

Profile of Carotid Artery Ultrasound in Chronic Kidney Disease (CKD) Patients Undergoing Hemodialysis at Dr. Soetomo General Hospital, Surabaya

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ABSTRACT

Chronic Kidney Disease (CKD) is recognized as a major contributor to global mortality. The Global Burden of Disease (GBD) 2017 report placed CKD as the 12th leading cause of death worldwide, with projections elevating it to the 5th position by 2040. Disruptions in calcium and phosphate regulation in CKD patients lead to vascular structural and functional abnormalities, promoting early arterial calcification and plaque formation. This research seeks to characterize the ultrasound findings of the common carotid artery and extracranial internal carotid artery in CKD patients receiving hemodialysis at Dr. Soetomo General Hospital, Surabaya. A descriptive observational method was utilized, collecting data through carotid artery ultrasound scans in CKD patients undergoing hemodialysis at the hospital from May to June 2025. Demographic data, laboratory and radiological examination results were taken from medical records according to the subject's current condition. The results of the study showed that patients with Chronic Kidney Disease (CKD) undergoing hemodialysis at Dr. Soetomo General Hospital were mostly female (55.8%). Of the 43 subjects, most were aged 41-60 years (72.1%) with a duration of hemodialysis ranging from 1-10 years (93.1%). Most of the subjects involved in this study were non-smokers (67.4%) and the most common etiology of the disease causing hemodialysis was hypertension (53.5%) followed by toxic nephropathy (25.6%). The majority had a normal body mass index (53.5%), normal calcium and phosphate levels (58.1% and 41.9%) followed by hypocalcemia (34.9%) and hyperphosphatemia (32.6%). Most subjects had normal triglyceride levels (67.4%), normal HDL levels (51.2%), and normal LDL levels (83.7%), and the group that experienced a significant increase in triglycerides (32.6%). The majority of subjects also had normal albumin levels (90.7%), and hypoalbuminemia was found in 9.3%. Carotid ultrasound examination found an 18.6% increase in carotid intima-media thickness (cIMT) and plaque in 60.5% of subjects. The most common location of plaque formation was in the carotid bulb followed by the distal common carotid artery, with most plaques having hyperechoic echogenicity (95.8%), where 100% of the plaques found caused stenosis of <50% of the arterial lumen.

KEYWORDS: Chronic Kidney Disease, Hemodialysis, Carotid Intima-Media Thickness, Atherosclerotic Plaque, Carotid Artery Stenosis

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INTRODUCTION

Chronic Kidney Disease (CKD) constitutes a critical global health burden. Data from the Global Burden of Disease (GBD) 2017 analysis show that CKD occupied the 12th rank among leading causes of death and is projected to ascend to the 5th rank by the year 2040 [1]. The findings from the 2018 RISKESDAS revealed that only 0.38% of the population in Indonesia were diagnosed with Chronic Kidney Disease. It was noted that about 60% of these individuals required dialysis treatment [2]. Data from the Indonesian Renal Registry (IRR) in 2016 from 249 reporting renal units recorded 30,554 active patients undergoing hemodialysis in 2015 and 89% were Chronic Kidney Disease (CKD) patients. A total of 1,234 patients died with a survival time during hemodialysis ranging from 1-317 months [3].

Chronic Kidney Disease (CKD) causes disruption in calcium and phosphate regulation which results in changes in the structure and function of blood vessels where early arterial stiffening can occur in patients. Chronic Kidney Disease (CKD) strengthens the inflammatory process and causes changes in endothelial function, increases vascular tone, wall thickening, and facilitates calcium accumulation on arterial walls [4]. In addition to the inflammatory process, malnutrition that often occurs in Chronic Kidney Disease (CKD) patients undergoing hemodialysis is also closely related to the occurrence of calcification on arterial walls [5]. Having this condition could increase the chances of developing severe cardiovascular issues like peripheral artery disease, heart attack, or stroke, which will vary depending on which blood vessels are affected [6].

Clinical data from a cohort of 2,204 ischemic stroke patients in the United States revealed that 365 cases (16.6%) were secondary

to large vessel disease. Findings from the analysis indicated that 8% of ischemic strokes were associated with extracranial internal carotid artery stenosis. In comparison, extracranial internal carotid artery occlusion and intracranial atherosclerosis were each responsible for 3.5% of cases. Stenotic lesions develop through luminal narrowing secondary to elevated carotid intima-media thickness (cIMT), plaque formation, or atherosclerotic changes. Epidemiological projections indicate that extracranial internal carotid artery stenosis accounts for approximately 41,000 stroke presentations annually across the United States [7]. Another study at a hospital in Japan on 455 patients who underwent carotid artery ultrasonography (US) examination found that increased carotid intima-media thickness (cIMT), plaque formation and stenosis in the internal carotid artery had a significant relationship with the occurrence of ischemic stroke [8].

US is a popular examination because of its non-invasive nature, low cost and wide availability in hospitals throughout Indonesia. Research conducted at hospitals in Pakistan and Brazil stated that US has quite good accuracy in detecting plaque and stenosis in the extracranial internal carotid artery with CT Angiography as a comparison [9,10]. Other research in Brazil stated that the sensitivity and specificity of US as an initial examination in detecting carotid artery stenosis increases especially in carotid artery stenosis that is >50% compared to CT Angiography and Digital Subtraction Angiography (DSA) [11].

Hemodialysis is one of the treatment efforts for Chronic Kidney Disease (CKD) patients where the patient's kidneys are no longer functioning, in this condition complications from Chronic Kidney Disease (CKD) are more prone to occur including complications in the carotid artery blood vessels. The present investigation focuses on characterizing ultrasonographic features of the carotid vasculature, with specific attention to stenosis resulting from plaque accumulation and tunica intima-media hypertrophy, in patients diagnosed with Chronic Kidney Disease (CKD) who are undergoing regular hemodialysis treatment at Dr. Soetomo General Hospital, Surabaya. The stated objective of this study is to comprehensively evaluate the carotid artery ultrasonography profile in the CKD hemodialysis population at Dr. Soetomo General Hospital Surabaya.

METHOD

Type of Research

The current research constitutes a descriptive observational investigation aimed at determining the ultrasonographic characteristics of the carotid artery in the Chronic Kidney Disease (CKD) population receiving hemodialysis treatment at Dr. Soetomo General Hospital Surabaya.

Research Design

This research is a prospective cross-sectional study with data collection in the form of carotid artery US examination in Chronic Kidney Disease (CKD) patients undergoing hemodialysis.

Research Location and Time

The research was conducted in the Hemodialysis Room, Dr. Soetomo General Hospital Surabaya from May-June 2025.

Research Subject Population

The target population is patients diagnosed with Chronic Kidney Disease (CKD) from examination by Internal Medicine Specialists, who undergo hemodialysis at Dr. Soetomo General Hospital. The accessible population is patients diagnosed with Chronic Kidney Disease (CKD) from examination by Internal Medicine Specialists, who undergo hemodialysis at Dr. Soetomo General Hospital in May-June 2025 who meet the inclusion criteria. Minimum sample size calculation was determined using the Lemeshow formula [12,13] for proportion data with population size. The minimum sample size for this study based on the above formula is 43 people.

Research Criteria

- 1) Inclusion Criteria
 - a. Subjects are Chronic Kidney Disease (CKD) patients from examination by Internal Medicine Specialists, who undergo hemodialysis at Dr. Soetomo General Hospital in May-June 2025
 - b. Adult men or women aged 18 to 60 years with stable general condition. General condition is determined from vital signs measurements during screening before hemodialysis, systolic blood pressure >100 mmHg, diastolic >60 mmHg, pulse rate 60-100 x/min, body temperature 36 - 37.2
 - c. Subjects have been informed about this study and signed the consent form
- 2) Exclusion Criteria
 - a. Obesity (Body mass index > 29.9)
 - b. Known history of primary thyroid and parathyroid disease
 - c. History of malignancy (cancer/tumor) that can cause thrombus
 - d. Known history of disease or trauma involving the carotid artery
 - e. Previously known history of carotid sinus hypersensitivity
 - f. Previous history of stroke or TIA
 - g. Medical device installed in the carotid artery

- h. Difficult to position for examination purposes
- 3) Withdrawal Criteria
 - a. Baroreceptor reflex occurs with or without syncope
 - b. Allergic reaction to ultrasound gel occurs
 - c. Subject requests examination to be stopped or withdraws from the study

Research Subject Sampling Technique

- a. Research subjects are selected by simple random sampling
- b. Research subjects state their agreement to participate in the research after receiving explanation from the researcher by signing a consent form witnessed by their close family member who also signs the consent form
- c. Consent forms to participate in the research are made for each subject and become an attachment to the research proposal

Research Instruments

Sogata Ultrasound type SG90 P/N 95-00182-00 SN 1811004 with linear probe type D12L40L

Data Collection and Analysis

Measurement and research data collection using Ultrasound by the researcher who is an advanced level Radiology resident under the supervision and guidance of a Radiology Specialist consultant expert in Neuro-radiology and Head-Neck. Data analysis uses a descriptive approach where for ratio scale data using parametric statistics namely mean, standard deviation, median and range while for nominal data using non-parametric analysis namely frequency and percentage.

Research Ethics

The author submitted research approval to the Ethics Committee of the Faculty of Medicine, Airlangga University Surabaya/Dr. Soetomo General Hospital Surabaya.

RESULT

Demographic Characteristics of Research Subjects Based on Gender, Age, Duration of Hemodialysis and Smoking History

The majority of research subjects were female, namely 55.8% and male 44.2%. The data shows that there are more female patients receiving hemodialysis for Chronic Kidney Disease (CKD) than male patients. This finding goes against the results of many studies that suggest Chronic Kidney Disease is more common in males than females [14,15]. However, this is in line with a study by Hockam et al. in 2022 [16] where in several Asian countries including Indonesia, the prevalence of Chronic Kidney Disease (CKD) is higher in females. This can be influenced by the higher survival rate of Chronic Kidney Disease (CKD) in women compared to men [17]. In addition, socioeconomic factors such as treatment costs that must be borne individually and the role of men as heads of families cause delays in access to treatment [16].

The proportion of older subjects having a higher percentage conforms with a meta-analysis done by Hustrini et.al. in 2024 [18] which showed that Chronic Kidney Disease (CKD) becomes more prevalent as individuals age. Similarly, a study at a hospital in Malang in 2023 found that the survival rate of CKD patients on peritoneal dialysis decreases over time, with rates dropping to 80% in the first year, 60% in the third year, and 52% in the fifth year [19].

The distribution of etiology of Chronic Kidney Disease (CKD) in this study where hypertension became the most common cause (53.5%) followed by toxic nephropathy (25.6%), Gout (16.3%) and DM (14.0%) is in line with a study by Hustrini et al. [18]. This study states that the etiology of Chronic Kidney Disease (CKD) in Southeast Asian countries varies, where in countries with lower middle income per capita such as Indonesia the main cause of Chronic Kidney Disease (CKD) is hypertension, different from countries with upper middle income per capita such as Malaysia, Singapore and Brunei Darussalam where the most common etiology of Chronic Kidney Disease (CKD) is Diabetes Mellitus. This can be caused by the level of welfare that influences lifestyle, consumption patterns and health management in a country [18].

The distribution of smoking history in this research subject where the highest percentage is the group of non-smoking subjects (67.4%) followed by subjects with smoking duration > 10 years (23.3%) can be caused by the number of subjects with female gender being more than male where culturally in Indonesia itself smoking is not common for women. However, smoking can increase mortality in Chronic Kidney Disease (CKD) patients undergoing hemodialysis although it has not been proven to increase the risk of cardiovascular complications in patients [20].

Basic Data on Body Mass Index, Serum Phosphate and Calcium Levels, Lipid Profile and Albumin as well as History of Vascular Calcification and Osteoporosis of Research Subjects

1) Basic Body Mass Index Data

Research findings show that of 46 research subjects involved, 23 people (53.5%) were in the normal body mass index (BMI) group and 23.3% were in the underweight and normal weight groups respectively. Body mass index has a complex relationship with

Chronic Kidney Disease (CKD). In general, an increase in BMI causes an increase in glomerular filtration rate where if there is an underlying disease or other condition, then kidney damage in overweight or obese people will occur faster [21].

In the advanced condition of Chronic Kidney Disease (CKD) undergoing hemodialysis, protein-energy wasting (PEW) can also occur which can be assessed from weight loss and body mass index (BMI) [5].

A study on body mass index in the population with Chronic Kidney Disease (CKD) in Australia showed that Chronic Kidney Disease patients in Australia have a body mass index that tends to be obese. However, this condition can be influenced by various factors and socioeconomic factors become a very strong predisposition. Body mass index is more associated with its strong correlation to become comorbid in patients with Chronic Kidney Disease (CKD) [22]. It should be remembered that body mass index is only one indicator and does not always accurately reflect body composition because there are many factors that can affect body mass index (BMI) [23].

2) Serum Phosphate and Calcium Level Data

From the research results, the highest percentage (41.9%) of subjects had serum phosphate levels within normal limits, namely between 3.5-5.5 mg/dL followed by 32.6% of subjects having high serum phosphate levels, namely >5.5 mg/dL and the remaining 25.6% having low phosphate levels, namely <3.5 mg/dL. In general, Chronic Kidney Disease (CKD) patients will experience hyperphosphatemia [24]. However, when already treated with hemodialysis and good nutrition provision, serum phosphate levels can be lowered and be within the therapeutic target where according to the 2009 Pernefri Consensus on Chronic Kidney Disease-Mineral and Bone Disorders (CKD-MBD), the target phosphate level in stage 5 Chronic Kidney Disease (CKD) is between 3.5-5.5 mg/dL.

This research data shows that the majority of research subjects (58.1%) had calcium levels within normal limits, namely between 8.5-10 mg/dL and 34.9% had low serum calcium levels, namely <8.5 mg/dL and a small proportion of subjects (7%) had serum calcium levels >10.5 mg/dL. This is in line with the condition of Chronic Kidney Disease (CKD) patients who tend to have hypocalcemia due to dysregulation of parathyroid hormone or vitamin D metabolism disorders [24]. Uncontrolled calcium and phosphate levels can trigger calcification on blood vessel walls where plaque formation can occur [25].

3) Lipid Profile Data

Dyslipidemia is a condition characterized by increased triglyceride levels, low HDL levels and high LDL levels. In this study, in general most samples had a good lipid profile but in 32% of subjects an increase in triglyceride levels was found, 9.3% of subjects had low HDL levels and 16.3% of samples had high LDL levels. In patients with Chronic Kidney Disease (CKD), usually high triglyceride levels and low HDL are found, while LDL can be normal or even low. Administration of therapy such as statin class in Chronic Kidney Disease patients can help lower cholesterol levels and help prevent or slow down cardiovascular complications in Chronic Kidney Disease (CKD) [26].

4) Serum Albumin Data

As discussed earlier, malnutrition in Chronic Kidney Disease, frequently identified as protein energy wasting (PEW), represents a significant clinical concern. Assessment procedures typically incorporate validated measures such as SGA and MIS to determine nutritional adequacy. Markers including hypoalbuminemia and reduced TIBC are characteristic findings in CKD patients experiencing malnutrition [23]. In this study, the majority of subjects (90.7%) had normal albumin levels and only 9.3% were in hypoalbuminemia condition. This is also in line with the body mass index picture where most subjects have a normal body mass index and only 18.5% are in underweight condition.

5) History of Blood Vessel Calcification and Osteoporosis Data

Vascular calcification is part of on Chronic Kidney Disease-Mineral and Bone Disorders (CKD-MBD), where osteoporosis is also a series of pathological processes that may be encountered [27]. By knowing the history of blood vessel calcification in other locations and the history of osteoporosis from other radiological examination modalities, it will provide a better and more comprehensive understanding of the detection of Chronic Kidney Disease-Mineral and Bone Disorders (CKD-MBD).

a. Lumen Diameter and Carotid Artery Intima-Media Thickness (cIMT) in the Common Carotid Artery and Extracranial Internal Carotid Artery

In this study, the blood vessels examined were divided into 4 segments, namely proximal common carotid artery (CCA proximal), distal common carotid artery (CCA distal), carotid bulb and proximal common carotid artery (ICA proximal). From blood vessel lumen diameter measurement data, the average lumen diameter in right CCA proximal was 7.3 mm, left CCA proximal 7.1 mm, right CCA distal 7.4 mm and left CCA distal 7.3 mm which is consistent with research by Ojaare et al. in 2011 [28] where the diameter of the right common carotid artery ranged from 6.39 ± 0.71 mm and the left carotid artery ranged from 6.28 ± 0.74 mm. While the average diameter of right ICA proximal was 8.0 mm and left 5.9 mm where the mean right ICA proximal diameter was larger than the normal value, namely 4.63 ± 0.63 mm and the left ICA proximal diameter was within normal limits, namely 4.61 ± 0.63 mm [28]. The high average blood vessel lumen diameter can be caused by dilation of the arterial lumen diameter which is more commonly found in subjects with hemodialysis duration >10 years.

From this research data, it was found that the occurrence of carotid artery intima-media thickness (cIMT) thickening occurs more in

males than females and the largest age group is 41-60 years. While for hemodialysis duration, the largest group is 5-10 years, but it is also found in subjects with hemodialysis duration <5 years and > 10 years.

Evidence suggests that functional arterial wall dysfunction precedes structural stiffening in Chronic Kidney Disease (CKD), as endothelial impairment manifests in participants experiencing mild glomerular filtration rate (GFR) deterioration. Structural remodeling processes, including arterial wall enlargement and thickening, are predominantly observable in advanced and end-stage CKD populations rather than in early-stage disease. The pathogenesis of carotid arterial wall enlargement appears to involve compromised vascular wall integrity under sustained deformation forces, leading to progressive elastic fiber thinning and fragmentation, a process designated as elastic fatigue. Investigation of experimental CKD models has revealed that qualitative and quantitative elastic fiber alterations are instrumental in mediating arterial wall enlargement [29].

Chronic Kidney Disease (CKD) and high blood pressure. In this scenario, thickening of the carotid artery is viewed as a way to balance out the stress on the artery walls when they expand or experience elevated blood pressure. Thus, with carotid enlargement occurring before wall thickening, the stress on the walls of the artery increases in later stages of CKD [29].

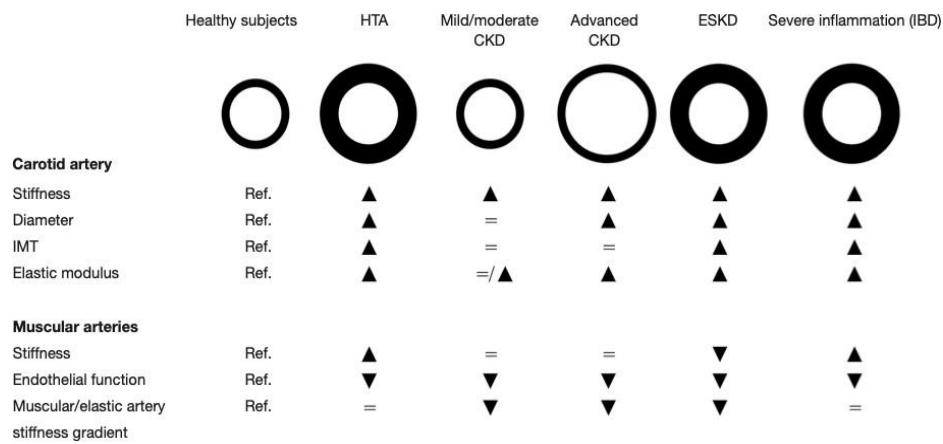


Figure 1: Arterial Phenotype in Chronic Kidney Disease (CKD), Hypertensive (HTA), End-stage Chronic Kidney Disease (ESKD) and inflammatory bowel disease (IBD) [29]

Other factors suspected to influence this process include nutritional status, serum phosphate and calcium levels and lipid profile. In this study, of 8 subjects with carotid artery intima-media thickness (cIMT) thickening, it was found that most subjects had normal examination values in these parameters, while in 12.5-25% of subjects experienced an increase in these parameters. This can be caused by the therapy given, considering these parameters are also parameters of therapeutic success that are evaluated regularly.

b. Plaque Occurrence and Plaque Characteristics in the Common Carotid Artery and Extracranial Internal Carotid Artery

Research data shows that of 43 research subjects, plaque occurrence was found, either in 1 location or several locations, in 26 subjects (60.5%) with almost all plaques (95.8%) being hyperechoic plaques. Hyperechoic plaques show dominant calcification components [30]. This is consistent with the pathophysiology of plaques in Chronic Kidney Disease (CKD) where calcium accumulation occurs on blood vessel walls [24].

Research by Pelisek et al. also supports this finding, where in that study, in patients who underwent carotid endarterectomy, histopathological examination was performed and compared between 41 people in the Chronic Kidney Disease (CKD) patient group compared to 56 people in the patient group without a history of Chronic Kidney Disease (CKD). In that study, it was found that in the group with Chronic Kidney Disease (CKD), plaques had dominant calcification components [31].

Plaque deposition occurs predominantly in the carotid bulb, with the distal common carotid artery being the next most common site. This pattern corroborates the observations reported by Kwon et al. in South Korea. Among 1,705 patients evaluated using angiography and carotid ultrasonography, the majority of plaques (72.7%) were identified in the carotid bulb, followed by 24% in the common carotid artery [32].

From this research data, it was found that of 26 subjects with plaque occurrence, plaque occurrence was found slightly more in males than females and the largest age group was 41-60 years (92.3%). Based on hemodialysis duration, plaques can be found in the <5 years and 5-10 years groups with balanced numbers (42.3%) and the remaining 11.5% in the hemodialysis group >10 years. In 34.6% of subjects had smoking duration > 10 years while 53.8% of subjects did not smoke. These factors can work together with Chronic Kidney Disease (CKD) in plaque formation, Chronic Kidney Disease (CKD) will increase the risk of plaque formation and progression and vice versa also in Chronic Kidney Disease (CKD) with older age, longer hemodialysis duration and smoking history [24,33].

Similar to the increase in carotid artery intima tunica thickness (cIMT) in this study, it was found that in plaque occurrence, most subjects were in the group with normal calcium and phosphate levels, albumin, lipid profile and nutritional status.

c. Stenosis in the Common Carotid Artery and Extracranial Internal Carotid Artery

In this study, of 26 subjects with plaques, a degree of stenosis <50% was found in 73.1% of subjects and no stenosis in 26.9%. This is due to the stenosis degree calculation method according to the North America Symptomatic Carotid Endarterectomy Trial (NASCET) in the carotid bulb which allows plaque formation not to cause significant stenosis.

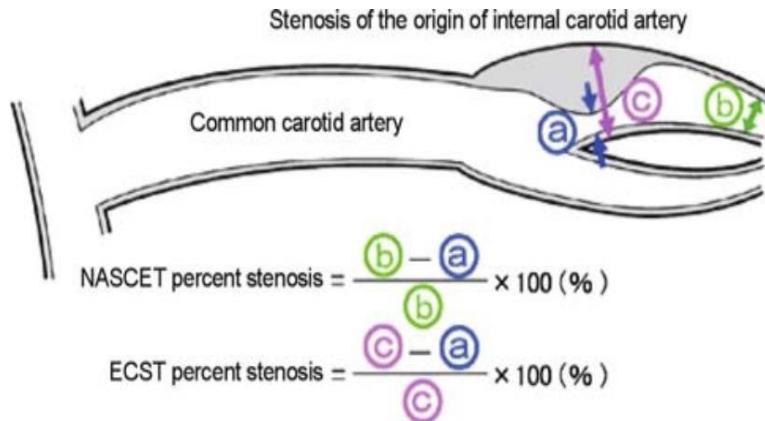


Figure 2: Stenosis measurement scheme in the carotid artery [30].

CONCLUSION

In Chronic Kidney Disease patients undergoing hemodialysis at Dr. Soetomo Hospital Surabaya, the occurrence of carotid intima-media thickness thickening is quite significant and, in most patients, hyperechoic plaques were found suggesting plaques with calcification components with the most common location in the carotid bulb area and distal common carotid artery, where stenosis caused by plaques is <50%. Demographically, female patients are slightly more than male and the largest age group is 41-60 years with hemodialysis duration <10 years, and the most common etiology of Chronic Kidney Disease (CKD) is hypertension. Laboratory parameters are mostly within normal limits suggesting optimal therapeutic achievement.

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