International Journal of Medicine
pISSN 1468-3814 | eISSN 2667-7008
https://theinternationalmedicine.com/

Original Researcher Article *DOI: 10.61336/im/26-2-14*

Echocardiographic Changes In Patients With Chronic Kidney Failure (Stage 5) On Hemodialysis: Prospective Cohort Study from tertiary care hospital in karnataka

[1]Dr Priyanka Phaniraj, [2]Dr Lakshmikantha CR, [3]Dr.Uppara Nagaraju
[1]Assistant Professor, Sridevi Medical college Tumkur.
[2]Assistant professor, Sridevi Medical college Tumkur.
[3]Assistant Professor, Sridevi Medical college Tumkur.

Correspondence:

Received: December 10, 2026
Revised: January 15, 2026
Accepted: February 09, 2026
Published: February 14, 2026

Abstract

Background & Objectives: Cardiovascular diseases (CVD) accounts for up to 50% of all deaths in patients undergoing haemodialysis and account for around one -third of their hospital admissions. Structural changes, in addition to functional changes are detected by echocardiography; which are vital steps for characterization amongst individuals with higher cardiovascular risk. LVMI (left ventricular mass index) is a predictor of cardiovascular morbidity in CKF (chronic kidney failure) patients undergoing haemodialysis. ***Aim:*** Aim of the study is to evaluate the changes in echocardiographic parameters in a patient with chronic kidney failure (stage 5) before and after initiating hemodialysis. ***METHODS:*** This study include 72 patients (23 females) with age ranged from 18 to 55 years. Those who were on continuous maintenance haemodialysis 3 times per week for 3months at least. Complete history with clinical examination, 12 lead ECG, and beside echocardiography was noted. Then all patients underwent regular follow up for XVI 6 months, the end points were the occurrence of fatal or non-fatal cardiovascular events. ***Results:*** 22 patients developed cardiovascular morbidity; 2 unstable angina and 2 CHF, 3 ventricular tachycardia, 2 atrial fibrillation,5 patients had coronary artery disease. 2 patients had sudden cardiac death's one due to SCD. Left ventricular mass index (LVMI) >289 gm/m2 had 66.67% sensitivity and 73.08% specificity for developing of cardiovascular morbidity and mortality. ***Conclusion:*** LVMI is a better predictor of cardiovascular morbidity as well as mortality amongst patients undergoing haemodialysis.

Keywords: CVD, CKF, LVMI, SCD.

INTRODUCTION

Cardiovascular diseases (CVD) results in 50% of all deaths in patients undergoing haemodialysis and account for one third of the hospital admissions among CKD patients1. Structural changes in addition to functional cardiovascular changes are detected by echocardiography; which are important for characterization of cardiovascular risk among CKD patients2.

LVMI (left ventricular mass index) is a predictor of cardiovascular morbidity in CKF (chronic kidney failure) patients undergoing hemodialysis3. CKD patients have a huge burden of cardiovascular disorders, ESRD on MHD patients are at the highest risk for development of cardiovascular events besides death 4. Amongst ESRD patients, idiosyncrasies in left ventricular (LV) structure as well as function are predictors of adverse clinical outcomes5.

We conducted a study on cardiovascular end results in terms of morbidity & mortality of end stage kidney disease patients who were initiated on haemodialysis and hence study the structural and functional cardiovascular changes with echocardiographic parameters, attributed to effects of haemodialysis in stage 5 CKD patients6.

Available data of LV structure as well as function are restricted by cross sectional studies, data of clinical trial participants7, which is generally less representative compared with enrolees of observational research data, hence there was a need to conduct a prospective follow up study8.

The Objective of our study was to evaluate the changes in the echocardiographic parameters in patients with chronic kidney failure (stage 5) before and after initiating on maintenance hemodialysis and to study the significance of echocardiographic parameters in

determining cardiovascuscular outcomes in CKD stage 5D before and after initiating hemodialysis.

MATERIALS AND METHODS

We conducted a Prospective cohort study over a duration of 2 years (September 2019 to September 2021) carried out in patients and out patients of hospitals- a tertiary care, a tertiary care teaching medical centre with alignment with department of nephrology. Institutional ethical committee clearance was obtained.

The calculated Sample Size was 68 patients. After explaining the study procedure and objectives to all the patients, a written informed consent was taken. Patients aged 18 years and above. Who are newly diagnosed as CKD stage 5 and is being initiated on regular haemodialysis (3 times a week) were included in our study.

Patients who had recent history of acute myocardial infarction (less than six months) Recent percutaneous or surgical revascularization, unstable angina or cerebrovascular accident, decompensated congestive heart failure, valvular heart disease. blood pressure >160/110 mmHg, uncontrolled atrial fibrillation or complex ventricular arrhythmia, anaemia with Hb less than 10g% and pregnant women were excluded from the study.

Detailed history, including age, sex, duration of dialysis and predisposing factors of the cardiovascular diseases were assessed and documented in proforma. Clinical examination with assessment of vitals, general and systemic examination were done, a 12-lead surface electrocardiography was recorded. A Doppler echocardiography was performed initially and repeated after six months, by single medical professional, trained and skilled in echocardiography. eGFR (estimated Glomerular Filtration Rate) was calculated using MDRD (Modification of Diet in Renal disease Study) formula. Staging of CKD was done as per by KDIGO (Kidney Disease Improving Global Outcomes). The following echo parameters were assessed:

- End diastolic septal thickness (EDST),
- End diastolic posterior wall thickness (EDPWT),
- Left ventricular end diastolic diameter (LVEDD)
- Left ventricular end systolic diameter (LVESD).
- Left ventricular mass (LVM)
- Left ventricular mass index LVMI. (LVMI = LVM / BSA)
- The relative wall thickness (RWT)
- E/A ratio.
- E/E' ratio.

A Complete blood picture (CBC) and Serum. Creatinine was tested and documented. Data was entered into Microsoft excel data sheet and was analysed using SPSS 22 version software. Categorical data was represented using the Frequencies and proportions. Continuous data was represented as mean and standard deviation. Independent t test was used as test of significance to identify the mean difference between two quantitative variables. ROC curve of 0.5. Area under ROC curve above 0.8 indicated fairly good prediction. Graphical representation of data: MS Excel and MS word was used to obtain various types of graphs. P value of 0.05 was considered as statistically significant after assuming all the rules of statistical tests.

RESULTS

Our study included 74 patients, after 6 months 3 patients were excluded (2 patients underwent renal transplantation,1 patient died due to non-cardiovascular Cause and 71 patients were studied.

TABLE 1: Sex distribution

	Number	percentage
Males	48	67.6%
Females	23	32.39%

Out of 71 patients, 48 were males, 23 were females.

TABLE 2: Shows age group distribution.

Age group			
		Frequency	Percent
	<30	7	9.6
	30 - 40	10	13.7
	40 - 50	8	10.9
	50 -60	21	28.8
	60- 70	16	21.9
	>70	11	15.1

	Total	73	100.0

Maximum patients were in the age group of 50 to 60 years.

TABLE – 3: CAUSES OF CKD

CAUSES OF CKD			Frequency	Valid Percent
		Type 2 DM	47	66.2
		CGN	1	1.4
		Hypertension	2	2.8
		Obstructive Uropathy	4	5.6
		Chronic interstitial Nephritis	3	4.2
		ADPKD	2	2.8
		Others	1	1.4
		IGA nephropathy	4	5.6
		FSGS	3	4.2
		Membranous nephropathy	3	4.2
		Others including LUPUS	1	1.4
		Total	71	100.0

Common cause of CKD among the study population was Type 2DM. Other causes are as represented in the Table 3

TABLE – 4 Describes the basic parameters of study patients.

CAUSES	MEAN	PERCENT
AGE	53.38	14.604
HEIGHT	159.71	9.466
WEIGHT	72.19	13.145
BMI	28.265753	5.2143557
BSA	1.7456	.17061
HB	11.431507	1.0745641
S. CREATININE	3.880822	1.2313788
EGFR	20.40	10.769
LVM	511.14	195.798
LVMI	280.686986	104.9231538

TABLE- 5: Showing echocardiographic parameters with mean and standard deviation at the time of initiating after 6 months of haemodialysis.

ECHOCARDIOGRAPHIC PARAMETERS	MEAN	STANDARD DEVIATION
EDST	1.047	0.174
EDST AFTER 6 MONTHS	1.135	0.234
EDPWT	1.203	0.271
EDPWT AFTER 6 MONTHS	1.354	0.417
LVEDD	3.679	0.523
LVEDD AFTER 6 MONTHS	4.527	0.674
LVESD	2.477	0.486
LVESD AFTER 6 MONTHS	3.312	2.397

TABLE- 6: Showing echocardiographic parameters with mean standard deviation with student t test and p value.

ECHO PARAMETESR	MEAN	STANDARD DEVIATION	t	P value
EDST	0.088	0.160	-4.701	<0.001***
EDPWT	0.151	0.347	-3.715	<0.001***
LVEDD	0.848	0.569	12.722	<0.001***
LVESD	0.836	2.362	3.023	0.0033**
LVM	226.8	158.885	12.116	<0.001***
LVMI	126.102	86.386	12.386	<0.001***
RWT	0.007	0.238	0.261	0.795
E/A	0.033	0.272	1.009	0.316
E/E’	0.010	0.105	0.812	0.420

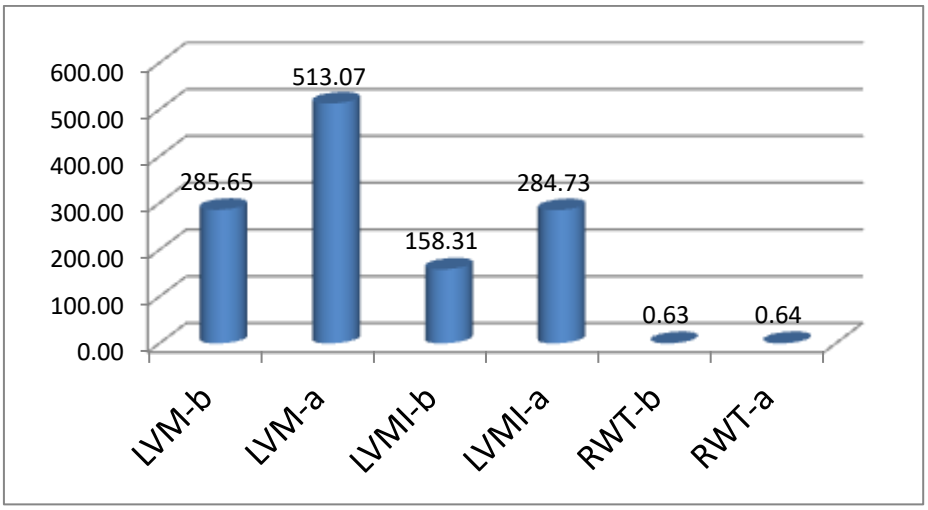

TABLE – 7: Mortality

		Frequency	Valid Percent
	Heart failure	2	7.7
	VT	3	11.5
	AF	2	7.7
	HF	6	23.1
	Death due to CVS cause	2	7.7
	UA	2	7.7
	Renal transplant	4	15.4
	CAD	5	19.2
	Total	26	100.0

TABLE showing number of patients who developed cardiovascular comorbidities during 6 months of follow up period.

TABLE – 8: Showing number of cardiovascular outcomes with s mean and standard deviation of LVM.

		N[a]	Mean	Std. Deviation
	Heart failure	2	341.000	168.291
	VT	3	197.667	77.694
	AF	2	399.000	91.924
	HF	6	342.833	64.008
	Death due to CVS cause	2	187.500	161.927
	UA	2	316.000	32.527
	Renal transplant	4	261.500	157.667
	CAD	5	235.000	70.459

TABLE- 9: Table showing number of patients who developed cardiovascular comorbidities during 6 months of follow up with mean and standard deviation of LVM.

		N[a]	Mean	Std. Deviation
	Heart failure	2	691.000	326.683
	VT	3	391.000	162.730
	AF	2	688.000	101.823
	HF	6	640.000	129.239
	Death due to CVS cause	2	301.500	258.094
	UA	2	522.500	85.560
	Renal transplant	4	468.250	289.497
	CAD	5	436.800	135.701

Table 10: - Comparison of mean age between two groups

	NO CV Outcome		CV outcome		P value
	Mean	SD	Mean	SD	
AGE	54	14	53	16	0.765

There was no statistically significant difference found between groups with respect to age

Table 11: - Comparison of mean echocardiographic parameters among the patients who developed cardiovascular outcomes and those without cardiovascular outcomes.

	NO CV Outcome		CV outcome		P value
	Mean	SD	Mean	SD	
EDST	1.1419	.2533	1.1171	.1805	0.685
EDPWT	1.3869	.4593	1.2710	.2780	0.285
LVEDD	4.4725	.5336	4.6619	.9394	0.280
LVESD	2.9327	.5102	4.2524	4.3273	0.179
LVM	461	147	635	246	**<0.01**
LVMI	254.5029	90.4444	345.5238	112.1422	**<0.01**
RWT	.6312	.1907	.6500	.3040	0.752
E/A	1.0629	.2907	1.0786	.1933	0.821
E/E	1.1431	.1151	1.1786	.0937	0.214
EF	1.6	.9	1.7	.7	0.797

There was a statistically significant difference found between groups with respect to LVM and LVMI

FIGURE: 3 SHOWING ECHOCARDIOGRAPHIC PARAMETERS AT THE TIME OF INITIATING HD AND 6 MONTHS AFTER INITIATION OF HD.

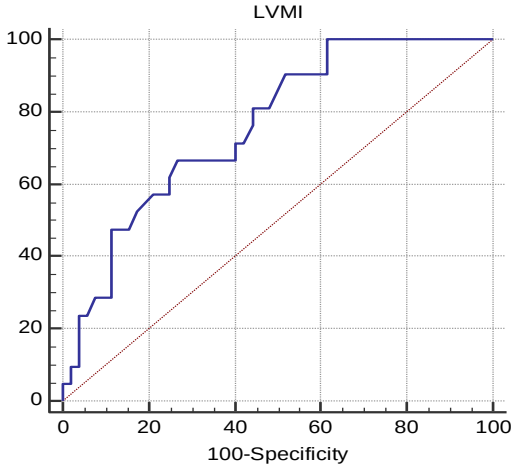

Figure: - ROC for LVMI in predicting outcome

TABLE- 12:

Cut off	Sensitivity	Specificity	+PV	-PV
>289	66.67	73.08	50.0	84.4

The LVMI for patients with cardiovascular outcomes had sensitivity of 66.67% and specificity of 73.08%. with cut-off of 289.

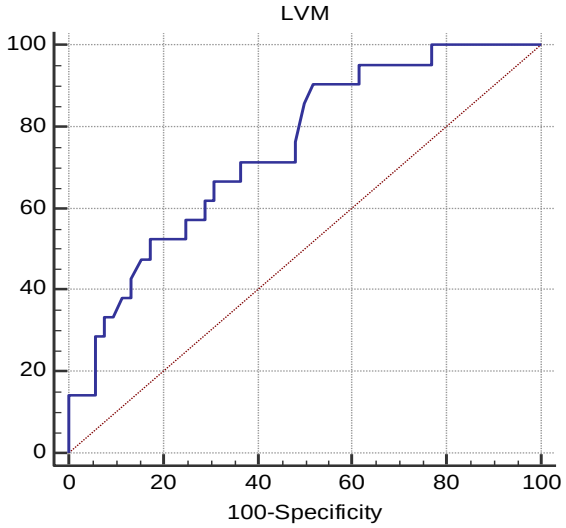

Figure: - ROC for LVM in predicting outcome

TABLE- 13:

Cut off	Sensitivity	Specificity	+PV	-PV
>448	90.48	48.08	41.3	92.6

The LVM for patients with cardiovascular outcomes had sensitivity of 90.48% and specificity of 43.08%. with cut-off of 448.

Figure: - ROC for LVM in predicting outcome

DISCUSSION

Cardiovascular complications are the main cause of mortality chronic kidney disease patients (CKD) undergoing haemodialysis therapy.9 The diagnosis of LV abnormalities by Doppler echocardiography is essential for the characterization of individuals with higher cardiovascular risk beside estimating the prevalence of primary heart disease to study its predisposing factors, prognostic impact and the effect of therapeutic interventions.10

The Doppler echocardiogram is a complementary, non-invasive examination, broadly used in the assessment of heart structure and function, bringing several ultra-sound techniques together in a single examination. 11

In this study our aim was to evaluate the predictive value of echocardiographic parameters for analysing cardiovascular outcomes in patients with chronic renal failure stage 5 undergoing maintenance haemodialysis.61 patients initiating on maintenance haemodialysis were included in this study. They were subjected to clinical and echocardiographic examination and within 6 months of follow up 16% of patients developed cardiovascular mortality and morbidity, we divided them in two groups – patients with cardiovascular outcomes, and those without cardiovascular outcomes.

Common cause of CKD in our study was type 2 dm. Mean LVM was 226.8 and LVMI was 126.12 Mean LVM among patients with no cardiovascular outcomes was 461, and in patients with CV outcomes was 635. Mean LVMI in patients with cv outcomes was 345.52, and in those with no cardiovascular outcomes was 254.50 The LVMI for patients with cardiovascular outcomes had sensitivity of 66.67% and specificity of 73.08%. with cut-off of 289.

The LVM for patients with cardiovascular outcomes had sensitivity of 90.48% and specificity of 43.08%. with cut-off of 448. Mean LVESD in patients with CVS outcomes was 4.25 compared to those with no CVS

outcomes was 2.9327. Mean LVEDD in patients with CVS outcomes was 4.66, compared to patients with no CVS outcomes which was 4.47. EDPWT in patients with CVS outcomes was 1.271, compared to patients with no CVS outcomes which was 1.3869. EDST in patients with CVS outcomes was 1.1171, compare to patients with no cardiovascular outcomes which was 1.1419.

In concordance to our study Zoccali et al in a prospective study in 161 haemodialysis patients tested the prognostic importance of changes in LVM on survival and incident cardiovascular events. After 4 years of follow up they found that the rate of increase of LVMI was significantly (P = 0.029) more amongst patients with incident cardiovascular events than in those without such events and concluded that changes in LVMI have an independent prognostic value for cardio-vascular events and provide scientific support to the use of repeated echocardiographic studies for monitoring cardiovascular risk in dialysis patients.13

In another study Chen et al, who studied 505 patients with stage 3–5 chronic kidney disease with 3 years follows up period found that increase in the left ventricular mass index (LVMI) independently associated with adverse CV outcomes in CKD patients with (P = 0.003). 14 Also, Mostovaya et al, who studied 327 patients on haemodialysis with mean follow up period of 2 years confirmed the relation between LVM and all-cause mortality. Furthermore, it demonstrated a markedly increase in the peril of unexpected death in individuals with a high LVM.15

In concordance with our study, Hillege et al. found that there was a significant correlation between the deterioration of congestive CCF and the progression of kidney failure16. Our study found that, with the decrease of renal function, there was a significant trend for a stepwise increase in LVMI and the presence of LVH and LVEF < 55% and a stepwise decrease in LVEF in diabetic nephropathy patients, which is consistent with the previous study findings.

We found that age and LVMI were the only predictors that can predict 6 months mortality in haemodialytic patients with significant statistical differences LVM (p value = 0.001) and LVMI (p value = 0.001). In another study Chen et al17 who studied 505 patients with stage 3–5 chronic kidney disease with 3 years follow up period found that elevated left ventricular mass index (LVMI) independently associated with adverse CV outcomes in CKD patients with (P = 0.001).

In disconcordance to our results, Siqueira et al18 who studied 60 patients with CKD undergoing haemodialysis for 6 months found that moderate to severe diastolic dysfunction was a non-dependent risk factor for cardiovascular events but in this study diastolic dysfunction was not associated with cardiovascular mortality or morbidity possible explanation may be short follow up period.

Also, in disconcordance to our results, Dogan et al19 who studied 45 chronic haemodialysis patients with complete standard and tissue Doppler imaging echocardiography with follow up period (26month) found that E/e [ratio of mitral E to peak early diastolic mitral annular velocity (e)] were significantly higher in patients who had major events. In Cox proportional hazard analysis only E/e ratio predicted combined endpoint of all-cause mortality and nonfatal cardiovascular events (p = 0.018).in this study no significant statistical differences between two groups (p value = 0.550) possible explanation might be short follow up period.

In our study, Of the total sample size of 68 patients, 26 (38.23%) patients developed cardiovascular comorbidities. 30.8% of the patients had hospital admissions secondary to heart failure, 19.2% had arrhythmias, 19.2% had coronary artery disease. LVMI, LVM, EDST, LVEDD were significantly elevated in these subgroups of patients with p value of <0.001.

In concordance to our study, study done by Chen, Szu-Chia et al. 20showed a significant stepwise increase in LVMI (P < 0.001), LVH (P < 0.001), and LVEF < 55% (P = 0.013) and a stepwise decrease in LVEF (P = 0.038) corresponding to advance in CKD stages. Taken together, the interaction of functional and structural derangements in the heart and kidney amplifies the progression of CKD and have unfavourable cardiovascular outcomes.21

CONCLUSION

Echocardiographic parameters have prognostic significance in determining cardiovascular morbidity and mortality in CKD patients on haemodialysis. LVM and LVMI are significantly elevated in patient who developed cardiovascular outcomes compared to patient who did not develop cardiovascular outcomes.

REFERENCES

1.Collins AJ, Foley RN, Herzog C, Chavers BM, Gilbertson D, Ishani A, Kasiske BL, Liu J, Mau LW, McBean M, Murray A, St Peter W, Guo H, Li Q, Li S, Li S, Peng Y, Qiu Y, Roberts T, Skeans M, Snyder J, Solid C, Wang C, Weinhandl E, Zaun D, Arko C, Chen SC, Dalleska F, Daniels F, Dunning S, Ebben J, Frazier E, Hanzlik C, Johnson R, Sheets D, Wang X, Forrest B, Constantini E, Everson S, Eggers PW, Agodoa L . Am J Kidney Dis. 2010;55(1 Suppl 1):S1.

2.Hunter JJ, Chien KR: Signaling pathways for cardiac hypertrophy and failure. N Engl J Med 341:1276-1283, 1999.

3.J. D. Harnett, P. S. Parfrey, S. M. Griffiths, M. H. Gault, P. Barre, and R. D. Guttmann, “Left ventricular

hypertrophy in end-stage renal disease," Nephron, vol. 48, no. 2, pp. 107– 115, 1988.
4.Foley RN, Parfrey PS, Harnett JD, et al. The prognostic importance of left ventricular geometry in uremic cardiomyopathy. J Am Soc Nephrol, 5:2024-2031, 1995.
5.Parfrey PS, Foley RN, Harnett JD, et al: Outcome and risk factors for left ventricular disorders in chronic uremia. Nephrol Dial Transplant, 11: 1277-1285, 1996.
6. Parfrey PS, Foley RN, Harnett JD, et al: Outcome and risk factors for ischemic heart disease in chronic uremia. Kidney Int, 49: 1428-1434, 1996.
6.(London GM, Marchais SJ, Guerin AP, et al. Arterial structure and function in end-stage renal disease. Nephrol Dial Transplant. 2002; 17: 1713–1724.
7.Foley RN, Parfrey PS, Hefferton D et al. Advance prediction of early death in patients starting maintenance hemodialysis. Am J Kidney dis, 23:836-845, 1994.
8.C. Zoccali, "How important is echocardiography for risk stratification in followup of patients with chronic kidney disease?" Nature Clinical Practice Nephrology, vol. 3, no. 4, pp. 178–179, 2007.
9.Chen S, Chan J, Liu W, et al. Echocardiographic parameters are independently associated with increased cardiovascular events in patients with chronic kidney disease. Nephrol Dial Transplant. 2011;1–7.
10.Caroll JD, Hess OM. Assessment of normal and abnormal cardiac function. In Braunwald's Heart Disease, 7th ed, p495, Elsevier Saunders, Philadelphia, 2005.
11.Chen, Szu-Chia et al. "Stepwise increases in left ventricular mass index and decreases in left ventricular ejection fraction correspond with the stages of chronic kidney disease in diabetes patients." Experimental diabetes research vol. 2012 (2012): 789325. doi:10.1155/2012/789325.
12. H. L. Hillege, A. R. Girbes, P. J. de Kam et al., "Renal function, neurohormonal activation, and survival in patients with chronic heart failure," Circulation, vol. 102, no. 2, pp. 203–210, 2000.
13. Stenvinkel P, Carrero JJ, Axelsson J, et al. Emerging biomarkers for evaluating cardiovascular risk in the chronic kidney disease patient: how do new pieces fit into the uremic puzzle? Clin J Am Soc Nephrol. 2008;3:505–521.)
14. .(London GM, Marchais SJ, Guerin AP, et al. Arterial structure and function in end-stage renal disease. Nephrol Dial Transplant. 2002; 17: 1713–1724
15. (Mitchell GF, Izzo JL, Lacourciere Y, et al. Omapatrilat reduces pulse pressure and proximal aortic stiffness in patients with systolic hypertension: results of the conduit hemodynamics of omapatrilat international research study. Circulation. 2002; 105: 2955–2961. Crossref. PubMed.)
16. Blacher J, Guerin AP, Pannier B, et al. Impact of aortic stiffness on survival in end-stage renal disease. Circulation. 1999; 99: 2434–2439
17. Klassen PS, Lowrie EG, Reddan DN, et al. Association between pulse pressure and mortality in patients undergoing maintenance hemodialysis. JAMA. 2002; 287: 1548–1555.)
18 .(Harnett JD, Foley RN, Kent GM, et al. Congestive heart failure in dialysis patients: prevalence, incidence, prognosis and risk factors. Kidney Int. 1995; 47: 884–890.)
19. Dai Y, et al. Correlative factors of left ventricular hypertrophy in end stage renal disease. J Tongji Med Univ, 13(4): 252-256, 1993.
20. Feigenbaum. Evaluation of systolic and diastolic function of left ventricle. In Feigenbaum's Textbook of Echocardiography, 6th ed, p148, Lippincott Williams & Wilkins, Philadelphia, 2005.
21. Caroll JD, Hess OM. Assessment of normal and abnormal cardiac function. In Braunwald's Heart Disease, 7th ed, p495, Elsevier Saunders, Philadelphia, 2005.
22. Frommer JP, Young JB, Ayus JC. Asymptomatic pericardial effusion in uremic patients: Effect of long tem dialysis. Nephron, 39(4): 296-301, 1985.
23. Gupta Amit, Malhotra KK, Dash SC. Late pericarditis in patients on maintenance hemodialysis. J Assoc Physicians India, 34: 857-859. 1986. 48. Feigenbaum. Pericardial Diseases. In Feigenbaum's Textbook of Echocardiography, p250, 6th ed, Lippincott Williams & Wilkins, Philadelphia, 2005.
24. Mosseri M, Yarom R, Gotsman MS and Hasin Y.Histologic evidence for small vessel coronary artery in patients with angina pectoris and patent large coronary arteries. Circulation 74: 964, 1986
25. . Parfrey PS, Foley RN, Harnett JD, et al: Outcome and risk factors for left ventricular disorders in chronic uremia. Nephrol Dial Transplant, 11: 1277-1285, 1996.
26. . Rambusek M, Amann K, Mall G and Ritz E. Structural causes of cardiac dysfunction in uremia. Ren Fail, 15: 421, 1993.
27 . Massry SG, Smogorzewski M. Mechanisms through which parathyroid hormone mediates its deleterious effects on organ function in uremia. Semin Nephrol, 14: 219, 1994.
28. Burt R, et al. Reversal of left ventricular dysfunction after renal transplantation. Ann Intern Med, 111:635, 1989.
29. Hunter JJ, Chien KR: Signaling pathways for cardiac hypertrophy and failure. N Engl J Med 341:1276-1283, 1999.
30. Braun J, Oldendorf M, Moshage W, et al: Electron beam computed tomography in the evaluation of cardiac calcification in chronic dialysis patients. Am J Kidney Dis 27:394-401, 1996.
31. Kramer W, Wizemann V, Lammlein G, et al: Cardiac dysfunction in patients on maintenance hemodialysis: II: Systolic and diastolic properties of the left ventricle assessed by invasive methods. Contrib Nephrol 52:97-109, 1986.
32. Wizemann V, Kramer W, Thormann J, et al: Cardiac arrhythmias in patients on maintenance

hemodialysis: Causes and management. Contrib Nephrol 52:42-53, 1986.
33. Verbeelen D, Bossuyt A, Smitz J, et al: Hemodynamics of patients with renal failure treated with recombinant human erythropoietin. Clin Nephrol 31:6-11, 1989.
34. Cannella G, La Canna G, Sandrini M, et al: Renormalization of high cardiac output and of left ventricular size following long-term recombinant human erythropoietin treatment of anemic dialyzed uremic patients. Clin Nephrol 34:272-278, 1990.
35. McMahon LP, Mason K, Skinner SL, et al: Effects of haemoglobin normalization on quality of life and cardiovascular parameters in endstage renal failure. Nephrol Dial Transplant 15:1425-1430, 2000.