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Original Research

To study thyroid function in chronic kidney disease patients in tertiary care centre

Dr. Sumit Pattaiya[1], Dr. Tariq Jalaly[2], Dr. Avinash Jhariya[3], Dr. Risabh Patel[4], Dr. Anubha Namdeo[5], Dr. Yash Mishra[6]

[1,3,4,5,6]PG Resident, [2]Professor, Department of Medicine, LN Medical College and JK Hospital, Bhopal, India

Corresponding Author
Dr. Sumit Pattaiya
PG Resident, Department of Medicine, LN Medical College and JK Hospital, Bhopal, India

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Abstract

Background: Chronic kidney disease (CKD) is a growing health concern worldwide. Thyroid dysfunction is common in CKD patients, affecting disease progression and patient outcomes.**Objectives:** To determine the prevalence of thyroid disorders in CKD patients and explore relationships with age, gender, CKD staging, and comorbidities.**Methods:** The present study enrolled 135chronic kidney disease patients from L.N. Medical College and Research Centre & J.K. Hospital, Bhopal. Inclusion criteria consisted of CKD diagnosis, elevated blood urea and serum creatinine, reduced creatinine clearance, and ultrasonography evidence. Exclusion criteria included pre-existing thyroid disorders, medications affecting thyroid function, acute illness, and hemodialysis.**Results:** Normal thyroid function was observed in 48.1% of patients.Primary subclinical hypothyroidism (19.3%), non-thyroidal illness (12.6%), and clinical/overt hypothyroidism (8.9%) were common.CKD staging revealed stages 3 and 4 as most prevalent (31.11% each).Thyroid disorders were significantly associated with CKD stages (p-value 0.002). No significant association was found between thyroid disorders and age (p-value 0.346) or gender (p-value 0.845).Hypertension (109) and comorbidities (101) were highly prevalent.**Conclusion:** Thyroid dysfunction is common in CKD patients, with primary subclinical hypothyroidism and non-thyroidal illness being prevalent. CKD staging significantly correlates with thyroid disorders. Regular thyroid function monitoring is crucial in CKD patients across all age groups and genders.

Keywords: Chronic Kidney Disease, Thyroid Dysfunction, Hypothyroidism, CKD Staging, Comorbidities.

Introduction

CKD is defined as kidney damage or glomerular filtration rate (GFR) <60 mL/min/1.73 m^2 for 3 months or more, irrespective of cause.[1] It is a worldwide public health problem with an increasing incidence and prevalence, poor outcomes, and high cost.[2] It encompasses a spectrum of pathophysiologic processes associated with abnormal kidney function and a progressive decline in glomerular filtration rate (GFR).[3] Kidneys' physiology is related to hormones produced by thyroid gland and it plays an important role in certain pathways of these hormones.[4] The function of the thyroid gland is one of the most important in the human body as it regulates majority of the body's physiological actions.[5] Thyroid hormones have distinct effects on cellular growth and differentiation. They also modulate important physiological functions in virtually every human tissue.[6]

Among CKD patients, low triiodothyronine (T3) is the most common laboratory finding. Iodothyroninedeiodinase enzyme function is impaired by conditions such as metabolic acidosis and protein loss in uremic patients, which results in a decreased conversion of thyroxine (T4) to T3. Reduced clearance causes an accumulation of inflammatory cytokines such as tumor necrosis factor (TNF)-α and (IL)-1, which block the production of 1 5'-deiodinase and result in low T3.[7] In individuals with chronic kidney disease (CKD), thyroid-stimulating hormone (TSH) levels can be normal or increased, while pituitary receptor sensitivity to thyrotropin-releasing hormone (TRH) is typically diminished. They have altered the glycosylation and TSH circadian rhythm. Furthermore, there is a decrease in TSH clearance, which results in an increase in half-life and a blunting of TSH's reaction to TRH. T4 levels in CKD patients may be normal or decreased due to monodeiodinase activity in the inner benzene ring, which results in the synthesis of reverse T3, which travels from the vascular space to extravascular and intracellular areas.[8]Hyperthyroidism is usually not associated with CKD in fact it may enhance CKD.[5]

Furthermore, patients with CKD have many signs and symptoms suggestive of thyroid dysfunction like dry skin, cold intolerance, asthenia, hyporeflexia and

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decreased BMR, hence in CKD it is difficult to exclude thyroid dysfunction on more clinical background. In view of the interrelationship between kidney function and thyroid hormone status and their variability, it is important for clinicians to understand their correlation. Despite a large number of available studies, there is a paucity of Indian data, especially in the central region of India regarding their correlation. So, the present study was planned on CKD patients to determine their thyroid profile status. The outcome of our study may help to understand the comorbid conditions associated with CKD.

Material and Method

The present observational, cross-sectional study was carried out among 135 patients diagnosed with chronic kidney disease (CKD) and admitted to the Department of General Medicine at L.N. Medical College and Research Centre & J.K. Hospital, Bhopal, specifically among patients

The study's inclusion criteria consisted of patients who fulfilled the diagnostic criteria for chronic kidney disease (CKD), characterized by the presence of uremic symptoms for three or more months, elevated blood urea and serum creatinine levels, reduced creatinine clearance, and ultrasonography evidence confirming CKD.The exclusion criteria eliminated patients or their attendants who failed to provide informed consent. Additionally, individuals with pre-existing thyroid disorders or those taking medications known to impact thyroid function (such as Amiodarone, Propranolol, steroids, dopamine, phenytoin, iodine-containing drugs, and oral contraceptive pills) were also excluded. Furthermore, patients experiencing acute illness, recent surgery, trauma, liver disease, or those undergoing hemodialysis were not eligible for participation in the study.Procedure planned and investigation details:

Patients fulfilling the inclusion criteria were selected for study. Relevant clinical data was recorded.Participants consented by endorsing a written consent form before samples were collected. 5ml venous fasting blood sample was collected from each participant and sent for laboratory investigations.

Laboratory investigation included CBC (hemoglobin, TLC, DLC, platelet), Liver function test (total bilirubin, direct bilirubin, indirect bilirubin, SGOT, SGPT, ALP, albumin), renal function test (urea, creatinine), serum electrolyte (Na+, K+), random blood sugar (RBS), prothrombin time (PT), activated partial thromboplastin clotting time (aPTT) and INR (international normalized ratio).

All study participants were categorized into various thyroid function groups based on results of thyroid function tests.

Determination of CKD Parameters

CKD was defined on the basis of National Kidney Foundation guidelines of having an estimated glomerular filtration rate (eGFR) <60 ml/min/1.732 m^2 for more than 3 months.
[Khatiwada S, Kc R, Gautam S, Lamsal M, Baral N. Thyroid dysfunction and dyslipidemia in chronic kidney disease patients. BMC endocrine disorders. 2015 Dec;15(1):1-7.]

Chronic Kidney Disease: eGFR< 60 ml/min per 1.73 m^2 for more than 3 months with or without evidence of kidney damage or albuminuria (≥ 30 mg/g) with or without decreased GFR for ≥ 3 months. Estimated glomerular filtration rate (eGFR) was computed from serum creatinine using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation [20].

eGFR =1.86 x (s.cr).x (age)ml/min per1.73m^2

Chronic kidney disease stages were defined as described by the Kidney Disease Improving Global Outcomes (KDIGO) and classify using estimated eGFR or urinary albumin creatinine ratio at the time of the study as:

- CKD1: eGFR> 90 ml/min and albuminuria,
- CKD 2: 60-89 mil/min and albuminuria,
- CKD 3a: 45-59ml/min,
- CKD 3b: 30-44ml/min,
- CKD 4: 29 - 15 ml/min and
- CKD 5:<15ml/min or dialysis [9,10]

Albuminuria was used to describe albumin creatinineratio(ACR) between 30 and 299 mg/g and 300 mg/g or over, respectively. [11,12]

Nephrotic range Proteinuria was defined as proteinuria of 3+ to 4 or as albuminuria of > 2.2g/g.

Radiological examination consisted of ultrasonography (USG) whole abdomen

Thyroid dysfunction

The abnormal thyroid function tests result wasclassified into any of the following:

• **Subclinical hypothyroidism**: TSH elevation >4.7 mIU/L in patients with normal serum TT3or FT3 and TT4 or FT4.

Primary subclinical hypothyroidism: TSH >4.7 mIU/L and suppressed serum TT3 or FT3 andTT4 or FT4T4.

Subclinical hyperthyroidism: suppressed TSH(<0.27) mIU/L and normal TT3 or FT3 and TT4or FT4 serum concentration.

• **Overt hyperthyroidism**: suppressed TSH (<0.27) mIU/L and elevated serum TT3 or FT3and TT4 or FT4 concentration

• **Non-thyroidal illness or low T3 syndrome**: Low TT3 or FT3 in the presence of normal TSH,TT4 and FT4 levels.

E**uthyroid hyperthyroxinaemia**: isolated elevation of FT4 or TT4 in the presence of TSH, FT3 and TT3 within reference limits [14]. • Reference ranges for the thyroid hormones were: TSH: 0.27 – 4.7 mIU/L, •

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FT4: 10.6 – 19.4 pmol/L, • FT3: 2.6 – 5.4pmol/L • TT4: 5.0 – 13.0 ug/mL • TT3: 0.52–1.85 ηg/dL.

Statistical analysis

Data was analysed statistically. Analysis was done in the form of percentages, proportions and represented as tables, charts, graphs wherever necessary. Appropriate tests of significance were applied with $p<0.05$

Results

Table 1: Age group wise distribution of study subjects

Age group (Years)	Frequency	Percent
<20	6	4.4
20-30	12	8.9
31-40	18	13.3
41-50	35	25.9
51-60	24	17.8
>60	40	29.6

Table 1 categorizes participants into six age groups, showing the frequency and percentage of participants in each group. The majority of participants are over 60 years old (29.6%), followed by those aged 41-50 (25.9%). The least represented age group is those under 20 years (4.4%).

Table 2: CKD stage wise distribution of study subjects

CKD stage	Frequency	Percent
1	1	0.7
2	19	14.07
3	42	31.11
4	42	31.11
5	31	22.96

Chronic kidney disease (CKD) stages are shown, with stages 3 and 4 being most common, each affecting 31.11% of participants.

Table 3: Distribution of study subjects according to thyroid disorder

Thyroid disorder	Frequency	Percent
Normal	65	48.1
Primary Subclinical Hypothyroidism	26	19.3
Subclinical Hypothyroidism	4	3.0
Clinical/overt Hypothyroidism	12	8.9
Non-Thyroidal Illness (Low T3 Syndrome)	17	12.6
Euthyroid Hyper thyroxinaemia	9	6.7
Overt Hyperthyroidism	2	1.5
Total	135	100.0

Table 3 categorizes participants based on thyroid function, with 48.1% having normal thyroid function, while others had various forms of hypothyroidism or non-thyroidal illness.

Table 4: Relation of thyroid disorder and CKD staging among study subjects

Thyroid disorder	CKD STAGE					Total
	1	2	3	4	5	
Normal	0	5	16	15	29	65
Primary Subclinical Hypothyroidism	0	3	4	4	15	26
Subclinical Hypothyroidism	1	0	2	0	1	4
Clinical/overt Hypothyroidism	0	2	2	1	7	12
Non-Thyroidal Illness (Low T3 Syndrome)	0	2	5	5	5	17
EuthyroidHyperthyroxinaemia	0	2	4	1	2	9
Overt Hyperthyroidism	0	0	0	0	2	2
Total	1	14	33	26	61	135

Chi square value – 48.793; p value -0.002*

Table 4 shows the relationship between thyroid disorders and chronic kidney disease (CKD) staging.Normal thyroid function CKD stages are distributed from stage 1 (0 cases) to stage 5 (15 cases), with the majority in stage 5.Primary Subclinical Hypothyroidism*: Mostly involves stage

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5 CKD (15 cases).Chi-square value 48.793 with a p-value of 0.002, indicating a significant relationship between thyroid disorders and CKD stages.

Table 5: Relation of thyroid disorder and Age and gender among study subjects

Thyroid disorder	Age group						Gender		
	<20	20-30	31-40	41-50	50-60	>60	Male	Female	
Normal	1	5	10	15	11	23	28	37	65
Primary Subclinical Hypothyroidism	2	0	2	7	7	8	13	13	26
Subclinical Hypothyroidism	0	1	1	1	0	1	1	3	4
Clinical/overt Hypothyroidism	0	3	2	3	2	2	5	7	12
Non-Thyroidal Illness (Low T3 Syndrome)	3	1	2	5	1	5	9	8	17
EuthyroidHyperthyroxinaemia	0	2	0	3	3	1	1	8	9
Overt Hyperthyroidism	0	0	1	1	0	0	0	2	2
Total	6	12	18	35	24	40	55	78	135
P value	0.346						0.845		

Table 6: Relation of thyroid disorder with comorbidities and lifestyle factors

Thyroid disorder	Presence of comorbidities		Presence of alcohol habit	Tobacco smoking or chewing	Anaemia
	DM	Hypertension			
Normal	30	53	27	31	53
Primary Subclinical Hypothyroidism	10	17	7	10	20
Subclinical Hypothyroidism	2	2	1	3	1
Clinical/overt Hypothyroidism	6	8	2	7	11
Non-Thyroidal Illness (Low T3 Syndrome)	8	11	4	7	14
EuthyroidHyperthyroxinaemia	3	8	7	4	8
Overt Hyperthyroidism	1	2	1	2	2
Total	60	101	49	64	109
P value	0.978	0.315	0.06	0.525	0.122

Table 5 examines the relationship between thyroid disorders and age/gender among chronic kidney disease (CKD) patients. The results show that thyroid disorders affect CKD patients across various age groups, with the majority (40) occurring in those over 60 years old. Normal thyroid function was most prevalent in the 41-50 and 50-60 age groups.

In terms of gender, females (78) outnumbered males (55), with normal thyroid function more common in females (37) than males (28). Primary subclinical hypothyroidism and non-thyroidal illness (Low T3 Syndrome) showed relatively even distribution across age groups, while clinical/overt hypothyroidism was more prevalent in females (7) than males (5).

Statistical analysis revealed no significant association between thyroid disorders and age (p-value 0.346) or gender (p-value 0.845), indicating that thyroid disorders affect CKD patients regardless of age or gender. The study's findings highlight the importance of thyroid function monitoring in CKD patients across all age groups and genders.This study examined the prevalence of thyroid disorders among patients with chronic kidney disease (CKD), alongside various comorbidities and lifestyle factors (table 6). The results showed that hypertension (109) and comorbidities (101) were highly prevalent, followed by anemia (64) and diabetes mellitus (64). Tobacco use (49) and alcohol consumption (27) were less common. Regarding thyroid disorders, the distribution included normal thyroid function (30), primary/subclinical hypothyroidism (10/20), clinical/overt hypothyroidism (6), non-thyroidal illness (Low T3 Syndrome) (8), euthyroid hyperthyroxinaemia (3), and overt hyperthyroidism (1). Statistical analysis revealed varying levels of significance, with p-values ranging from 0.061 to 0.978, indicating no significant difference in thyroid disorder distribution among the study population.

Discussion

Chronic kidney disease (CKD) poses a significant global health concern, substantially impacting healthcare expenditures, morbidity, and mortality from non-communicable diseases worldwide.[66]The complex interplay between kidney function and thyroid hormone status necessitates clinician awareness. Noting the scarcity of Indian data, especially from the central region, this study seeks to bridge the gap by examining thyroid profiles in CKD patients. Hence, the present study aimed to analyse the thyroid function in patient with chronic kidney disease in tertiary care centre and to study the

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prevalence of thyroid disorders in patients with chronic kidney disease as well as to correlate thyroid function with severity of renal failure. A statistically significant association was found between thyroid disorders and the severity of chronic kidney disease (CKD) stages (p = 0.002). Notably, primary subclinical hypothyroidism was disproportionately prevalent among patients with stage 5 CKD in the present study.

The kidneys play a crucial role in regulating thyroid hormones. In chronic renal disease, impaired kidney function leads to iodine accumulation, acid-base disturbances, and changes in thyroid hormone levels, compromising thyroid function.[11] In the present study, 48.1% having normal thyroid function, while others had various forms of hypothyroidism or non-thyroidal illness that comprised of 19.3% had primary subclinical hypothyroidism, 3.0% had subclinical hypothyroidism, 8.9% had clinical/overt hypothyroidism, 12.6% had non-thyroidal illness (low T3 syndrome), 6.7% had euthyroid hyper thyroxinaemia, 1.5% had overt hyperthyroidism. Analysing, chronic kidney disease (CKD) stages, stages 3 and 4 were found to be most common, each affecting 31.11% of participants followed by 22.96% with stage 5. Our results are in concordance with previous studies that have reported similar prevalence rates, with subclinical hyperthyroidism occurring in 4.1% of CKD patients in a multicentred study among patients on peritoneal dialysis by **Ng YY et al.**[9] Similarly, a study by **Shantha GPS et al**[10] found that 24.8% of end-stage renal disease patients suffered from subclinical hypothyroidism. A study by **Khatiwada S et al.**[11] found that 38.6% of chronic kidney disease (CKD) patients had thyroid dysfunction, with subclinical hypothyroidism being the most common (27.2%). In a corresponding study by **Tapper M et al**[12], overt hyperthyroidism was detected in 1.4% of subjects, while subclinical hyperthyroidism was observed in 4.0% (6/140) of participants, with varying stages of chronic kidney disease (CKD) - three in stage 1, two in stage 2, and one in stage 4. Notably, hyperthyroidism, whether overt or subclinical, is an uncommon finding in CKD patients. The observed hyperthyroidism in CKD patients may be attributed to impaired kidney excretion leading to iodine retention in thyroid follicle cells, potentially triggering the Jod-Basedow phenomenon. Another alike study by **Lo JC et al**[13] reveals a strong inverse relationship between glomerular filtration rate (GFR) and hypothyroidism prevalence, hypothyroidism affected 5.4% of individuals with normal GFR (≥90 mL/min/1.73 m²), increasing to 23.1% in those with severely impaired GFR (<30). Subclinical hypothyroidism accounted for 56% of cases. Anotherstudy by **Kaptein EM et al**[14] demonstrated that chronic kidney disease (CKD) enhances iodide absorption by the thyroid gland due to decreased iodide excretion, leading to elevated plasma inorganic iodide levels. This triggers the Wolff-Chaikoff effect, inhibiting thyroid hormone production and potentially explaining the increased prevalence of hypothyroidism and subclinical hypothyroidism (SCH) in CKD patients. Consistent with these findings, **Alshammari F et al**[15] reported a significant proportion of CKD patients experiencing hypothyroidism. Given the association between hypothyroidism and increased mortality risk, as well as adverse effects on health-related quality of life, these studies underscore the critical importance of recognizing and managing hypothyroidism in CKD patients.

The present study found association between thyroid disorders and chronic kidney disease (CKD) stages and it was found that primary subclinical hypothyroidism was predominantly found in stage 5 CKD. The chi-square test indicates a significant relationship between thyroid disorders and CKD stages (p-value = 0.002). Our results stand in line with study carried by **Ansari I et al**[16] that found 91.5% of patients (181/200) had thyroid abnormalities, including low T3 syndrome (57%), low T4 syndrome (23%), and primary hypothyroidism (10.5%). Notably, TSH levels increased significantly (p=0.04) as CKD stages progressed, indicating a link between CKD severity and thyroid dysfunction. Similarly, in the study by **Chandra A**[17], overt hypothyroid patients had higher TSH and lower free T4 levels than nonhypothyroid individuals. Hypothyroid patients (clinical and subclinical) also showed lower serum albumin and calcium, and higher intact parathyroid hormone levels. Notably, hypothyroidism prevalence increased as glomerular filtration rate decreased, indicating a link between renal impairment and thyroid dysfunction. Another corresponding study by **Lo et al**[18] reported a 23.1% prevalence of hypothyroidism in CKD patients with an estimated glomerular filtration rate (eGFR) below 30 mL/min/1.73 m^2.

Our study also found no significant association between thyroid disorder, age and gender which is in concordance with **Chonchol et al.**[19] It was found that primary subclinical hypothyroidism was more common in participants over 60. However, the chi-square test indicates no significant association between thyroid disorder and age group (p-value = 0.346). Further, the present study found normal thyroid function is more common in males, while primary subclinical hypothyroidism affects both genders equally. However, the chi-square test indicates no significant association between thyroid disorder and gender (p-value = 0.845).

As per HBA1C levels according to American Diabetes association, about 46.7% had normal HbA1C levels (<5.7), while 27.4% had levels 5.7-6.5, 24.4% had levels indicating diabetes (6.5-9) and 1.5% had levels >9 among CKD patients. The present study found that primary subclinical hypothyroidism was slightly more common in those without diabetes, while euthyroidhyperthyroxinaemia was slightly more

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common in those with diabetes. However, the chi-square test indicates no significant association between thyroid disorder and diabetes (p-value = 0.978) in our study whereas **Bajaj Set al**[20]reported that hypothyroidism is often linked to diabetic kidney disease (DKD). The prevalence of hypothyroidism increased with renal decline. The overall population had 14 (34.1%) hypothyroid cases, 12 (29.3%) of which were subclinical and 2 (4.8%) overt. With DKD severity, hypothyroidism prevalence and mean thyroid stimulating hormone levels increased.

According to the European Society of Cardiology and the European Society of Hypertension (ESC/ESH), hypertension—defined as a blood pressure of ≥140/80 mmHg—affects approximately 30% of the general adult population and up to 90% of individuals with chronic kidney disease (CKD). Hypertension plays a dual role in CKD, serving as both a causal factor and a consequence, and exacerbating disease progression. Notably, the prevalence and severity of hypertension increase as estimated glomerular filtration rate (eGFR) declines. Furthermore, hypertension and CKD independently heighten the risk of cardiovascular disease (CVD), and their coexistence substantially amplifies CVD-related morbidity and mortality. The present study examined the relationship between thyroid disorders and hypertension (HTN) among participants. The results showed that normal thyroid function was more common in subjects with hypertension (53 patients) than those without (12 patients). Primary subclinical hypothyroidism and other thyroid disorders also had higher occurrences in subjects with hypertension. However, the chi-square test indicated no statistically significant association between thyroid disorders and hypertension (p-value > 0.05).

Thyroid hormones regulate blood pressure by influencing metabolism, cardiac workload, and vascular resistance. Hyperthyroidism increases heart rate, cardiac output, and blood pressure, while hypothyroidism decreases heart rate and cardiac output, leading to elevated blood pressure due to increased vascular resistance. Clinicians must be cautious when managing hyperthyroid patients with concurrent heart disease, as increased metabolic demands can strain myocardial function.[21]In contrast to hyperthyroidism, hypothyroidism is characterized by decreased cardiac activity, including bradycardia, reduced cardiac output, and increased systemic vascular resistance. This leads to mild hypertension and narrowed pulse pressure. Although cardiac function is impaired, heart failure is uncommon due to decreased metabolic rate and oxygen demand. Hypothyroidism also affects blood volume, with increased salt sensitivity and renal sodium reabsorption resulting in a 5.5% expansion.[22]

In the present study, 47.4% of participants had tobacco habits (smoking/chewing) and 36.3% consumed alcohol. No significant association was found between alcohol consumption and thyroid disorders (p=0.061). Tobacco usage also showed no correlation with thyroid disorders (p=0.525). **Chen X et al**[23] no significant link was found between smoking and subclinical hypothyroidism (SHO) and thyroid nodules (TNs) in multivariate analysis.

Thyroid dysfunction, even subclinical, significantly contributes to anemia development in chronic kidney disease (CKD) patients.[24]The present study analysis showed that participants with anaemia were more likely to have normal thyroid function (53 patients) than those without anaemia (12 patients). However, the chi-square test indicated no statistically significant association between thyroid disorders and anaemia (p-value = 0.122). Although present study found statistically non-significant results, however literature reports association of thyroid dysfunction with low hemoglobin levels in CKD patients. A study by **Bargenda A et al**[25] carried out analysis of dialysis patients and revealed that thyroid dysfunction is more prevalent when hemoglobin levels are below 12.5 mg/dL with the most common thyroid abnormality reported in CKD patients was low T3 syndrome, characterized by low T3 concentrations with normal TSH and free thyroxine levels, and is considered an adaptive response to severe illness. Further, in advanced CKD, limited erythropoietin production exacerbates anemia, and low T3 syndrome is more frequent in patients with severe anemia. Both subclinical and clinical hypothyroidism increase the risk of CKD development within 5 years in patients over 65. Additionally, these conditions worsen hemoglobin levels and anemia risk.[26]

The limitations include the single-center design and relatively small sample size.

Based on the study's findings, several key recommendations emerge to enhance the management and care of chronic kidney disease (CKD) patients. Firstly, regular thyroid function screening is crucial for CKD patients to facilitate early detection and treatment of thyroid disorders. Secondly, an integrated approach to managing CKD, hypertension, anemia, and diabetes is essential to mitigate the complex interplay between these conditions and improve patient outcomes.

Conclusion

To conclude, thyroid disorders were prevalent among CKD patients with 51.9% of participants exhibiting abnormal thyroid function, including primary subclinical hypothyroidism (19.3%), non-thyroidal illness (12.6%), and clinical/overt hypothyroidism (8.9%).

A significant relationship was observed between thyroid disorders and CKD stages (p-value = 0.002), with primary subclinical hypothyroidism predominantly affecting stage 5 CKD patients. These findings underscore the importance of regular thyroid function monitoring in CKD patients, as well as comprehensive management of CKD, hypertension, anemia, and diabetes to improve patient outcomes.

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Ultimately, these insights can inform clinical practice guidelines and help the management of CKD patients with thyroid disorders.

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