15
aPP, mm Hg	35.30±10.60	34.25±12.59	0.38
CI, ml/min/m^2	3.04±0.51	3.14±0.58	0.31
SVI, ml/min/m^2	35.99±9.54	37.32±7.40	0.14
SW, g m/beat	114.21±28.12	122.96±34.90	0.16

Abbreviations are same as Table 1, * indicates statistical significance

Table 3: Baseline and BH/CH parameters is subgroups based on eGFR cutoff 60 (matched by total number, age, and gender)

Parameter, unit	eGFR <60 (*n*=26)	eGFR ≥60 (*n*=26)	*P*
Age, years	58.46±9.79	58.00±9.32	0.86
M/F (no)	11/17	11/17	1.00
Height, cm	157.69±8.91	159.5±9.13	0.47
Weight, kg	64.19±11.65	68.58±11.37	0.18
BMI, kg/m^2	26.01±5.65	27.01±4.89	0.47
BSA, m^2	1.65±0.19	1.73±0.18	0.20
Physically active (number)	6/20	11/15	0.24
Duration, Years	5.06±5.27	6.90±5.95	0.18
Hypertension (+/-)	10/16	7/19	0.56
BP control (+/-)	21/5	20/6	>0.99
ACEI users (+/-)	20/6	22/4	0.72
Proteinuria (+/-)	15/11	9/17	0.16
S Creatinine, mg/dL	1.70±0.62	1.06±0.19	**<0.0001***
HR, bpm	87.15±16.02	87.23±14.55	0.99
BH			
SBP, mm Hg	139.69±27.77	138.46±17.82	0.80
DBP, mm Hg	90.19±17.35	86.35±10.99	0.50
MBP, mm Hg	108.96±28.45	109.81±11.64	0.96
PP, mm Hg	49.50±19.99	52.12±17.71	0.43
PPI	0.35±0.08	0.37±0.09	0.39
RPP, mm Hg.bpm	122.57±34.56	120.78±25.39	0.83
CH			
aSBP, mm Hg	129.31±26.67	127.35±18.07	0.87
aDBP, mm Hg	92.35±17.73	87.12±12.53	0.28
aPP, mm Hg	36.96±17.58	40.23±14.96	0.27
CI, ml/min/m^2	3.19±0.68	3.01±0.45	0.26
SVI, ml/min/m^2	37.96±10.24	34.62±6.20	0.16
SW, g m/beat	123.81±41.56	120.26±31.41	0.78

Abbreviations are same as Table 1, * indicates statistical significance

publication,[7] we found AS to be associated with measures of DN in diabetics with mild-to-moderate grade DN. So we tested the association with BH and CH with DN in same study group of diabetics.

Females had significantly higher BH and CH than males in accordance with our previous studies done in same age groups.[4-6] This gender factor along with age must be considered while drawing any conclusion of BH and CH. eGFR was better correlated with BH, CH than Proteinuria. This in line with the concept of existence of nonalbuminuric kidney disease[15] and the same can be measured in terms of quantitative eGFR. Thus, eGFR is considered a better variable than macroproteinuria that is significant in our setups, where microalbuminuria testing is difficult to implement. SBP was the only significant factor that correlates with DN. It is due to the mean age 56 and fact that DBP accelerates after 60 sec. It is the SBP which is raised; that augments pulse pressure and such pulsatile flow lead to end organ damage to kidney that manifests as DN.[16]

We found no difference in BH and CH parameters between subgroups of diabetics stratified by proteinuria and eGFR (cutoff 60). So these hemodynamic parameters were not associated with DN in contrast to most other studies.[17-19] This can be due to: 1) mean age, which was higher in other studies, that mostly focused elderly and mean duration, which was only 4.76 years; 2) grade of DN, which was mild to moderate and there was not much eGFR decline; and 3) predominant hypertension in most study subjects that were using angiotensin converting enzyme inhibitors and beta blockers, both of which are known to have positive impact on cardiovascular health. We found the same scenario in diabetics with than without antihypertensives in our previous studies on various cardiovascular parameters.[3,20,21] 4) We did matching of subgroups by age and gender, and other confounders were also comparable, which was not the case in many other studies, 5) glycemic control was poor in most diabetics alike our previous studies[3,5,20,21] and that overshadows other risk factors, 6) both BH and CH were measured simultaneously by same device, which is not so in tonometry-based devices,[22] which are used in most studies. 7) It was a cross-sectional design with moderate sample as opposed to vertical studies with large sample.

Table 4: Correlation between DN parameters and BH/CH parameters

Parameters	S Creatinine		eGFR	
Statistics	r	*P*	R	*P*
bSBP	0.11	0.16	-0.19	**0.0158***
bDBP	0.09	0.27	-0.12	0.20
bMBP	0.11	0.18	-0.15	0.056
bPP	0.01	0.85	-0.12	0.12
HR	-0.08	0.06	0.03	0.67
PPI	-0.04	0.61	-0.03	0.70
RPP	0.02	0.83	-0.10	0.20
aSBP	0.09	0.26	-0.17	**0.0309***
aDBP	0.07	0.41	-0.08	0.33
aPP	0.01	0.87	-0.08	0.32
CI	-0.05	0.56	-0.09	0.25
SVI	0.06	0.44	-0.12	0.12
SW	0.11	0.17	-9.74	0.33

Abbreviations are same as Table 1, * indicates statistical significance

However, one study (done in general population, mean age 57.2 years, 55.3% women), alike us, suggests that central SBP and PP measured with a stand-alone noninvasive BP monitor do not improve diagnostic accuracy for end-organ damage over corresponding brachial measures.[23] In another study, patients with CKD stages 3 or 4 and mild or no-proteinuria, peripheral and central BP did not change significantly during a one-year observation period despite the significant decline of eGFR and seems not to participate in the CKD progression.[24] One recent study, central BP in patients with CKD stage 3 and albuminuria were compared with matched patients without CKD, and there were no significant differences of central BP parameters between these two groups of patients[25] like us and suggested that the kidney function has impact of on central BP, may be only in more advanced CKD.[26] This also raises a question concerning the importance of targeting these parameters in early stages of CKD.

CH is known to be associated with target organ damage (TOD) including DN better than BH but in our study, TOD was present in 1 out of 6 and mean eGFR was 70, which is more than DN cutoff 60. Mean values BPs were also below cutoffs and 5 out of 6 diabetics were given antihypertensives that blocks a rennin angiotensin aldosterone system. Mean duration of disease was 4.76 years, which adequates to improve hemodynamics.[27] So, this treatment is beneficial for BP more than DN if glycemic control is suboptimal and that could have led to lack of association between CH and DN. Or, in other words, BP lowering that corrects hemodynamics does not necessarily prevent DN to same extent. Progression of DN is threatened by poor glycemic control as well as poor BP control as hypertension and diabetes co-exist and other risk factors are there with this duo super adding to ethnic risk of our population and poor health literacy in majority. It is possible that with worsening grade of nephropathy, this association may become stronger. To ascertain same, a study is needed with normotensive diabetics, not using antihypertensives and with glycemic control assessed by HbA1c.

Similarly, we need a better parameter of cardiovascular risk in such cases, which can correlate macrovascular changes better with DN. AS, especially aortic stiffness, holds promising in this regard. In same population, we found AS to be associated significantly with DN.[7] AS is more discrete and direct than hemodynamics. AS that precedes hemodynamic changes like BP is not routinely measured. Aortic pulse wave velocity is a gold standard that infers about macrovascular change in immediate vicinity of a cardiac pump. It is found to be affected even with predisposition for diabetes[12] or hypertension[13] in young individuals with positive family history of same as recently published. BH and CH still are needed to have better inference especially that of cardiac output related parameters, which tells about the ultimate function of heart. BH, CH, and AS are measured simultaneously and noninvasively, by same validated device Mobil-o-graph and calls for further work in this direction.

Healthcare systems including primary care will need to be equipped to deal with double burden of communicable plus noncommunicable diseases. Changing epidemiology of disease burden in India necessitates expansion of scope of services to include prevention, screening, and management of noncommunicable diseases.[28] Diabetes and its complications like nephropathy needs a definite attention at all level and primary care with prevention is better than cure. Family medicine is ever expanding branch and primary healthcare systems have to play an active role in linking those who need it with advanced levels of care.[28] Availability of diagnostics for screening (like PWA-based central hemodynamics) and early detection will be important to play this role.[28]

We had some limitations like lack of baseline data, cross-sectional nature, nonavailability of glycated hemoglobin and biomarkers of vascular ageing, nonavailability of 24-h proteinuria, and nonavailability of albumin-to-creatinine ratio.

Conclusion

In middle-aged predominantly hypertensive and ACEI using Gujarati diabetics with mild-to-moderate nephropathy, poor disease control, mild-to-moderate nephropathy, oscillometric PWA-derived BH and CH parameters are not associated with means of nephropathy, thought slightly better with eGFR than proteinuria, suggesting need of other cardiovascular parameter for correlation of the same.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form the patient (s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

References

1. Atre S. The burden of diabetes in India. Lancet Glob Health 2019;7:e418.
2. Sun D, Zhou T, Heianza Y, Li X, Fan M, Fonseca VA, *et al.* Type 2 diabetes and hypertension: A study on bidirectional causality. Circ Res 2019;124:930-7.
3. Solanki JD, Makwana AH, Mehta HB, Gokhale PA, Shah CJ. Hypertension in type 2 diabetes mellitus: Effect of the disease and treatment on development of peripheral artery disease. Int J Diabetes Dev Ctries 2015;35(Suppl 3):S380-4.
4. Solanki JD, Mehta HB, Shah CJ. Aortic blood pressure and central hemodynamics measured by noninvasive pulse wave analysis in Gujarati normotensives. Int J Clin Exp Physiol 2018;5:75-80.
5. Solanki JD, Munshi HB, Mehta HB, Shah CJ. Central hemodynamics and arterial stiffness in Gujarati diabetics not receiving any antihypertensive: A case–control study based on oscillometric pulse wave analysis. J Family Med Prim Care 2019;8:1352-8.
6. Solanki JD, Mehta HB, Shah CJ. Oscillometric pulse wave analysis in newly diagnosed never treated Gujarati hypertensives. Vasc Invest Ther 2018;1:62-7.
7. Solanki JD, Patel RB, Hadiyel IN, Mehta HB, Munshi HB, Kakadia PJ. Arterial stiffness parameters derived by oscillometric pulse wave analysis are related to estimated glomerular filtration rate but not proteinuria in Gujarati diabetics. J Indian Coll Cardiol 2019;9:32-8.
8. American Diabetes Association. 6. Glycemic targets: Standards of medical care in diabetes-2018. Diabetes Care 2018;41:S55-64.
9. Tuomilehto J, Rastenyte D, Qiao Q, Barengo NC, Matz K. Epidemiology of macrovascular disease and hypertension in diabetes mellitus. International Textbook of Diabetes Mellitus. 4th ed.. Hoboken: Wiley; 2015. p. 1005-30.
10. Weiss W, Gohlisch C, Harsch-Gladisch C, Tölle M, Zidek W, van der Giet M, *et al.* Oscillometric estimation of central blood pressure: Validation of the Mobil-O-Graph in comparison with the SphygmoCor device. Blood Press Monit 2012;17:128-31.
11. Weber T, Wassertheurer S, Rammer M, Maurer E, Hametner B, Mayer CC, *et al.* Validation of a brachial cuff-based method for estimating central systolic blood pressure. Hypertens 2011;58:825-32.
12. Solanki JD, Mehta HB, Shah CJ. Pulse wave analyzed cardiovascular parameters in young first degree relatives of type 2 diabetics – A cross-sectional study. Indian Heart J 2018;70:341-5.
13. Solanki JD, Mehta HB, Shah CJ. Pulse wave analyzed cardiovascular parameters in young first degree relatives of hypertensives. J Res Med Sci 2018;23:72.
14. Sun P, Yang Y, Cheng G, Fan F, Qi L, Gao L, *et al.* Noninvasive central systolic blood pressure, not peripheral systolic blood pressure, independently predicts the progression of carotid intima-media thickness in a Chinese community-based population. Hypertens Res 2019;42:392-9.
15. Madhu SV. Normoalbuminuric diabetic kidney disease: A distinct entity? Int J Diabetes Dev Ctries 2019;39:241-2.
16. Osawa T, Fujihara K, Harada M, Yamamoto M, Ishizawa M, Suzuki H, *et al.* Higher pulse pressure predicts initiation of dialysis in Japanese patients with diabetes. Diabetes Metab Res Rev 2019;35:e3120.
17. Okamura T, Ushigome E, Kitagawa N, Oyabu C, Tanaka T, Hasegawa G, *et al.* Maximum morning home systolic blood pressure is an indicator of the development of diabetic nephropathy: The KAMOGAWA-HBP study. J Diabetes Investig 2019. doi: 10.1111/jdi. 13040.
18. Rahman M, Hsu JY, Desai N, Hsu CY, Anderson AH, Appel LJ, *et al.* Central blood pressure and cardiovascular outcomes in chronic kidney disease. Clin J Am Soc Nephrol 2018;13:585-95.
19. Haas ME, Aragam KG, Emdin CA, Bick AG, Hemani G, Smith GD, *et al.* Genetic association of albuminuria with cardiometabolic disease and blood pressure. Am J Hum Genet 2018;103:461-73.
20. Solanki JD, Patel KJ, Lalwani N, Mehta HB, Shah CJ, Lakhtaria MN. Effect of coexisting hypertension, blood pressure control, and antihypertensive treatment on QT interval parameters in type 2 diabetics: A cross-sectional study. J Pharmacol Pharmacother 2018;9:21-6.
21. Solanki JD, Basida SD, Mehta HB, Panjwani SJ, Gadhavi BP, Patel P. Impact of disease control and co-existing risk factors on heart rate variability in Gujarati type 2 diabetics: An observational study. J Family Med Prim Care 2016;5:393-8.
22. Carlsen RK, Peters CD, Khatir DS, Laugesen E, Bøtker HE, Winther S, *et al.* Estimated aortic blood pressure based on radial artery tonometry underestimates directly measured aortic blood pressure in patients with advancing chronic kidney disease staging and increasing arterial stiffness. Kidney Int 2016;90:869-77.
23. Lindroos AS, Langén VL, Kantola I, Salomaa V, Juhanoja EP, Sivén SS, *et al.* Relation of blood pressure and organ damage: Comparison between feasible, noninvasive central hemodynamic measures and conventional brachial measures. J Hypertens 2018;36:1276-83.
24. Kuczera P, Kwiecień K, Adamczak M, Bączkowska T, Gozdowska J, Madziarska K, *et al.* Different relevance of peripheral, central or nighttime blood pressure measurements in the prediction of chronic kidney disease progression in patients with mild or no-proteinuria. Kidney Blood Press Res 2018;43:735-43.
25. Goupil R, Dupuis D, Agharazii M, Hamet P, Troyanov S, Madore F. Central blood pressures in early chronic kidney disease: An analysis of CARTaGENE. Nephrol Dial Transplant 2017;32:976-83.
26. Fernández-Llama P, Pareja J, Yun S, Vázquez S, Oliveras A, Armario P, *et al.* Cuff-based oscillometric central and brachial blood pressures obtained through ABPM are similarly associated with renal organ damage in arterial hypertension. Kidney Blood Press Res 2017;42:1068-77.
27. Solanki JD, Mehta HB, Panjwani SJ, Munshi HB, Shah CJ. Effect of antihypertensive pharmacotherapy on oscillometric pulse wave analysis parameters in treated Gujarati hypertensives: A cross-sectional study. J Pharmacol Pharmacother 2018;9:153-9.
28. Mohan P, Sethi H, Reddy KR, Bhan MK. Designing primary healthcare systems for future in India. J Family Med Prim Care 2019;8:1817-20.