http://www.pjbs.org

PJBS

ISSN 1028-8880

Pakistan Journal of Biological Sciences

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Pakistan Journal of Biological Sciences 14 (17): 844-848, 2011
ISSN 1028-8880 / DOI: 10.3923/pjbs.2011.844.848

Common Carotid Artery Intima-media Thickness and Atherosclerotic Plaques in Carotid Bulb in Patients with Chronic Kidney Disease on Hemodialysis: A Case-control Study

[1]Abolhassan Shakeri, [1]Mehdi Abdi, [2]Hamid Tayyebi Khosroshahi and [1]Rohollah Fadaei Fouladi
[1]Department of Radiology, Tabriz University of Medical Sciences,
Imam Reza Hospital, Tabriz, Iran
[2]Department of Nephrology, Tabriz University of Medical Sciences, Imam Reza Hospital, Tabriz, Iran

Abstract: The Common Carotid artery Intima-Media Thickness (CCIMT) can reflect systemic atherosclerosis in renal patients on hemodialysis. This study aimed to compare CCIMT measured by color Doppler ultrasonography between two groups including dialytic patients and normal subjects. In this case-control setting, 48 patients with Chronic Kidney Disease (CKD) on hemodialysis (case group) and 46 age and sex-matched healthy subjects (control group) were enrolled in this study. Color Doppler ultrasound was used to measure CCIMT and determine presence of atherosclerotic plaques in carotid bulb in both groups. Various laboratory parameters were also determined. Serum levels of triglyceride, total cholesterol, low-density lipoprotein, fasting sugar, ionized calcium, inorganic phosphorus and magnesium were comparable between the two groups. Hypertension and elevated levels of serum C-reactive protein, as well as the mean levels of serum non-fasting homocysteine and phosphate were significantly higher in the case group. Mean levels of serum high-density lipoprotein and albumin were significantly higher in the controls. Mean maximum CCIMT was significantly higher in the case group than in controls (0.73±0.15 vs. 0.68±0.08 mm, p = 0.01) even after adjusting for other confounding variables. Frequency of patients with atherosclerotic plaques in carotid bulbs was not significantly different between case and controls. In conclusion, this study showed that CCIMT is significantly higher in CKD patients on hemodialysis comparing with matched normal counterparts. Furthermore, this difference was independent of other conventional risk factors for atherosclerosis.

Key words: Chronic kidney disease, intima-media thickness, color doppler ultrasound, atherosclerosis, risk factor

INTRODUCTION

Base on available data, cardiovascular problems constitute one of the major causes of morbidity and mortality in patients with Chronic Kidney Disease (CKD) (Cooper, 2001). Furthermore, it is definitely shown that the incidence of cardiovascular diseases and pathologic atherosclerotic changes in particular, is considerably high in CKD patients under maintenance dialysis. This is thought to be due to higher rates of metabolic and endocrine disarrangements, such as abnormalities in lipid profile and uremic dyslipidemia, increased oxidant stress, hyperhomocysteinemia, disorders of calcium and phosphorus metabolism and metabolic deficiencies of glucose (Assal *et al*., 2006; Nasri and Baradaran, 2006; Ragab and Ragab, 2007; Atwa *et al*., 2011; Onyeneke *et al*., 2007; Reis *et al*., 2002; Foley *et al*., 1998; Kimura *et al*., 2001). Various studies have proposed that Intima-Media Thickness (IMT) and atherosclerotic plaques in great arteries are good indicators of a more generalized atherosclerosis (Alaee and Khademloo, 2008; Jaarin *et al*., 2006; Leskinen *et al*., 2003; Rossi *et al*., 1996; Mikovanov *et al*., 2006). Indeed, ultrasonography of the carotid arteries is claimed to be a fundamental technique for noninvasive investigation of atherosclerosis in hemodialysis patients (Gelev *et al*., 2008). There are a limited number of studies in the literature investigated IMT of carotid arteries in dialytic patients (Mutluay *et al*., 2010; Bevc *et al*., 2008; Karaman *et al*., 2008) with heterogeneous consequences due to flawed methodology or small sample sizes. The current study aimed at comparing the IMT of common carotid artery (CCIMT), as

Corresponding Author: Rohollah Fadaei Fouladi, Department of Radiology, Tabriz University of Medical Sciences, Imam Reza Hospital, Tabriz, Iran Tel: +98-914-4122542

well as frequency of cases with atherosclerotic plaques in common carotid artery and bulb in CKD patients on hemodialysis and normal controls.

MATERIALS AND METHODS

Study design and patients: In this case-control setting, 89 outpatients on hemodialysis (age>40 year), as the case group and 90 age and sex-matched healthy subjects, as the control group, were recruited in Imam Reza Teaching Centre, Tabriz, Iran from April 2010 to June 2011. Written consent was obtained from each participant. This study was approved by the ethics committee of Tabriz University of Medical Sciences. Obese patients (body mass index = 30), cases with Diabetes Mellitus (DM), mineral bone disease, or underlying coronary artery disease and cigarette smokers were excluded. Finally 48 dialytic patients and 46 controls were left.

Color doppler ultrasound: All subjects were evaluated by a single skilled radiologist specialized in Doppler ultrasonography of the vascular system and the CCIMT was calculated. The sonographist was blind to the grouping of subjects. Sonographic assessment was performed by using Aloka ProSound SSD 3500 plus color Doppler machine (Aloka Ltd., Tokyo, Japan) equipped with a 7MHz linear array transducer with subjects in supine position with a slight extension of the neck. All scans were performed by one observer following the method described by Geroulakos *et al*. (1994). The anterior and lateral projections were employed for imaging the common carotid artery longitudinally. The CCIMT was evaluated at the wall of artery 2 cm proximal to its bifurcation. Internal carotid artery and the bulb of carotid artery were also included in this assessment. The images were zoomed to standard size. The CCIMT was calculated as the mean value of six individual measurements at different points within the region of interest (three for the right and three for the left artery). A plaque was defined as a distinct area with an IMT exceeding twice that of neighboring sites. The CCIMT was calculated in both sides and the maximum reading was also considered as a parameter for evaluation.

Variables: Serum levels of triglyceride, High-Density Lipoprotein (HDL), Low-Density Lipoprotein (LDL), total cholesterol, Fasting Sugar (FBS), ionized calcium, inorganic phosphorus, magnesium, non-fasting homocysteine, phosphate, albumin and C-Reactive Protein (CRP) were measured. The serum level of CRP>6 mg dL^{-1} was considered as elevated. Hypertension was defined as a systolic blood pressure ≥140 mmHg and a diastolic blood pressure ≥90 mmHg.

Statistical analysis: The SPSS software ver. 15.0 employed for analysis. Differences between the groups regarding the numerical data were assessed using the unpaired t test. Differences between the groups regarding the categorical data were assessed using the Chi-square test or the Fisher's exact test. Stepwise logistic regression analysis was used to identify the independent factors among the parameters. p-values<0.05 were considered statistically significant.

RESULTS

Mean duration of CKD was 157.40±29.23 (range: 142-165) months and mean duration of hemodialysis was 43.52±9.92 (range: 54-63) months. Patients in the case and control groups were matched for age, gender, serum levels of triglyceride, total cholesterol, LDL, FBS, ionized calcium, inorganic phosphorus and magnesium, as well as the history of taking lipid/lowering agents. Percentage of hypertensive patients (29.2 vs. 0%; p<0.001) and those with elevated serum CRP (35.4 vs. 4.3%; p<0.001), as well as mean levels of serum non-fasting homocysteine (46.22±6.20 vs. 10.21±5.23 nmol mL^{-1}; p<0.001), phosphate (2.29±1.38 vs. 0.6±0.02 nmol L^{-1}; p<0.001), creatinine (3.83±0.72 vs. 0.92±0.22 mg dL^{-1}; p<0.001) and BUN (87.56±14.61 vs. 9.75±2.24 mg dL^{-1}; p<0.001) were significantly higher in the case group. On the other hand, mean levels of serum HDL (49.22±8.27 vs. 52.52±7.01 mg dL^{-1}; p = 0.04), hemoglobin (10.09±1.54 vs. 11.71±1.84 mg dL^{-1}; p = 0.03), hematocrit (35.45±4.12 vs. 43.02±4.52%; p<0.001) and albumin (3.34±1.04 vs. 5.34±0.67 g dL^{-1}) were significantly higher in the controls (Table 1).

Based on Doppler ultrasound findings, mean right CCIMT (0.71±0.11 vs. 0.66±0.09 mm; p<0.01), left CCIMT (0.71±0.10 vs. 0.63±0.08 mm; p<0.001) and maximum CCIMT (0.73±0.15 vs. 0.68±0.08 mm; p = 0.01) were significantly higher in the case group. Accordingly, atherosclerotic plaques were more frequent in cases in right CCA (20.8 vs. 0%; p<0.001) and in left CCA (16.7 vs. 0%; p<0.001). Frequency of patients with atherosclerotic plaques in carotid bulbs was not significantly different between case and controls (Table 2).

To detect independent variables with significant difference between the case and control groups, the significant parameters in univariate tests mentioned before were analyzed in a proper multivariate model. Based on the outcomes of this model, there was no

Table 1: Characteristics and general data of subjects in the case and control groups

Variables	Case (n = 48)	Control (n = 46)	p-value
Age (year)	52.52±9.81 (47-71)	51.11±8.01(42-75)	0.46
Gender (male)	22 (45.8)	25 (54.3)	0.71
Hypertension	14 (29.2)	0 (0)	<0.001
Serum triglyceride (mg dL^{-1})	105.52±14.53 (96-298)	109.32±12.82 (81-202)	0.06
Serum total cholesterol (mg dL^{-1})	117.71±43.72 (97-221)	117.91±30.61 (83-191)	0.98
Serum low-density lipoprotein (mg dL^{-1})	119.51±22.08 (101-206)	113.06±13.24 (77-173)	0.46
Serum high-density lipoprotein (mg dL^{-1})	49.22±8.27 (11-67)	52.52±7.01 (23-89)	0.04
Lipid/cholesterol lowering agents	4 (8.3)	0 (0)	0.117
Serum fasting blood sugar (mg dL^{-1})	85.86±34.22 (65-265)	85.14±21.82 (58-211)	0.74
Hemoglobin (mg dL^{-1})	10.09±3.54 (8-13)	11.71±3.84 (9-18)	0.03
Hematocrit (%)	35.45±6.12 (24-39)	43.02±4.52 (36-48)	<0.001
Serum non-fasting homocysteine (nmol mL^{-1})	46.22±6.20 (37-53)	10.21±5.23 (3-21)	<0.001
Serum ionized calcium (mg dL^{-1})	5.34±1.07 (2.6-8.8)	5.01±1.21 (3.8-8.9)	0.08
Serum inorganic phosphorus (mg dL^{-1})	4.35±1.65 (2.5-6.9)	3.97±0.12 (1.3-4.9)	0.65
Serum phosphate (mmol L^{-1})	2.29±1.38 (1.8-4.1)	0.6±0.02 (0.1-0.89)	<0.001
Serum magnesium (mg dL^{-1})	2.34±0.34 (2.1-2.98)	2.04±0.43 (1.9-2.56)	0.35
Serum creatinine (mg dL^{-1})	3.83±0.72 (3.1-4.9)	0.92±0.22 (0.3-1.1)	<0.001
Blood urea nitrogen (mg dL^{-1})	87.56±14.61 (56-113)	9.75±2.24 (7.4-14.8)	<0.001
Serum albumin (g dL^{-1})	3.34±1.04 (1.9-3.8)	5.34±0.67 (4.9-5.8)	<0.001
Elevated serum C-reactive protein level	17 (35.4)	2 (4.3)	<0.001

Data presented as mean±standard deviation (range) and frequency (%) p = 0.05 is statistically significant

Table 2: Findings of color Doppler ultrasound in the case and control groups

Variables	Case (n = 48)	Control (n = 46)	p-value	OR	95% CI*
Right CCIMT (mm)	0.71±0.11 (0.56-0.78)	0.66±0.09 (0.45-0.68)	<0.01	-	-
Left CCIMT (mm)	0.71±0.10 (0.55-0.79)	0.63±0.08 (0.43-0.65)	<0.001	-	-
Maximum CCIMT (mm)	0.73±0.15 (0.68-0.79)	0.68±0.09 (0.64-0.68)	0.01	-	-
Atherosclerotic plaque in right CCA	10 (20.8)	0 (0)	<0.001	1.3	1.1-1.5
Atherosclerotic plaque in left CCA	8 (16.7)	0 (0)	<0.001	1.3	1.1-1.4
Atherosclerotic plaque in right bulb	4 (8.3)	0 (0)	0.1	1.1	1-1.2
Atherosclerotic plaque in left bulb	2 (4.2)	0 (0)	0.5	1	1-1.1

Data presented as Mean±SD (range) and number (%), CCA: Common Carotid Artery, CCMIT Common Carotid Intima-Media Thickness, CI: Confidence Interval, OR: Odds Ratio. *For the odd ratio. $p \leq 0.05$ is statistically significant

Table 3: Outcomes of multivariate model in evaluation of variables with significant difference between the case and controls

Variables	p-value	Exp (B)
Hypertension	0.26	0.54
Serum high-density lipoprotein	0.09	0.34
Serum non-fasting homocysteine	0.03	1.11
Serum phosphate	0.02	1.00
Elevated serum C-reactive protein level	0.12	0.05
Serum albumin	0.56	0.54
Maximum CCIMT	0.03	0.98

CCMIT: Common Carotid Intima-Media Thickness. Serum non-fasting homocysteine and phosphate and maximum CCIMT are independent variables with significant difference between the case and control groups

significant difference between the two groups in terms of hypertension, as well as mean levels of serum HDL, CRP and albumin. On the other hand, serum non-fasting homocysteine (p = 0.03) and phosphate (p = 0.02), as well as maximum CCIMT (p = 0.03) were independently and significantly different between the case and control groups (Table 3).

DISCUSSION

Based on results of current study, atherosclerosis is a major finding in patients on hemodialysis. This is in line with previous reports indicating that process of atherosclerosis is accelerated in CKD (Balsam *et al*., 2009). To investigate atherosclerotic changes in different settings, a non-invasive, simple and reproducible method is proffered. Our study showed that this could be attained by using color Doppler ultrasound and measurement of CCIMT in patients with CKD and under hemodialysis. Accordingly, the mean CCIMT was significantly higher in these patients comparing with than in a group of well-matched healthy counterparts (0.73 vs. 0.68 mm; p = 0.01). This finding is in conformity with previous studies on CKD patients, reporting a wide range for CCIMT from 0.6 to 2 mm (Kumar *et al*., 2009; Prasad *et al*., 2009; Balci *et al*., 2010). Methodological shortcomings such as absences of a well-matched healthy control, errors in IMT readings and small sample size may justify this available heterogeneity. In addition, it should be born in mind that despite a significant progression made over

the past years on recognizing pathophysiology of atherosclerosis in CKD patients, the exact mechanism is not well established yet. Age (Kuang *et al*., 2009), diabetes mellitus (Sanchez-Alvarez *et al*., 2010), hypertension (Ekart *et al*., 2009), duration of dialysis (Nakamura *et al*., 2010), high serum CRP (Tirmenstajn-Jankovic and Dimkovic, 2005) low serum albumin (Sezer *et al*., 2002), high serum calcium (Ohya *et al*., 2010), high serum phosphate (Ishimura *et al*., 2005), low serum magnesium (Turgut *et al*., 2008), abnormal lipid profile (Zumrutdal *et al*., 2007) and high serum homocysteine (Suliman *et al*., 2006) have been proposed as underlying contributors of increased risk of atherosclerosis in these patients. In line with some of these reports, we also showed a significant difference between the case and control groups in terms of FBS, hypertension and serum phosphate, albumin and creatinine. However, other factors were comparable between the two groups. To the best of our knowledge, there is not a well-controlled methodologically appropriate study with enough sample size investigating role of these parameters altogether. Accordingly, our findings could be regarded unique in this regard; because they all were entered in a multivariate model, comparing two groups of participants including dialytic patients and normal subjects. Based on the final outcome, maximum CCIMT was and independent indicator of atherosclerosis in patients on hemodialysis (Exp (B) = 0.98). In another example, Pascazio *et al*. (1996) showed that the number of patients with carotid plaques were significantly higher in the uremic dialytic cases vs. normal controls. However, they did not report a significant difference in term of atheromatous lesions in hemodialysis patients compared with control subjects. In contrast with this report, atherosclerotic changes in common carotid artery were significantly more common and more advanced in the case than in control group in the present study. This conflict may be attributed to lack of multivariate analysis in Pascazio's series. As mentioned earlier, there is no similar study to test our finding in comparison with. So, further studies are recommended to be carried out in this regard for a definite conclusion could be drawn.

CONCLUSION

According to present findings CCIMT is an indicator of atherosclerosis in dialytic patients due to CKD. Comparing with healthy counterparts, atherosclerosis was significantly and independent of other traditional risk factors more advanced in the case group, indicating a possible role for hemodialysis.

REFERENCES

Alaee, A. and M. Khademloo, 2008. Evaluation of correlation between carotid artery intima media wall thickness and coronary artery stenosis in sari, North of Iran. Pak. J. Biol. Sci., 11: 2360-2363.

Assal, H.S., H.M. Emam and N.A. El-Ghaffar, 2006. Health related quality of life among Egyptian patients on hemodialysis. J. Med. Sci., 6: 314-320.

Atwa, H.A., H. Shora and H. Fahmy, 2011. Normal adiponectin level and glycemic control could delay subclinical atherosclerotic changes in lean type 1 diabetic children. J. Med. Sci., 11: 145-151.

Balci, M., A. Kirkpantur, M. Gulbay and O.A. Gurbuz, 2010. Plasma fibroblast growth factor-23 levels are independently associated with carotid artery atherosclerosis in maintenance hemodialysis patients. Hemodial. Int., 14: 425-432.

Balsam, A., M.M. El-Kossi, R. Lord and A.M. El-Nahas, 2009. Cardiovascular disease on hemodialysis: Predictors of atherosclerosis and survival. Hemodial. Int., 13: 278-285.

Bevc, S., S. Sabic and R. Hojs, 2008. Atherosclerosis in hemodialysis patients: The role of microinflammation. Ren. Fail., 30: 1012-1016.

Cooper, L., 2001. USRDS. 2001 annual data report. Nephrol. News Issues, 15: 31-38.

Ekart, R., R. Hojs, B. Pecovnik-Balon, S. Bevc and B. Dvorsak, 2009. Blood pressure measurements and carotid intima media thickness in hemodialysis patients. Ther. Apher. Dial., 13: 288-293.

Foley, R.N., P.S. Parfrey and M.J. Sarnak, 1998. Clinical epidemiology of cardiovascular disease in chronic renal disease. Am. J. Kidney Dis., 32: 112-119.

Gelev, S., G. Spasovski, S. Dzikova, Z. Trajkovski, G. Damjanovski, V. Amitov and A. Sikole, 2008. Vascular calcification and atherosclerosis in hemodialysis patients: What can we learn from the routine clinical practice? Int. Urol. Nephrol., 40: 763-770.

Geroulakos, G., D.J. O'Gorman, E. Kalodiki, D.J. Sheridan and S.N. Nicolaides, 1994. The carotid intima-media thickness as a marker of the presence of severe symptomatic coronary artery disease. Eur. Heart J., 15: 781-785.

Ishimura, E., H. Tamiwaki, T. Tabata, Y. Tsujimoto and S. Jono *et al*., 2005. Cross-sectional association of serum phosphate with carotid intima-medial thickness in hemodialysis patients. Am. J. Kidney Dis., 45: 859-865.

Jaarin, K., M. Norhayati, G. Norzana, U. Nor Aini and S. Ima-Nirwana, 2006. Effects of heated vegetable oils on serum lipids and aorta of ovariectomized rats. Pak. J. Nutr., 5: 19-29.

Karaman, O., R. Albayrak, M. Colbay, S. Yuksel, I. Uslan, G. Acarturk and H. Saglam, 2008. Carotid hemodynamic parameters in hemodialysis patients. Int. Urol. Nephrol., 40: 779-784.

Kimura, H., R. Miyazaki, S. Suzuki, F. Gejyo and H. Yoshida, 2001. Cholesteryl ester transfer protein as a protective factor against vascular disease in hemodialysis patients. Am. J. Kidney. Dis., 38: 70-76.

Kuang, D., H. You, F. Ding, J. Xue, J. Chen, C. Ronco and Y. Gu, 2009. Intima-media thickness of the carotid artery and its correlation factors in maintenance hemodialysis patients: A cross-sectional study. Blood. Purif., 28: 181-186.

Kumar, K.S., A.Y. Lakshmi, P.V.S. Rao, G.C. Das and V.S. Kumar, 2009. Carotid intima-media thickness in patients with end-stage renal disease. Indian J. Nephrol., 19: 13-14.

Leskinen, Y., T. Lehtimaki, A. Loimaala, V. Lautamatti and T. Kallio *et al*., 2003. Carotid atherosclerosis in chronic renal failure-the central role of increased plaque burden. Atherosclerosis, 171: 295-302.

Mikovanov, IuS, Miu, Dzitoeva, E.M. Shilov, V.V. Safonov, V.A. Brazhnik and L.N. Savina, 2006. Atherosclerosis/calcinosis of the carotid and peripheral arteries in patients with initial and terminal stages of chronic renal failure. Ter. Arkh., 78: 55-59.

Mutluay, R., C. Konca, Y. Erten, H. Paşaoglu and S.M. Deger *et al*., 2010. Predictive markers of asymptomatic atherosclerosis in end-stage renal disease patients. Ren. Fail., 32: 448-454.

Nakamura, S., R. Kono, A. Matsuda, O. Matsumura and T. Mitarai, 2010. Predictive value of ultrasonographical assessments of carotid artery for cardiovascular events in patients under hemodialysis: Add on comparison with stroke patients. Nihon. Jinzo. Gakkai. Shi., 52: 505-514.

Nasri, H. and A. Baradaran, 2006. Lipids in association with leptin in maintenance hemodialysis patients. J. Medical Sci., 6: 173-179.

Ohya, M., H. Otani, K. Kimura, Y. Saika, R. Fujii, S. Yukawa and T. Shigematsu, 2010. Improved assessment of aortic calcification in Japanese patients undergoing maintenance hemodialysis. Int. Med., 49: 2071-2075.

Onyeneke, E.C., K.E. Adebisi, G.E. Eriyamremu, S.I. Ojeaburu, S.O. Asagba and O.M. Oluba, 2007. Effect of lipid-based diet on some lipid-metabolizing enzymes. J. Medical Sci., 7: 1283-1289.

Pascazio, L., F. Bianco, A. Giorgini, G. Galli, G. Curri and G. Panzetta, 1996. Echo color Doppler imaging of carotid vessels in hemodialysis patients: Evidence of high levels of atherosclerotic lesions. Am. J. Kidney Dis., 28: 713-720.

Prasad, N., S. Kumar, A. Singh, A. Sinha and K. Chawla *et al*., 2009. Carotid intimal thickness and flow-mediated dilatation in diabetic and nondiabetic continuous ambulatory peritoneal dialysis patients. Perit. Dial. Int., 29: S96-S101.

Ragab, M. and A. Ragab, 2007. Assessment of lipid profile in Egyptian children with chronic kidney diseases on conservative therapy and those under regular hemodialysis. J. Medical Sci., 7: 825-829.

Reis, S.E., M.B. Olson, L. Fried, V. Reeser and S. Mankad *et al*., 2002. Mild renal insufficiency is associated with angiographic coronary artery disease in women. Circulation, 105: 2826-2829.

Rossi, A., L. Bonfante, A. Giacomini, A. Calabro and G. Rossi *et al*., 1996. Carotid artery lesions in patients with nondiabetic chronic renal failure. Am. J. Kidney Dis., 27: 58-66.

Sanchez-Alvarez, J.E., P. Delgado-Mallen, A. Gonzalez-Rinne, D. Hern?ez-Marrero and V. Lorenzo-Sellares, 2010. Carotid ultrasound: Prevention of heart disease and mortality on haemodialysis. Nefrologia, 30: 427-434.

Sezer, S., F.N. Ozdemir, Z. Arat, M. Turan and M. Haberal, 2002. Triad of malnutrition, inflammation and atherosclerosis in hemodialysis patients. Nephron, 91: 456-462.

Suliman, M.E., P. Stenvinkel, T. Jogestrand, Y. Maruyama and A.R. Qureshi *et al*., 2006. Plasma pentosidine and total homocysteine levels in relation to change in common carotid intima-media area in the first year of dialysis therapy. Clin. Nephrol., 66: 418-425.

Tirmenstajn-Jankovic, B. and N. Dimkovic, 2005. C-reactive protein as an independent risk factor for carotid atherosclerosis in hemodialysis patients. Med. Pregl., 58: 127-135.

Turgut, F., M. Kanbay, M.R. Metin, E. Uz, A. Akcay and A. Covic, 2008. Magnesium supplementation helps to improve carotid intima media thickness in patients on hemodialysis. Int. Urol. Nephrol., 40: 1075-1082.

Zumrutdal, A., M. Baltali, H. Micozkadioglu, D. Torun, S. Sezer, F.N. Ozdemir and M. Haberal, 2007. Determinants of coronary artery disease in nondiabetic hemodialysis patients: A matched case-control study. Ren. Fail., 29: 67-71.