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Original Article

Characteristics of Parathyroid Ultrasound in Chronic Kidney Disease Patients Undergoing Hemodialysis

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Abstract

Research on parathyroid ultrasound in kidney failure patients is highly relevant for understanding the relationship between parathyroid hormone levels and clinical conditions, optimizing therapeutic management for CKD patients. This study employs a quantitative observational descriptive design with cross-sectional approach to provide comprehensive overview of parathyroid ultrasound characteristics in CKD patients. Data were obtained from secondary medical records and parathyroid ultrasound examinations of CKD patients undergoing hemodialysis. This research shows that majority of chronic kidney disease (CKD) patients undergoing hemodialysis at Dr. Soetomo Regional Hospital in Surabaya have elevated serum iPTH and phosphate levels, while calcium levels are generally normal, though some patients experience hypocalcemia. Demographically, majority of patients are women (58%), aged 41–60 years, undergoing hemodialysis for 1–10 years. Parathyroid gland examination through ultrasound shows most patients have hypoechoic echogenicity, oval shape, well-defined borders, solid architecture, and size of 0.51–1 cm. More than half show no detectable vascularization, while some show perilesional blood flow patterns, serving as important indicators for detecting parathyroid hyperplasia. There is correlation between serum iPTH levels and morphological characteristics of parathyroid glands, including echogenicity, shape, size, and vascularization. At iPTH levels <500 pg/dL, parathyroid appears isoechoic to hypoechoic, oval, solid, measuring approximately 0.51–1 cm, with minimal vascularization. At 500–1000 pg/dL, perilesional vascularization begins appearing. When iPTH levels >1000 pg/dL, parathyroid enlarges (>1 cm), becomes hypoechoic in texture, and vascularization increases significantly, indicating more prominent morphological and vascular changes associated with increasing iPTH levels.

Keywords: Chronic Kidney Disease Patients, Hemodialysis, Parathyroid Ultrasound Characteristics.

1. Introduction

Chronic kidney disease (CKD) is a public health problem that poses a global threat. In 1990, CKD ranked 27th as the leading cause of death worldwide, rising to 18th in 2010 (IHME, 2013). In Indonesia, approximately 0.2% of the population aged ≥15 years has been diagnosed with CKD. The incidence of CKD increases with age, showing a significant surge in the 35–44 age group (0.3%) compared to the 25–34 age group (0.1%) (Badan Penelitian dan Pengembangan Kesehatan Kementrian Kesehatan RI, 2013). According to data from the Indonesian Renal Registry (IRR) in 2016, out of 249 reporting kidney units, there were 30,554 active patients undergoing hemodialysis in 2015, with 89% of them being CKD patients. A total of 1,234 patients died with a survival period during hemodialysis ranging from 1 to 317 months.

In CKD, several factors such as calcium, hypocalcemia, and reduced active vitamin D production stimulate parathyroid hormone (PTH) secretion, resulting in a state of hyperparathyroidism. If this condition persists, it can cause parathyroid hyperplasia (Thomas et al., 2008). Parathyroid hyperplasia is typically suspected due to elevated PTH levels detected in routine biochemical testing. Ultrasonography (USG) is a feasible imaging method capable of identifying parathyroid hyperplasia. USG serves as a screening tool and for evaluating the therapeutic response to parathyroid hyperplasia in CKD patients (Pavlovic & Tomic Brzac, 2006).

This radiological study is inexpensive, non-invasive, has no additional effects, does not contribute to ionizing radiation, and can be repeated as often as necessary. On ultrasound, the parathyroid glands are normally not visible, with only about 8.3% being successfully detected. Parathyroid gland enlargement is defined as a weight exceeding 0.5 g (equivalent to 0.5 cm^3) or a diameter greater than 0.5 cm. Patients with chronic kidney disease experience parathyroid hyperplasia, with an average maximum detected parathyroid gland diameter of 11.0 ± 0.7 mm (Okuno et al., 2003). There is a correlation between the pattern of parathyroid hyperplasia and gland weight, where glands weighing more than 500 mg (Tominaga et al., 1997). Patients with chronic kidney disease (CKD) showed parathyroid hyperplasia in 24 patients (77.4%) (Arnold, 2017). In the subgroup of patients with iPTH <1000 pg/ml, no significant correlation was found between the size and weight of the parathyroid glands and parathyroid hormone levels in hemodialysis patients with secondary hyperparathyroidism (Fang et al., 2015). Ultrasound imaging significantly showed the incidence of parathyroid carcinoma with larger size, higher depth-to-width ratio, heterogeneous echotexture, irregular shape, non-circular margins, intra-nodular calcifications, unclear borders, cystic changes, and the presence of suspicious lymph nodes compared to benign parathyroid lesions (Liu et al., 2020).

Understanding the ultrasound characteristics of parathyroid glands in patients with kidney failure is important because it can aid in early diagnosis and management of complications associated with PGK. Therefore, research on parathyroid ultrasound in patients with renal failure is highly relevant for improving understanding of the relationship between parathyroid hormone levels and patients' clinical conditions, as well as for optimizing therapeutic management for those suffering from PGK. Based on this reason, the researchers aim to provide a comprehensive review of the characteristics of parathyroid ultrasound in CRF patients undergoing routine hemodialysis at Soetomo General Hospital in Surabaya.

2. Methods

2.1. Research Design

This study used a quantitative observational descriptive design with a cross-sectional approach to obtain a comprehensive picture of the characteristics of parathyroid ultrasound in these patients.

2.2. Research Subjects

The research subjects were patients with chronic kidney disease undergoing hemodialysis at the hospital. The research sample was selected using purposive sampling, where the inclusion criteria included patients who had been diagnosed with chronic kidney disease and had undergone hemodialysis for at least 1 year and had undergone parathyroid ultrasound examination. Patients with a history of parathyroid disease or conditions affecting parathyroid ultrasound results were excluded from the study sample.

2.3. Research Criteria

To maintain validity and reliability of research results, subject selection that aligns with the study objectives is required. The inclusion and exclusion criteria used in this research are as follows:

Inclusion Criteria:

1) Patients with complete medical records from December 2023 to December 2024
2) Patients with CKD undergoing routine hemodialysis for more than one year who have undergone parathyroid ultrasound at the hemodialysis unit of Dr. Soetomo General Hospital in Surabaya
3) Patients with levels of PTH, calcium, and phosphate

Exclusion Criteria:

1) Incomplete medical records from December 2023 to December 2024
2) Patients who did not undergo parathyroid ultrasound
3) History of thyroid or parathyroid removal surgery.
4) History of parathyroid tumors

2.4. Research Instruments

In this study, the data used were derived from secondary medical records and parathyroid ultrasound examination results in patients with chronic kidney disease undergoing hemodialysis. The research instruments used include:

1) Parathyroid Ultrasound

The parathyroid ultrasound examination protocol used in this study employed grey scale and color Doppler imaging to assess echogenicity, internal architecture, size, shape, location, and vascularization of the parathyroid glands. Ultrasound data were obtained using a high-frequency transducer (7–12 MHz).

2) Patient Medical Records

The secondary data collected in this study included medical records containing complete medical information about the patients, such as:

a. Demographic data of PGK patients:

This data included age, gender, and duration of hemodialysis. This data can indicate how long the patient has been undergoing hemodialysis and whether there is an effect on the condition of their parathyroid glands.

b. Serum levels of Phosphate, Calcium, and PTH

Information about serum levels of phosphate, calcium, and PTH during hemodialysis. This data can indicate how long the patient has been undergoing hemodialysis and whether there is an effect on the condition of their parathyroid glands.

2.5. Data Collection and Analysis Data Collection

2.5.1. Data collection

Measurement and collection of research data from medical records and raw DICOM ultrasound data from the ultrasound machine by researchers who are advanced radiology residents under the supervision and guidance of a consultant radiologist specializing in head and neck with over 20 years of experience. Data from medical records and ultrasound examinations were collected and organized into case report forms. After data collection, ultrasound examination results of the parathyroid glands were organized into tables and evaluated.

2.5.2. Data Analysis

Researchers identified subjects who met the inclusion criteria and underwent parathyroid ultrasound examinations and medical record reviews. The collected data will be analyzed using descriptive analysis methods. The analysis results will be presented in the form of tables and graphs to provide a visual overview of the characteristics of the parathyroid glands in PGK patients. The percentage of each category will be calculated to show the proportion of each finding.

2.6. Research Ethics

This study will comply with applicable medical research ethics standards. The data collected will be kept confidential and used only for the purposes of this study.

3. Results and Discussion

3.1. Research Results

3.1.1. Demographic Characteristics of PGK Patients Undergoing Hemodialysis

Gender and age are important demographic factors that influence the prevalence and response to chronic kidney disease (CKD) requiring hemodialysis. In this study, the majority of patients were women, and the largest age group was in the 41–60 years range, indicating a tendency for increased CKD cases in productive to elderly age groups.

The duration of hemodialysis is an important factor that can influence a patient's health condition, including its impact on body metabolism, particularly in the regulation of calcium, phosphorus, and parathyroid function. In patients with chronic kidney disease, the duration of hemodialysis therapy may be associated with the development of complications, one of which is secondary hyperparathyroidism, which can be detected in parathyroid ultrasound examinations. Out of a total of 100 patients, the majority, 48 patients (48%), had undergone hemodialysis for 1–5 years. The group with a hemodialysis duration of 6–10 years included 39 patients (39%). Meanwhile, 7 patients (7%) were in the 11-15 year range, and only 6 patients (6%) had undergone hemodialysis for more than 15 years. This data indicates that the majority of hemodialysis patients at Dr. Soetomo General Hospital in Surabaya were in the 1-10 year range for undergoing the therapy.

3.1.2. Basic Data on Serum IPTH, Phosphate, and Calcium Levels in PGK Patients Undergoing Regular Hemodialysis

Disorders in IPTH, phosphate, and calcium levels often occur in PGK patients undergoing hemodialysis, which can worsen their health condition. Out of a total of 100 patients, the majority, 34 patients (34%), had serum PTH levels below 200 pg/mL, with 8 patients having levels below 65 pg/mL, and 26 patients (26%) having levels between 65– < 200 pg/mL in 26 patients. The group with serum IPTH levels between 200–500 pg/mL included 21 patients (21%), and the group with serum IPTH levels between 501–1000 pg/mL included 20 patients (20%), while 25 patients (25%) had serum IPTH levels > 1000 pg/mL, with 15 patients in the 1001–2000 pg/mL range, 6 patients in the 2001–3000 pg/mL range, and only 4 patients showing IPTH levels exceeding 3000 pg/mL. These data indicate that PGK patients undergoing hemodialysis at Dr. Soetomo General Hospital in Surabaya have relatively elevated or high serum IPTH levels compared to the normal range.

Out of the total 100 patients, the majority, 30 patients (30%), had phosphate levels > 7 mg/dL, categorised as severe hyperphosphataemia, with 14 patients in the range of 7.1–7.9 mg/dL, 15 patients in the range of 8.0–9.9 mg/ , and 1 patient with a range of >1000 mg/dL.

The second-largest group consisted of patients with phosphate levels in the normal range of 2.5–4.5 mg/dL, comprising 27 patients. Meanwhile, 25 patients were in the moderate hyperphosphatase group with a phosphate level range of 5.5–7.0 mg/dL, and 18 patients were in the mild hyperphosphatase group with a phosphate level range of 4.5–5.5 mg/dL. These data indicate that most PGK patients undergoing hemodialysis at Dr. Soetomo General Hospital in Surabaya have elevated or high phosphate levels.

Of the 100 patients analysed, the majority (58 patients, or 58%) had serum calcium levels in the normal range of 8.50–10.5 mg/dL. The second largest group was patients with hypocalcaemia, where calcium levels were <8.5 mg/dL, with 3 patients having calcium levels of 4.0–5.9 mg/dL and 39 patients having calcium levels of 6.0–8.4 mg/dL. Meanwhile, 3 patients were classified as having mild hypercalcaemia with calcium levels >10.5 < 12 mg/dL. No calcium levels above > 12 mg/dL were found. These data indicate that most PGK patients undergoing hemodialysis at Dr. Soetomo General Hospital in Surabaya have normal calcium levels and hypocalcaemia.

3.1.3. Ultrasound of the Parathyroid Glands in PGK Patients Undergoing Hemodialysis

Ultrasound examination of parathyroid glands in CKD patients undergoing hemodialysis is important for assessing structural changes due to calcium and phosphorus metabolism disorders. Of 100 patients, 82% experienced parathyroid hyperplasia, indicating a high prevalence of this condition. The majority of hyperplasia cases (62%) were bilateral, demonstrating dominant involvement of both sides of the parathyroid glands in CKD patients undergoing hemodialysis therapy.

3.1.4. Echogenicity and Internal Architecture of the Parathyroid Glands in Chronic Kidney Disease Patients Undergoing Hemodialysis Using Ultrasound

Echogenicity and internal architecture of the parathyroid glands are important parameters in evaluating structural changes in chronic kidney disease (CKD) patients undergoing hemodialysis. Ultrasound examination can identify echogenicity levels and internal architectural patterns of the glands, reflecting cellular activity and the possibility of hyperplasia occurrence.

From 82 CKD patients with parathyroid hyperplasia, the majority (69.6%) showed hypoechoic echogenicity, while the remainder (30.4%) were isoechoic. No anechoic or hyperechoic echogenicity was found. The distribution of echogenicity based on iPTH levels shows that the higher the iPTH levels, the greater the tendency toward hypoechoic echogenicity. This confirms that hypoechoic echogenicity is a common characteristic of parathyroid glands experiencing hyperplasia in CKD patients undergoing hemodialysis, and can serve as an indicator of secondary hyperparathyroidism development.

Table 1. Internal Architecture of the Parathyroid Glands in PGK Patients Undergoing Hemodialysis with Ultrasound

No	Types of Internal Architecture	Total	Percentage
1	Cystic	0	0
2	Solid	82	100
3	Mixed	0	0
4	Classification	0	0
	Total	82	100

Source: Processed research data, 2025

Table 2. Internal Architecture of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis Using Ultrasound Based on Serum iPTH Levels

No	Types of Internal Architecture	IPTH serum pq/dL			
		< 200	200-500	>1000	Total
1	Cystic	0	0	0	0
2	Solid	18	22	23	82
3	Mixed	0	0	0	0
4	Classification	0	0	0	0
	Total	12	22	23	82

Source: Processed research data, 2025

Table 1 and 2 present the distribution of internal architecture of the parathyroid glands in Chronic Kidney Disease (CKD) patients undergoing hemodialysis, as assessed by ultrasound (USG). Among the 82 patients who showed parathyroid hyperplasia, the analysis revealed that the majority 82 patients (100%) exhibited a solid internal architecture across all serum iPTH level criteria. This finding indicates hyperplasia or increased gland activity as a result of secondary hyperparathyroidism. No patients were found with cystic, mixed, or calcified architecture, which are typically associated with degenerative changes or long-term metabolic disturbances. These findings suggest that solid architecture is a primary characteristic of the parathyroid gland in CKD patients on hemodialysis, potentially serving as an indicator of pathological changes due to chronic metabolic disorders.

3.1.5. Shape and Margins of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

The shape of the parathyroid gland may undergo changes due to increased parathyroid hormone activity secondary to metabolic disturbances in CKD patients on hemodialysis. Ultrasound examination allows for the evaluation of gland shape, whether oval or round. This subsection will elaborate on the variations in parathyroid gland shape observed in CKD patients and the possible factors influencing such morphological changes.

Table 3. Shape of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

No	Gland Shape	Total	Percentage
1	Oval		
	Well-defined margins / Circumscribed	82	100
	Ill-defined margins / Irregular	-	-
2	Round		
	Well-defined margins / Circumscribed	-	-
	Ill-defined margins / Irregular	-	-
	Total	82	100

Table 4. Shape of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

No.	Gland Shape	IPTH serum pq/dL			
		< 200	200-500	>1000	Total
1	Oval				
	Well-defined margins / Circumscribed	18	22	19	82
	Ill-defined margin / Irregular	-	-	-	-
2	Round				
	Well-defined margins / Circumscribed	-	-	-	-
	Ill-defined margins / Irregular	-	-	-	-
	Total	12	22	19	82

Tables 3 and 4 show the distribution of parathyroid gland shapes in Chronic Kidney Disease (CKD) patients undergoing hemodialysis, based on ultrasound (USG) examination. Among the 82 patients diagnosed with parathyroid hyperplasia, the analysis revealed that all 82 patients (100%) had oval-shaped parathyroid glands with well-defined (circumscribed) margins across all serum iPTH level criteria. These findings indicate that the oval shape is predominant in CKD patients on hemodialysis, although structural changes due to secondary hyperparathyroidism may still occur.

3.1.6. Size of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

The size of the parathyroid gland is a crucial indicator in assessing the progression of secondary hyperparathyroidism in CKD patients. Through USG, gland size can be measured accurately to detect enlargement or hypertrophy in response to imbalances in calcium, phosphate, and parathyroid hormone levels. This subsection explores the differences in parathyroid gland size among CKD patients on hemodialysis and the contributing factors to such variations.

Table 5. Size of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

No	Gland Shape	Total	Percentage
1	0,1 – 0,50 cm	2	2,4
2	0,51 – 1 cm	54	65,9
3	> 1 cm	26	31,7
	Total	82	100

Source: Processed research data, 2025

Table 6. Size of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound Based on Serum iPTH Levels

No.	Gland Shape	IPTH serum pq/dL			
		< 200	200-500	501-1000	>1000
1	0,1 – 0,50 cm	-	1	1	2
2	0,51 – 1 cm	15	16	13	7
3	> 1 cm	3	5	5	15
	Total	18	22	19	23

Source: Processed research data, 2025

Based on the data above regarding the size of the parathyroid gland in Chronic Kidney Disease (CKD) patients undergoing hemodialysis as observed through ultrasound, it was found that the majority of patients with parathyroid hyperplasia had gland sizes in the range of 0.51–1 cm, accounting for 54 patients or 65.9%, distributed across all serum iPTH levels. Meanwhile, 26 patients (31.7%) had gland sizes greater than 1 cm, with the following distribution: 3 patients with iPTH < 200 pg/dL, 10 patients with iPTH between 200–1000 pg/dL, and 15 patients with iPTH > 1000 pg/dL. Only 2 patients (2.4%) had the smallest gland sizes, within the range of 0.1–0.50 cm. In total, 82 patients were included in the study. Overall, the majority of parathyroid glands measured between 0.51–1 cm in patients with serum iPTH levels between 200–1000 pg/dL, while glands in patients with iPTH levels above 1000 pg/dL were mostly larger than 1 cm.

3.1.7. Parathyroid Gland Vascularisation via Doppler Mapping in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

Parathyroid gland vascularisation may change as a result of increased parathyroid hormone activity and the progression of hyperplasia in CKD patients undergoing hemodialysis. Doppler mapping using ultrasound can help assess the blood flow pattern within the parathyroid gland, offering insight into the level of gland activity. This subsection presents findings related to parathyroid gland vascularisation and its relevance in monitoring CKD patients undergoing hemodialysis therapy.

Table 7. Parathyroid Gland Vascularisation via Doppler Mapping in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

No.	Doppler Mapping	Total	Percentage
1	Absent	45	54,9
2	Present	37	45,1
	Total	82	100

Source: Processed research data, 2025

Table 8. Parathyroid Gland Vascularisation via Doppler Mapping in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound Based on Serum iPTH Levels

No.	Doppler Mapping	IPTH serum pq/dL				Total
		< 200	200-500	501-1000	>1000	
1	Absent	12	13	12	6	43
2	Present	6	9	7	17	39
	Total	18	22	19	23	82

Source: Processed research data, 2025

Table 9. Types of Parathyroid Gland Vascularisation via Doppler Mapping in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound

No	Type of Vascularization on Doppler Mapping:	Total	Percentage
1	Peri-lesional	24	65
2	Intra-lesional	4	11
3	Intra- and peri-lesional	9	24
	Total	39	100

Source: Processed research data, 2025

Table 10. Types of Parathyroid Gland Vascularisation via Doppler Mapping in CKD Patients Undergoing Hemodialysis as Seen on Ultrasound Based on Serum iPTH Levels

No.	Doppler Mapping	IPTH serum pq/dL				
		< 200	200-500	501-1000	>1000	Total
1	Peri-lesional	4	7	5	10	26
2	Intra-lesional	0	1	2	0	3
3	Intra- and peri-lesional	2	1	0	7	9
	Total	16	9	7	17	39

Source: Processed research data, 2025

From the 82 patients with parathyroid hyperplasia, the results showed that 54.9% of patients did not show vascular mapping in the parathyroid gland, and 45.1% of patients showed vascularisation with the distribution of 6 patients at iPTH levels < 200 pg/dL, 9 patients at iPTH levels 200–500 pg/dL, 7 patients at iPTH levels 501–1000 pg/dL, and 17 patients at iPTH levels > 1000 pg/dL with types of parathyroid gland vascularisation distributed as follows: perilesional 65%, intralesional 11%, and intra- and perilesional 24%.

These findings indicate that although the majority of patients did not have detectable vascularisation, there is still a significant proportion with blood flow patterns, particularly at iPTH levels > 1000 pg/dL, most of whom exhibited increased vascularisation with perilesional vascular types identified in CKD patients undergoing hemodialysis.

3.2. Discussion

3.2.1. Ultrasound Imaging of the Parathyroid Gland in CKD Patients Undergoing Routine Hemodialysis at RSUD Dr. Soetomo Surabaya

Ultrasound (USG) imaging of the parathyroid gland in Chronic Kidney Disease (CKD) patients undergoing routine hemodialysis at RSUD Dr. Soetomo Surabaya. This study aims to understand various aspects related to the condition of the parathyroid glands in these patients, including serum levels of intact parathyroid hormone (iPTH), phosphate, and calcium as key metabolic parameters involved in secondary hyperparathyroidism. In addition, demographic characteristics of the patients, such as gender, age, and duration of hemodialysis, were also analysed to determine the distribution pattern of patients with CKD-related bone metabolic disorders.

Through ultrasound examination, further evaluation was conducted on the echogenicity and internal architecture of the parathyroid glands to identify structural changes such as hyperplasia or fibrosis. The shape and size of the parathyroid glands were also analysed to determine the possibility of enlargement or deformation due to metabolic imbalance. Moreover, this study evaluated the vascularisation pattern of the parathyroid glands through Doppler mapping, which can provide insights into the level of glandular activity and blood perfusion. By understanding these parameters, this research is expected to provide deeper insights into parathyroid gland changes in CKD patients undergoing routine hemodialysis and their implications for the management of secondary hyperparathyroidism.

3.2.2. Demographic Characteristics of CKD-MBD Patients

The findings of this study present information on the demographic characteristics of patients with Chronic Kidney Disease (CKD) undergoing hemodialysis at RSUD Dr. Soetomo Surabaya, with an emphasis on ultrasound (USG) findings of the parathyroid glands. The demographic analysis includes variables such as gender, age, and duration of hemodialysis, which are important in understanding the clinical condition of patients and the potential complications associated with calcium and phosphate metabolic disorders.

Based on the data collected, the majority of patients in this study were female, accounting for 58%, while males represented only 42% of the total respondents. This finding indicates that more women undergo hemodialysis compared to men. This difference may be influenced by several factors, such as the higher prevalence of CKD in women or the tendency of women to be more proactive in seeking healthcare services than men. In addition, hormonal factors may also affect the development of CKD and the response to hemodialysis therapy.

Some previous studies have shown that there may be differences in parathyroid hormone regulation between men and women that could affect calcium and phosphate metabolism (Nolan & Qunibi, 2005).

The age distribution of patients showed that the 41–60 years age group was dominant with 65%, followed by the 20–40 years group (20%) and those over 60 years (15%). This finding indicates that the majority of patients undergoing hemodialysis are in the productive to pre-elderly age range. This aligns with literature explaining that CKD generally emerges in middle age, often due to comorbidities such as diabetes mellitus and hypertension, which are major risk factors for CKD (Nistala & Savin, 2017).

Younger age groups (20–40 years) were also found in this study, although in smaller numbers. This may suggest genetic factors or other medical conditions such as congenital kidney disease leading to CKD at a younger age. Meanwhile, patients over 60 years old undergoing hemodialysis have a higher risk of complications, including metabolic disorders that may affect parathyroid gland function.

The duration of hemodialysis is one of the crucial factors that can influence a patient's clinical condition. In this study, most patients had undergone hemodialysis for 1 to 10 years, with 46% in the 1–5 year range and 39% in the 6–10 year range. Meanwhile, only 7% had been on hemodialysis for 11–15 years, and 6% for more than 15 years. As the duration of hemodialysis increases, patients are at higher risk of developing complications such as secondary hyperparathyroidism due to calcium and phosphate metabolic disturbances (Sezai et al., 2013).

From this study, it can be concluded that most patients with Chronic Kidney Disease (CKD) undergoing hemodialysis at RSUD Dr. Soetomo Surabaya were female, aged 41 to 60 years, and had been on hemodialysis for 1–10 years. These findings provide important insights into the characteristics of patients at risk for calcium and phosphate metabolism disorders associated with parathyroid gland dysfunction.

3.2.3. Baseline Data on Serum iPTH, Phosphate, and Calcium in CKD Patients Undergoing Regular Hemodialysis

The research findings revealed that serum levels of iPTH, phosphate, and calcium in CKD patients undergoing hemodialysis at RSUD Dr. Soetomo Surabaya varied, reflecting differences in mineral and bone metabolism among the patients. According to the study results, the majority 66 patients had serum iPTH levels above 200 pg/mL, with the group of patients having iPTH levels between 200–500 pg/mL comprising 21 patients, and the group with levels between 501–1000 pg/mL comprising 20 patients. Meanwhile, 25 patients had iPTH levels > 1000 pg/mL, with 15 patients between 1001–2000 pg/mL, 6 patients between 2001–3000 pg/mL, and only 4 patients with levels above 3000 pg/mL. Meanwhile, 34 patients had serum iPTH levels < 200 pg/mL, with 8 patients showing normal levels < 65 pg/mL, and 26 patients having levels > 65 to < 200 pg/mL. This grouping is based on the initial dose of vitamin D analogue (calcitriol) therapy for patients with secondary hyperparathyroidism in chronic kidney failure.

The high iPTH levels in these patients are likely indicative of secondary hyperparathyroidism, a condition commonly found in CKD patients on long-term hemodialysis, which if persistent, may lead to parathyroid hyperplasia (Thomas et al., 2008). Treatment with vitamin D analogues (calcitriol) may be administered to those with levels > 200 pg/mL, while for those with iPTH < 200 pg/mL, vitamin D had not yet been administered (Ribeiro et al., 2016).

The study results also showed that the majority 73 patients had high phosphate levels, with 30 patients in the severe hyperphosphatemia group > 7 mg/dL. Distribution in this group included 14 patients in the range of 7.1–7.9 mg/dL, 15 patients in the range of 8.0–9.9 mg/dL, and 1 patient with levels > 10 mg/dL. Meanwhile, 25 patients were in the moderate hyperphosphatemia group with phosphate levels of 5.5–7.0 mg/dL, and 18 patients were in the mild group with phosphate levels of 4.5–5.5 mg/dL.

Hyperphosphatemia is a condition commonly found in CKD patients due to impaired phosphate excretion as kidney function declines (Nolan & Qunibi, 2005). Elevated phosphate levels may lead to complications such as vascular calcification, increased risk of cardiovascular disease, and higher mortality rates (Geddes et al., 2013; Nolan & Qunibi, 2005).

The study also found that the majority 58 patients had normal serum calcium levels in the range of 8.5–10.5 mg/dL. However, 42 patients had lower calcium levels < 8.5 mg/dL, possibly indicating hypocalcaemia due to parathyroid hormone dysregulation or vitamin D metabolism disorders (Muppidi et al., 2023).

Only 3 patients had serum calcium levels above 10.5 mg/dL, which may pose a risk of soft tissue calcification if not well controlled. Uncontrolled serum phosphate and calcium levels can stimulate increased parathyroid hormone secretion, contributing to the development of metabolic complications in CKD patients undergoing hemodialysis and resulting in hyperparathyroidism and parathyroid hyperplasia (Ribeiro et al., 2016). Secondary hyperparathyroidism due to elevated iPTH levels may accelerate bone resorption, while high phosphate levels increase the risk of vascular calcification, contributing to cardiovascular morbidity. Therefore, regular monitoring of iPTH, phosphate, and calcium levels is essential to adjust optimal therapy, whether through phosphate binders, vitamin D supplementation, or appropriate dietary management (Nowak & Chonchol, 2020).

Overall, the results of this study affirm the importance of managing mineral balance and bone metabolism in CKD patients undergoing hemodialysis. A more comprehensive approach in therapy and biochemical parameter monitoring is needed to improve patients' quality of life and reduce the risk of long-term complications (Hou et al., 2018).

3.2.4. Ultrasound Results of the Parathyroid Gland in CKD Patients Undergoing Hemodialysis

Ultrasound examination of the parathyroid can be a useful diagnostic tool for detecting structural changes in the parathyroid glands caused by metabolic disorders commonly occurring in CKD patients undergoing hemodialysis (Kunstman et al., 2013). Parathyroid ultrasound examination becomes important in monitoring structural and functional changes of the parathyroid glands, especially in patients with longer hemodialysis duration (Goodman, 2005). Therefore, regular monitoring of the parathyroid condition in hemodialysis patients is highly recommended to prevent further complications.

Meanwhile, the results of the study showed that the majority, i.e. 82 patients (82%), had experienced parathyroid hyperplasia. Meanwhile, 18 patients (18%) had non-visualised parathyroid glands. A total of 62.2% experienced bilateral parathyroid enlargement, both right and left. As many as 23.2% of patients experienced enlargement in the right parathyroid gland, while 14.6% experienced enlargement on the left side. This data illustrates that most hemodialysis patients at Dr. Soetomo General Hospital Surabaya experienced parathyroid hyperplasia. In general, there are at least two main mechanisms that determine the severity of secondary hyperparathyroidism in CKD. The first is increased synthesis and secretion of PTH, and the second is increased parathyroid gland mass, mostly due to increased cell proliferation (hyperplasia).

This is consistent with previous research showing that CKD patients undergoing hemodialysis experience parathyroid enlargement referred to as secondary hyperparathyroidism (Lau et al., 2018). CKD patients experience parathyroid hyperplasia with an average maximum detectable parathyroid gland diameter of 11.0 ± 0.7 mm. Arnold et al., 2014 found that CKD patients had detectable parathyroid hyperplasia in 24 patients (77.4%). Secondary hyperparathyroidism (SHPT) almost always manifests as multiglandular parathyroid disease (Centello et al., 2023). Other studies also mentioned that secondary hyperparathyroidism can be characterised by asymmetrical enlargement of the parathyroid glands (Prince & Wilson, 2005).

3.2.5. Echogenicity and Internal Architecture of the Parathyroid Glands in CKD Patients Undergoing Hemodialysis with Ultrasound

Research results on echogenicity and internal architecture of the parathyroid glands in CKD patients undergoing hemodialysis indicate significant structural changes. These changes are closely related to the development of secondary hyperparathyroidism as a common complication in CKD patients (Cunningham et al., 2011).

Based on the study results from 82 patients with parathyroid hyperplasia analysed, the majority 57 patients (69.6%) showed mostly hypoechoic echogenicity found at all serum IPTH levels, and 30.4% of patients had isoechoic echogenicity. Additionally, 100% showed solid internal architecture of the parathyroid glands.

Echogenicity on ultrasound reflects the ability of tissue to reflect sound waves. Dense tissues such as stones or bone appear bright (hyperechoic), tissues that transmit more waves appear dark (hypoechoic), and tissues that almost completely transmit waves appear black (anechoic). Additionally, phenomena such as posterior acoustic shadowing and posterior acoustic enhancement help differentiate tissue types and structural abnormalities on ultrasound examination (Herring, 2020).

Each normal parathyroid gland is a yellowish-brown organ weighing about 25–40 mg. These glands primarily consist of chief cells containing fat and a thin fibrous capsule dividing the gland into lobules. Additionally, there are larger oxyphil cells with acidophilic cytoplasm due to mitochondria but lacking secretory granules. Stromal fat is also found in the gland. The percentage of stromal fat content correlates with overall body fat, averaging around 17% (Morris et al., 2022). When enlargement or hyperplasia of the parathyroid gland occurs, this fat structure decreases (Centello et al., 2023).

In CKD patients, the parathyroid glands tend to undergo hyperplasia due to increased parathyroid hormone (PTH) levels (Galassi et al., 2019). Generally, there are at least two main mechanisms that determine the severity of secondary hyperparathyroidism in CKD patients. The first is increased synthesis and secretion of PTH, and the second is an increase in parathyroid gland mass that becomes enlarged and dense, mostly due to increased cell proliferation (hyperplasia).

Thus, in hyperparathyroidism, this hypoechoic aspect is caused by the enlargement and densification of the parathyroid glands and the reduction of fat components within the lesion (Centello et al., 2023; Morris et al., 2022). This is proven in the results of this study, where the higher the IPTH level especially at the IPTH level of 500–1000 pg/dL the larger the size, and the more hypoechoic the echogenicity. This hypoechoic aspect can indicate a dense/solid tissue which is possibly a secondary hyperplasia, adenoma, or malignancy. However, sonographically, it is nearly impossible to differentiate between glandular hyperplasia and adenomatous forms (Centello et al., 2023).

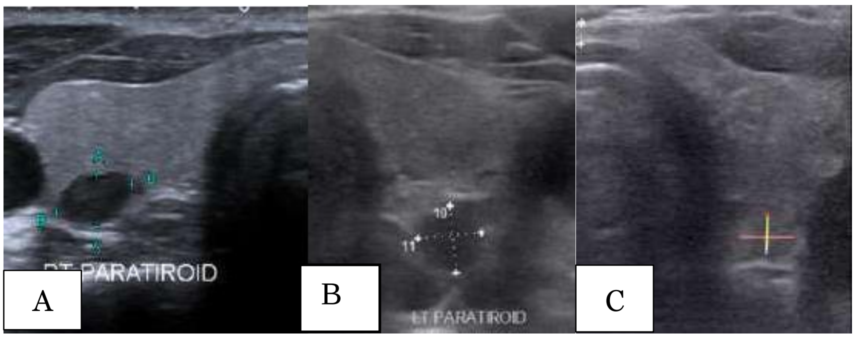

Figure 1. Echogenicity of Parathyroid Hyperplasia

In addition, in parathyroid hyperplasia, hyperechoic echogenicity may also be found, which is usually associated with pathological conditions such as calcification, typically occurring in degenerative conditions or due to more advanced or chronic metabolic disorders.

Anechoic echogenicity can also be observed in the parathyroid, indicating a parathyroid cyst. Parathyroid cysts are very rare. In the literature, various etiologies of parathyroid cysts can be found. One suggests that the cyst originates embryologically from remnants of the 3rd and 4th branchial pouches. Another theory states that parathyroid cysts may form through the enlargement or fusion of several parathyroid microcysts. A recurring thesis assumes that the initiation of a functional parathyroid adenoma formation may begin with degeneration, hemorrhage, or infarction of the parathyroid gland or adenoma.

Parathyroid cysts can be divided, based on their ability to secrete hormones, into non-secreting or non-functional cysts (85–90%) and secreting or functional cysts (10–15%). Non-secreting cysts are 2.5 times more frequently found in women, while secreting cysts are 1.6 times more commonly found in men. Both types of cysts are characterised by very high PTH levels in the cyst fluid; however, elevated serum PTH levels are only found in hormone-secreting lesions.

These cystic lesions can be found in both benign and malignant conditions but are generally more often associated with hyperplasia than adenoma (Centello et al., 2023). In this study, no patients were found with anechoic or hyperechoic echogenicity. From these results, it can be concluded that the dominance of the hypoechoic echogenicity pattern and solid architecture can be an important indicator in detecting parathyroid hyperplasia and the development of secondary hyperparathyroidism in CKD patients undergoing hemodialysis across all IPTH serum level ranges, especially at levels > 500 pg/dL, where the higher the IPTH level, the more hypoechoic the echogenicity. This reinforces the hypothesis that secondary hyperparathyroidism due to mineral metabolic disorders in CKD contributes to changes in the echogenicity of the parathyroid glands (Vulpio et al., 2010). On ultrasound imaging, it is observed as a relatively hypoechoic area (in relation to the thyroid parenchyma), oval to round in shape, with well-defined borders (Ozcan & Oktay, 2009).

This finding has important clinical implications in the management of secondary hyperparathyroidism in CKD patients. Ultrasound examination can be a useful diagnostic tool in detecting structural changes of the parathyroid glands, allowing for early intervention, such as optimisation of pharmacological therapy or surgical measures if necessary. Thus, monitoring the echogenicity and internal architecture of the parathyroid glands in CKD patients undergoing hemodialysis may help improve patient quality of life and reduce complications from more advanced metabolic disorders (Prince & Wilson, 2005).

3.2.6. Shape and Margins of the Parathyroid Glands in CKD Patients Undergoing Hemodialysis with Ultrasound

The study results on the shape of the parathyroid glands in CKD patients undergoing hemodialysis using ultrasound revealed that, of the 82 patients with parathyroid hyperplasia analysed, the majority 82 patients (100%) had oval-shaped parathyroid glands with well-defined or circumscribed margins, observed across all IPTH serum levels.

This aligns with previous studies where sonographic examination typically found an oval shape, as seen in research by Chunxia Xi et al., where 70.8% of parathyroid glands were found to be oval in shape. The oval shape is generally considered a normal physiological form. However, in CKD patients experiencing metabolic disorders due to hemodialysis, an oval shape may also indicate hyperplasia, where there is enlargement or growth of parathyroid gland cells that remain well organised (Vulpio et al., 2010).

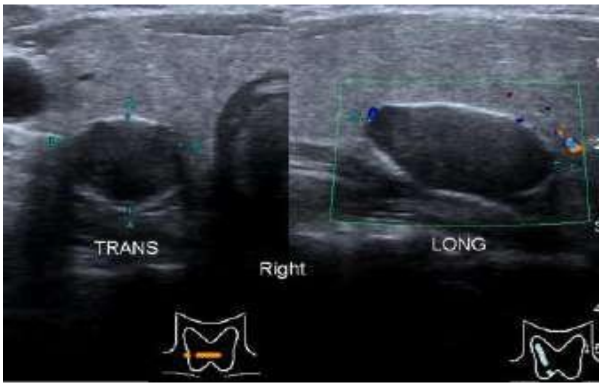

Figure 2. Shape of Parathyroid Hyperplasia
Description: Oval shape of parathyroid gland undergoing hyperplasia with circumscribed borders

This provides an indication that, although there is a metabolic disorder occurring in CKD patients due to hemodialysis, the changes occurring in the parathyroid glands, the possibility of hyperplasia, can still be explained by the phenomenon of secondary hyperparathyroidism, in which the parathyroid glands attempt to increase parathyroid hormone production to compensate for metabolic disturbances in CKD patients (Łebkowska et al., 2003).

To distinguish whether the parathyroid hyperplasia lesion is a benign or malignant mass, it can be assessed by the lesion's border. In glandular hyperplasia and adenomas, which are benign lesions, the borders are well-defined or circumscribed. In contrast, malignant lesions or malignancies typically have poorly defined or irregular borders (Centello et al., 2023; Mohammadi et al., 2012).

Table 11. Ultrasonography (US) Features of Parathyroid Lesions on B-Mode, Color Doppler, Contrast-Enhanced US (CEUS), and Ultrasound Elastography (USE) Examination

	B-Mode	Color Doppler US	CEUS	USE
Parathyroid hyperplasia	More than one symmetrically or asymmetrically enlarged, hypoechoic, oval shaped, lobulated gland. Significantly smaller than adenoma. Cystic inclusions may be seen.	Feeding polar vessels entering the pole and then extending around the periphery.	Fast intense homogeneous enhancement. Fast homogeneous wash-out.	Stiffer than proper parathyroid glands.
Parathyroid adenoma	Enlarged, circumscribed, hypoechoic, oval shaped lesion, delineated by hyperechoic halo. Cystic inclusions may be seen.	Feeding polar vessels entering the pole and then extending around the periphery.	Early peripheral hyperenhancement. Central wash-out in the later phases.	Stiffer than hyperplastic parathyroid glands.

	B-Mode	Color Doppler US	CEUS	USE
Parathyroid carcinoma	Length > 3 cm, depth/width ratio > 1. Lobulated, heterogeneous, hypoechoic lesion. Irregular borders. Thick capsule. Intranodular calcifications. Cystic inclusions may be seen.	Intralesional disordered vascularity.	Early heterogeneous enhancement. Early homogeneous wash-out.	Stiffer than proper, hyperplastic, and adenomatous parathyroid glands.

In the results of this study, well-defined or circumscribed borders were observed in all patients with parathyroid enlargement, indicating that the lesions were benign whether they were cases of secondary hyperparathyroidism or adenomatous lesions. This is because, sonographically, it is nearly impossible to differentiate between glandular hyperplasia and adenomatous lesions (Centello et al., 2023).

3.2.7. Size of Parathyroid Glands in CKD Patients Undergoing Hemodialysis via Ultrasound (US)

The research findings on the size of the parathyroid glands in CKD patients undergoing hemodialysis revealed several important insights related to the progression of secondary hyperparathyroidism and the gland's response to the metabolic disorders occurring in these patients. Based on the results, a total of 82 patients were included in the study, with the size distribution of the parathyroid glands indicating that the majority ranged from 0.51–1 cm in size at serum iPTH levels of < 200–1000 pg/dL, whereas those with iPTH levels > 1000 pg/dL generally had gland sizes > 1 cm.

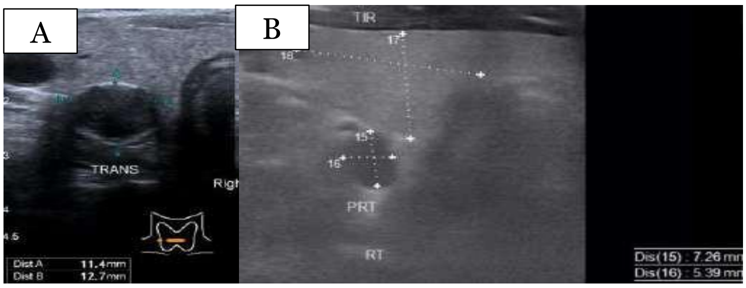

Figure 3. Size of Parathyroid Hyperplasia
Description: (A) parathyroid gland with serum iPTH level > 1000 pg/dL and (B) serum iPTH level < 1000 pg/dL

In CKD patients, the parathyroid glands tend to undergo hyperplasia due to increased parathyroid hormone (PTH) levels (Galassi et al., 2019). Generally, there are at least two distinct mechanisms that determine the extent of secondary hyperparathyroidism in CKD patients. The first is increased synthesis and secretion of PTH, and the second is an increase in the mass of the parathyroid glands, which become larger and denser, primarily due to increased cell proliferation (hyperplasia).

Okuno et al. (2003), found that patients with chronic kidney disease experienced parathyroid hyperplasia with an average maximum diameter of detectable parathyroid glands of 11.0 ± 0.7 mm. Tominaga et al. (1997), stated that there is a relationship between the hyperplasia pattern and gland weight, with glands weighing more than 500 mg. Arnold (2017), showed that parathyroid hyperplasia was detected in 24 patients (77.4%) with chronic kidney disease (CKD).

In a previous study, it was also found that in patients with serum iPTH levels >60 and <250 pg/mL, the parathyroid glands could not be detected by ultrasound, indicating that at these PTH levels, the gland size remained normal or below the detection threshold of USG. Additionally, most patients with moderate secondary hyperparathyroidism (iPTH range >250 pg/mL to <800 pg/mL) had undetectable PTG in approximately 20% of cases (Taniguchi et al., 2008).

Overall, these findings indicate that parathyroid gland enlargement represents the physiological response to systemic metabolic dysregulation, and ultrasonographic evaluation enables precise monitoring of parathyroid structural alterations, serving as a critical biomarker in the clinical management of chronic kidney disease patients. It may also help predict serum iPTH elevation through the size of the hyperplastic parathyroid glands. Further research is needed to identify other factors that may play a role in variations in parathyroid gland size in CKD patients and how these relate to their clinical conditions.

3.2.8. Parathyroid Gland Vascularization via Doppler Mapping in CKD Patients Undergoing Hemodialysis with Ultrasound (US)

Vascularization of the parathyroid glands in CKD patients undergoing hemodialysis reveals important information about gland activity and the progression of secondary hyperparathyroidism. Based on research findings, the distribution of parathyroid gland vascularization obtained through Doppler mapping examination using USG showed two main patterns: the presence and absence of vascularization, along with the type of vascularization observed.

Out of 82 patients who experienced parathyroid hyperplasia and were analyzed, the majority, 45 patients (54.9%), showed no vascularization in the parathyroid glands, while 45.1% of patients had vascularization. The distribution was as follows: 6 patients with iPTH < 200 pg/dL, 9 patients with iPTH 200–500 pg/dL, 7 patients with iPTH 501–1000 pg/dL, and 17 patients with iPTH > 1000 pg/dL. The types of vascularization observed in the parathyroid glands included: perilesional (65%), intralesional (11%), and both intra- and perilesional (24%). These findings indicate that the higher the iPTH level, the more pronounced the vascularization in the hyperplastic parathyroid glands.

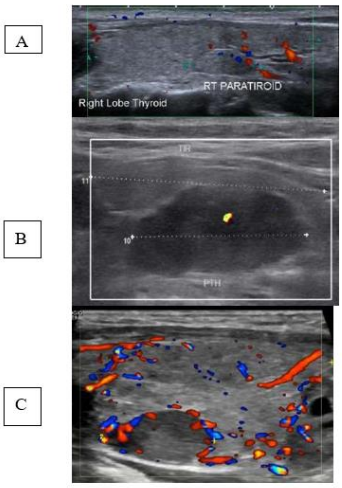

Figure 4. Vascularization of Parathyroid Hyperplasia
Description: (A) Perilesional vascularization, (B) intralesional, and (C) mixed / intraperilesional

In this case, the vascular pattern is characterized by the base of the artery and the continuous flow observed during diastolic motion (Onoda, 2003). On Color Doppler US imaging, both adenoma and hyperplasia in most cases show a prominent polar vessel, entering the pole and then extending around the periphery of the enlarged gland (Centello et al., 2023). CDFI flow is divided into 4 categories: grade 0 (no flow), grade I (minimal flow), grade III (moderate flow), and grade IV (marked flow). Meanwhile, in another study, CDFI classified flow as undetectable, central hypervascularity, peripheral hypervascularity (or ring-shaped), uniform hypervascularity (referred to as “hot spots”), or a combination of central and peripheral hypervascularity (Centello et al., 2023). Color Doppler sonography shows that parathyroid nodular hyperplasia exhibits perinodular vascularity in 38% of cases, while in diffuse PTG hyperplasia, hypervascularity is found in 22%, internal vascularity in 28%, and no vascularity in 12% of PTG (Pavlovic & Tomic Brzac, 2006; Prince & Wilson, 2005). One study showed that 60% of glands without power Doppler signal were associated with diffuse hyperplasia or hyperplasia with early nodularity, while 83.7% of glands showing power Doppler signal exhibited nodular hyperplasia, even in parathyroid glands weighing 0.5 g or less. The causes of the absence of vascularization in pathological parathyroid glands include: 1) size less than 1 cm; 2) deep location; 3) location near large blood vessels, which causes transmission artifacts; and 4) the presence of necrotic areas (Onoda, 2003).

Another study shows that CKD patients undergoing regular hemodialysis have a prevalence of secondary hyperparathyroidism of 41%, with significant disturbances in calcium and phosphate metabolism (Muppidi et al., 2023). In hyperparathyroidism, excessive calcium levels can deposit in the blood vessel walls, and high phosphate levels (hyperphosphatemia) in chronic kidney disease (CKD) trigger vascular smooth muscle cells (VSMCs) in the blood vessel walls to differentiate into osteoblast-like cells. The combination of hypercalcemia and hyperphosphatemia accelerates the formation of calcium-phosphate crystals, which damage the vascular endothelium and trigger cell apoptosis and plaque / calcification formation. Vascular calcification causes narrowing of the blood vessel lumen and reduces blood flow. This potentially reduces vascularization density, in this case the absence or minimal mapping vascular signal on Doppler of the parathyroid gland.

Basically, Doppler uses a vascular pattern characterized by the base of the artery with continuous flow observed during diastolic motion (Onoda, 2003). Therefore, the use of antihypertensive drugs is suspected to reduce the sensitivity of Doppler on the parathyroid gland, where the mechanism and hypotensive effects of these antihypertensive drugs cause vasodilation of blood vessels and thus reduce blood flow to organs. For example, calcium channel blocker drugs work by lowering blood pressure by slowing the movement of calcium into heart cells and arterial walls (blood vessels that carry blood from the heart to tissues), causing the arteries to relax and reduce blood pressure and flow.

ACE inhibitors work by inhibiting the conversion of angiotensin I to angiotensin II, causing vasodilation and decreased aldosterone secretion. In addition, bradykinin degradation is also inhibited so that bradykinin levels in the blood increase and contribute to the vasodilation effect of ACE inhibitors. Vasodilation directly lowers blood pressure, while reduced aldosterone causes water and sodium excretion and potassium retention. ACE inhibitors also block bradykinin degradation and stimulate the synthesis of substances that cause vasodilation. Increased bradykinin enhances the blood pressure-lowering effect. Angiotensin receptor blockers (ARBs) work by preventing the effects of angiotensin II, these compounds relax smooth muscle and promote vasodilation. Selective α1 receptor blockers act on peripheral blood vessels and inhibit catecholamine uptake in smooth muscle cells, causing vasodilation and lowering blood pressure. Monitoring vascularization using Doppler mapping and ultrasound can provide useful information to assess parathyroid gland activity and monitor the progression of hyperparathyroidism in CKD patients.

4. Conclusion

Based on the results of a study involving 100 hemodialysis patients at Dr. Soetomo General Hospital in Surabaya, the majority of respondents were female and aged 41–60 years, with treatment durations ranging from 1 to 10 years. Most patients showed abnormal levels of IPTH, phosphate, and calcium, predominantly elevated IPTH and hyperphosphatemia, along with either normal or low calcium levels (hypocalcemia). Ultrasonographic findings indicated that most patients' parathyroid glands exhibited hypoechoic echogenicity, solid architecture, oval shape with well-defined margins, and sizes ranging from 0.51–1 cm for IPTH < 1000 pg/dL and >1 cm for IPTH > 1000 pg/dL. Vascularization was mostly undetectable; however, in patients with high IPTH levels (>1000 pg/dL), perilesional vascularization was more dominant. Overall, the combination of echogenicity, architecture, shape, margin, size, and vascularization of the parathyroid glands correlates with IPTH levels, making it an important indicator in detecting parathyroid hyperplasia in chronic kidney disease patients undergoing hemodialysis.

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