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ORIGINAL RESEARCH

Assessment of Renal Artery Resistive Index and Shear Wave Elastography in Healthy Individuals and Patients with Chronic Kidney Disease-A Prospective cross sectional study

[1]Dr. Vimal Chaudhary, [2]Dr. Adarsh Ad, [3]Dr. Anil Kumar Sakalecha, [4]Dr. Anees Dudekula, [5]Dr. Manjunatha N, [6]Dr. Kush Malik

[1,6]Postgraduate, [2]Professor, [3]Professor & HOD, [4]Associate Professor, Department of Radiodiagnosis, SDUMC, Kolar, Karnataka, India
[5]Associate Professor, Department of General Medicine, SDUMC, Kolar, Karnataka, India

Corresponding author
Dr. Vimal Chaudhary
Postgraduate, Department of Radiodiagnosis, SDUMC, Kolar, Karnataka, India
Email- drvimaldavid@gmail.com

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ABSTRACT

Background: Chronic kidney diseases (CKD) is progressive condition associated with significant global morbidity, often driven by underlying disorders such as hypertension and diabetes mellitus. Noninvasive imaging modalities like shear wave elastography (SWE) and Doppler-based renal resistive index (RI) measurements are emerging as promising tools to assess renal parenchymal changes and predict disease progression. **Methods:** In a prospective case-control study, 60 participants (30 CKD patients, 30 healthy controls) underwent renal ultrasound with SWE and Doppler evaluation. Tissue stiffness (YM) was measured using Philips ELASTPQ technology, and RI was derived from segmental renal arteries. Data were statistically analysed usings SPSS v22, withcorrelations examined between imaging parameters and clinical, laboratory, and demographic variables. **Results:** YM show a significant -ve correlations with estimate glomerular filtrations rate (eGFR) ($r = -0.394$, $p < 0.001$) &+ ve correlations with serumcreatinine ($r = 0.426$, $p < 0.001$) & serum urea ($r = 0.368$, $p < 0.001$). RI was significantly highers in patient with diabete, cardiovascular disease, smokings habit, and highers serums phosphorus, and inversely correlated with hemoglobin and eGFR. Multivariate analysis confirmed eGFR, phosphorus, and cardiovascular disease as independent predictors of RI. no Significant corelation was observe b/W YM & RI. **Conclusion:** Both YM and RI serve as valuable noninvasive markers reflecting renal fibrosis and vascular resistance, respectively. RI appears to be influenced by both renal and systemic factors, independent of eGFR. These findings support the integration of elastography and RI assessment in CKD evaluation and highlight the need for further multicenter studies and interventional trials to validate their prognostic value.

Keywords: Chronic Kidney Diseases (CKD), Shears Wave Elastography (SWE), Renal Resistive Indexs (RI), Young's Modulus (YM), Renal Fibrosis, eGFR

INTRODUCTION

Chronic kidney disease (CKD) has become a substantial globalshealths challenge, impacting millions of people globally. The progressive characteristics of chronic kidney disease (CKD), sometimes influenced by underlying illnesses including diabetes mellitus and hypertension, result in renal fibrosis, diminished glomerular filtration rates (GFR), & ultimately renal failure. Early identification and classification of chronic kidney diseases are essential for prompt intervention and therapy[1].

Recent years have seen an increasing focus on indicators of subclinical renal impairment, as they offer precise predictions of overall cardio-renal outcomes. Consequently, diverse indicators derived from many imaging techniques have been implemented to enhance the evaluation of CKD severity[2]. Ultrasonography (US) is the ideal imaging

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modality for evaluating renal disorders due to its cost-effectiveness, noninvasiveness, and accessibility[3].

Ultrasoundbased elastography, which is noninvasively quantifies tissue stiffnesses, represents notable improvement in ultrasound imaging[1]. It has been extensively utilised in evaluating fibrosis in hepatic disorders and in forecasting the existence of gastro-esophagealvarice in cirrhotics individuals[4]. Shears wave imagings (SWE) is a method in which dynamics stress is exerted on tissue. Elastography point quantifications (ElastPQ) shear wave-based elastography techniques developed by Philip, in which an ultrasonics pressures wave is emitted by the transducers, generating shears wave that propagate perpendicularly to axis of initial pressures wave within the tissues. ElastPQ incorporates auxiliary Doppler functions that measures velocity of shear waves to assess tissue stiffness.Assessments of tissue Young's modulus (YM), expressed in kilopascals [kPa], can be calculated from shear wave velocity, with elevated values indicating a greater extent of fibrosis[5].

The renal resistive index (RI), obtained from Doppler ultrasound of the kidneys, serves as an independent prognostic indicator in the advancement of chronic kidney disease (CKD). RI indirectly quantifies microcirculation resistance or impedance. In chronic kidney disease (CKD), progressive glomerular atrophy, renal mass reduction, and fibrosis of tubular-interstitial tissues lead to diminished renal parenchymal blood flow, thereby decreasing the spectral wave profile amplitude and increasing intrarenal resistance, which results in elevated resistance index (RI) values (>0.7)[6].

The objective of this study to examine use of shears wave elastography (SWE) and assess renals artery resistance indexs (RI) in both healthys individuals and patients with chronic kidney diseases.

METHODOLOGY

This study is a prospective cross sectionalinvestigation carried out in the Department of Radiodiagnosis. Sixty subjects will be enrolled, comprising 30 cases and 30 controls. The sample size was calculated based on the disparity in mean Young's modulus (YM) measurements between cases and controls, utilising data from the study of Shivarajkumar K. Lakshmana et al.,[1] which reported YM values of 3.47 ± 1.39 and 7.19 ± 2.56, respectively. A sample size of 27 participants per group was determined using MedCalc software, with a 95% confidence interval and 90% power. Considering a 10% nonresponse rate, the final sample size was adjusted to 30 patients per group. The formula utilised includes the $Z\alpha/2$ and $Z\beta$ values, standard deviation, and the lowest observable difference between means.

Participants will be chosen according to the following criteria: healthy persons over 18 years of age and individuals diagnosed with chronic kidney disease (CKD) in accordance with the National Kidney Disease Foundation standards. Exclusion criteria encompass those with diminished renal cortical thickness (<10 mm), structural renal pathologies (e.g., calculi, infections), dyspnoea attributable to airway disorders, or conditions such as hydroureteronephrosis and polycystic kidney disease. Ultrasound elastography will be conducted utilising a Philips EPIQ5 system equipped with ELASTPQ technology, employing a 5C-1 curvilinears broadbands transducer (1–5 MHz). Patient will undergo scanning in left and right lateralsdecubitu positions, wit breath held at mid-respiration to reduce motion artefacts. The regions of interests (ROI) will be situated in the midscortical area of kidney, with stiffness quantified in kilopascals (kPa) via shear wave elastography. The Renal Resistive Index (RI) will be computed from the superior, middle, and inferior segmental arteries, with the average utilised for analysis.

The collected data will be inputted into Microsoft Excel and analysed with SPSS version 22. Categorical variables will be represented as frequencies and percentages, whilst continuous variable will be articulated as mean & standard deviation. The Chi-square test will analyse categorical data, whereas the independent t-test will evaluate differences in mean values between groups. A p-value below 0.05 will be deemed statistically significant.

RESULTS

YM measures exhibited no significant correlation with ages in the control group, whereas a moderate -ve correlation with ages was observed in the CKD groups ($r = -0.340$, $p < 0.001$). The Spearmans correlations value indicated a moderate n-velinears associations b/w YM measures & eGFR ($r = -0.394$, $p < 0.001$). Moderate +ve linear correlationwere identified b/w the YM measures & blood creatinine ($r = 0.426$, $p < 0.001$) as well as serum ureas ($r = 0.368$, $p < 0.001$). YM measures exhibited no substantial connection with BMI in eithers the case or control groups.

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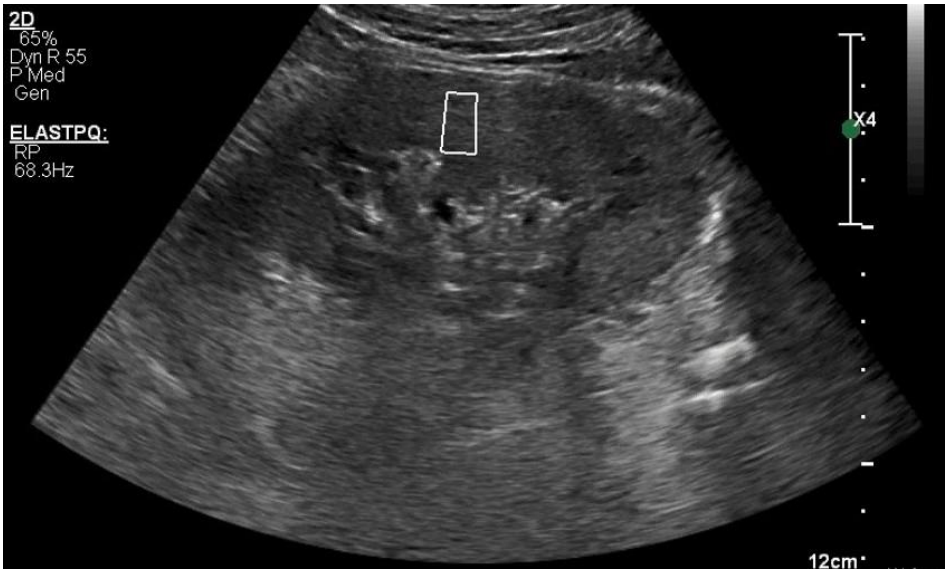

Figure 1: Elastography sample taken in the interpole region of the cortex

While we did find a slight positive association between parenchymal flexibility and RI in individuals with CKD, we failed to discover a meaningful correlation between kidney stiffening and PSV in either the instances or the controls($r = 0.268$, $p < 0.05$).

A substantial relationship exists between age, serum the mineral phosphorus eGFR, urea, nor haemoglobin with continuous RI. Patients whose smoked cigarettes, had insulin resistance, and a history , cardiovascular disease had significantly higher mean RI levels ($p = 0.001$, 0.013, etc.). There was not a significant connection ($p = 0.229$, 0.184, 0.772, respectfully) between kidney function and whole proteinuria, systolic blood pressure, or diastolic blood pressure according to univariate regression analysis. Table 2 displays the results of the single-variable regression tests.The findings retained significance after controlling for key characteristics strongly correlated with RI, including age and haemoglobin, which were incorporated in one or more stages of model development.

TABLE 1: Basal characteristic of patient: Overall and by RI risk categorie.

	Overall (n = 73)	**<0.65 (n=29)**	**0.65-0.70 (n=15)**	**>0.70 (n=29)**	**P**
Age, years	57.6+17.2	54.7+16.3	55.4+17.5	60.6+16.5	0.113
Gender MALE, %	69.4	65.3	86.9	65.4	0.213
Diabete, %	19.5	10.3	20.1	27.7	0.051
CVD, %	20.8	10.5	6.5	37.5	0.001
Smoker, %	30.2	17.1	40.7	37.4	0.033
Etiology of CKDs, %					0.201
HTN/DN/PKD	12.4	7.3	7.6	21.9	
GN,	55.2	61.7	71.6	39.8	
TIN,	31.5	30.2	21.1	39.9	
BP. mmHg	133+16/78+11	134+13/78+8	128+16/78+10	135+15/78+11	0.136/0.155
Pulse Pressures, mmHg	54.6+13.2	53.5+11.3	49.8+13.6	58.2+13.6	0.005
PTH.Pg/mL	191[56-364]	218[66-363	137(28-226)	191(79-409)	0.516
eGFRs, mL/min/1.73 m2	55.1(30.1-84.4)	69.7/51.0-96.7	55.3(33.5-79.1)	30.4(16.7-59.3)	0.001
Urea, mg/dL	73.7+47.3	51.4+30.6	66.7+38.2	73.4+47.7	0.001
Phosphorus, mg/dL	3.6+0.8	3.5+0.7	3.5+0.7	4.1+0.7	0.015
Serum potassiums, mEq/L	4.8+0.5	4.6+0.5	4.7+0.4	4.5+0.7	0.887
Uric acids, mg/dL	5.98+1.83	5.76+1.87	5.73+1.53	6.21+1.95	0.681
Hemoglobins, g/dL	13.1+2.4	14.2+2.0	12.6+2.3	12.1+1.9	0.001
Uprots, g/24h	1.6 [0.7-3.5]	1.1 [0.5-2.7]	1.4 (0.6-2.7)	3.1 (1.4-5.1)	0.085
Urinary Na, mmol/24h	138+70	132+83	145+55	139+64	0.835
RAAS-inhibitor, % pts	42.6	44.9	46.3	37.7	0.811
Ccb, %pts	28.6	13.7	33.8	41.3	0.072
Bb, %pts	19.1	13.5	20.1	24.4	0.613

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TABLE 2: Univariate linear regressions analysis es for renal resistives index (RI) in CKD patient under nephrology cares

Characteristic	Coefficient (95% CI)	P
Age, year	0.0015 (0.0003-0.0027)	0.017
Gender male (vs female)	0.0067 (-0.0389-0.0523)	0.772
Diabete (yes vs no)	0.0389 (0.0136-0.0912)	0.035
CVD, %	0.0870 (0.0394-0.1345)	0.0001
Smoker (yes vs no)	0.0557 (0.0120-0.0995)	0.011
Etiology of CKD		
HTN/DN/PKD	1	
GN ,	-0318(-0.0998-0.0363)	0.355
TIN,	-.0055 (-0.0781-0.0672)	0.874
Systolic BP, mmHg	0.0009 (-0.0004-0.0023)	0.188
Diastolic BP, mmHg	-0.0003 (-0.0026-0.0019)	0.763
Pulse Pressures , mmHg	0.0016 (-0.0001-0.0032)	0.272
PTH, pg/mL	0.0001 (-0.0001-0.0001)	0.696
eGFR, for 10 mL/min/1.73 m2	-0.0141 (-0.0192- 0.0091)	<0.001
Urea, mg/dL	0.0011 (0.0008-0.0016)	<0.001
Phosphorus, mg/dL	0.0406 (0.0111-0.0701)	0.006
Serum potassiums, mEq/L	0.0010 (-0.0410-0.0430)	0.986
Uric acid, mg/dL	0.0045 (-0.0070-0.0159)	0.412
Hemoglobin, g/dL	-0.0189 (-0.0277--0.0102)	<0.001
Uprot, g/24h	0.0027 (-0.0018-0.0072)	0.238
Urinary Na, mmol/24h	-0.0001 (-0.0004-0.0002)	0.628
RAAS-inhibitors (yes vs no)	-0.0179 (-0.0601-0.0243)	0.410
Ccb (yes vs no)	0.0561 (-0.0917-0.1004)	0.167
Bb (yes vs no)	0.0442 (-0.008-0.0963)	0.186

DISCUSSION

Worldwide, kidney failure (CKD) is incredibly common. Over time, glomerulosclerosis, vascular multiple sclerosis, tubular and capillary damage, resulting in fibrosis of the interstitial spaces and tubular atrophy, are all histological changes that accompany persistent kidney disease (CKD). There is a chance of sampling errors, procedural issues, and invasiveness connected to histological evaluation using kidney biopsy. Shear waves might move faster across tissues that are injured due to a higher stiffness caused by chronic kidney disease (CKD). As a result, the speed of bending waves travelling in the kidney tissue is directly connected to the extent of fibrosis, therefore, the decrease in Gmp relates to this relationship. We set out to figure out the relationship between Young's Modulus (YM), a measure of tissue stiffness, and renal function (RI), a marker of kidney function.

Our study's main takeaway is that increased RI can be predicted by a mix of modifiable & ineffective risk factors, independent of eGFR levels. a little more precise, the average RI, calculated at the beginning of the research, was 0.036 ($p = 0.021$) higher in smokers in comparison to non-smokers, or 0.024 ($p = 0.042$) to 0.061 ($p = 0.009$) higher in individuals without type-2 diabetes or a positive history of heart failure. According to the results equal the analysis of continuous variables, RI rose up by an average of 0.047 units for each additional unit in blood phosphate concentration ($p = 0.001$) while reducing by 0.011 units for every 10 mL/min/1.73m² improvement in eGFR ($p < 0.001$). According with prior studies, each significant risk factor's contribution to the equation's fit was eGFR, dietary phosphorus levels, and history of CVD the most substantial risk variables that could explain a shift to RI classified, exhibiting an additive and independent effect (no interaction effect was observed). A study by Kimura et al.[8] found that renal resistive index (RI) in chronic kidney disease patients is positively correlated with age, blood pressure, interstitial fibrosis, and arteriosclerosis, while negatively correlated with creatinine clearance and peritubular capillary density, highlighting significant determinants and risk factors for renal impairment.

The results indicated that YM metrics had a positive correlation with creatinine levels in the blood and the existence of CKD, while were negatively correlated with eGFR. In agreement with the finding that higher tissue fibrosis increases shear wave acceleration, the YM values grow as the disease degree increases. Previous investigations using the SWE tackle by Leong et al.,9 Radulescu et al.,10 Yu et al.,11 Samir et al.,5 all showed a statistically significant distinction in the YM/SWV values between the CKD cohort and the group of healthy controls, lending validity to this result.

Numerous prior research have investigated the parameters correlated with an elevated ultrasonography RI. Ponte et al.[12]found that age, heart rate, blood pressure levels (systolic and diastolic and

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RI decline in the general population were strongly related.

The average Tp values in people with good health are 3.47 ± 1.39 kPa, according to our analysis. The capability to make distinctions between various phases was insufficient.Nonetheless, early and late stages of chronic kidney disease (CKD) can be distinguished by stiffness values that exhibit considerable differences between CKD stages 2 and 5, as well as between stages 3 and 5. This information may be crucial for the prompt implementation of appropriate therapies to avert further decline in renal function.

Our investigation revealed no correlation between systolic, diastolic, or pulse pressure values and RI in both univariate and multivariate analyses. A potential reason is that the patients in our study exhibit a slight decrease in eGFR (median 54.1 mL/min/1.73m²). In their analysis of patients with identical amounts of renal failure, Doi et al.13 found no statistically significant disparity in blood pressure in both diastolic and s between those with renal impairment grades below the median and those in addition to it. The authors found an important difference in blood pressure measurements across RI groupings when they separated the measurements by eGFR levels (≥ and < 60 mL/min/1.73m²).

Consequently, we cannot dismiss the possibility that a more severe level of renal impairment is required to detect this link in the particular context of CKD patients, as demonstrated in other studies.

Our research possesses several limitations. The predominant causes of renal diagnosis in our sample were GN and TIN, consequently not always reflective of the broader aetiology or chronic kidney disease. Secondly, the study's single-center design restricts the generalisability of its findings.

CONCLUSION

In conclusion, among CKD patients monitored in an outpatient renal clinic, those exhibiting elevated RI levels typically present with reduced eGFR, diabetes, a history of cardiovascular disease, increased serum phosphate, and a smoking habit. In addition to the elevated eGFR number and peripheral atherosclerosis, further research will be required to find out whether a high RI implies a more complex mechanism of intrarenal destruction. The results indicate the need for additional research studies, particularly random clinical trials, that evaluate the efficacy of drugs for could improve cardio-renal consequences in patients with persistent kidney failure by modifying renal impairment-related metrics.

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