Analysis of Urea Levels in Chronic Kidney Disease Patients Based on Age, Sex, and Hemodialysis Frequency

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Abstract.

Introduction: Chronic kidney disease (CKD) is a progressive condition characterized by declining renal function and accumulation of metabolic waste such as urea. Hemodialysis is essential in advanced CKD to reduce urea levels, which serve as an important marker for renal function and dialysis adequacy. Variations in urea levels may be influenced by demographic factors such as age and sex, as well as treatment-related factors including hemodialysis frequency. Aims: This study aimed to analyze urea levels and hemodialysis frequency among CKD patients based on age groups (<50 years, 51–60 years, and ≥61 years) and sex. Methods: A descriptive quantitative study with a cross-sectional design was conducted using secondary data from medical records of CKD patients undergoing hemodialysis at PKU Muhammadiyah Gamping Hospital from 2021 to 2023. A total of 78 complete records were included. Urea levels and hemodialysis frequency were analyzed descriptively, and an independent t-test was used to assess differences between male and female patients. Results: Urea levels varied across age groups within each sex. In males, the highest mean urea level was observed in the 51–60 years group, while females showed a progressive increase with age. Male patients exhibited greater variability, especially in older age groups, whereas females showed more consistent patterns. Hemodialysis frequency remained relatively stable in males but increased with age in females. However, statistical analysis revealed no significant difference in urea levels between sexes (p = 0.919), with mean values of 99.35 mg/dL in males and 100.38 mg/dL in females. Conclusion: Urea levels in CKD patients vary according to age and demonstrate different patterns between sexes, but no significant sex-based differences were identified. These findings suggest that urea dynamics are influenced by multiple factors, highlighting the importance of individualized management strategies in CKD patients undergoing hemodialysis.

Keywords : *Chronic Kidney Disease; Urea Levels and Hemodialysis Frequency.*

I. INTRODUCTION

Chronic kidney disease (CKD) represents a major global health burden characterized by progressive and irreversible deterioration of renal function, ultimately leading to end-stage renal disease (ESRD) requiring renal replacement therapy such as hemodialysis. The global prevalence of CKD continues to rise, particularly among aging populations, making it a critical public health concern associated with high morbidity, mortality, and healthcare costs . Hemodialysis remains the most widely used modality for managing advanced CKD, aiming to remove metabolic waste products, including urea, and maintain homeostasis. Urea is a key biochemical marker widely used to assess renal function and the adequacy of dialysis therapy. It is the end product of protein metabolism and is primarily excreted by the kidneys. In CKD patients, impaired renal function leads to the accumulation of urea in the blood, resulting in a condition known as uremia, which is associated with various systemic complications, including cardiovascular disease, neurological impairment, and increased mortality risk [1,2]. Therefore, monitoring serum urea levels is essential in evaluating disease progression and the effectiveness of hemodialysis treatment. Hemodialysis plays a crucial role in reducing urea concentration in the bloodstream. The effectiveness of hemodialysis is commonly assessed using parameters such as the urea reduction ratio (URR) and Kt/V, both of which reflect the clearance of urea during dialysis sessions [3]. Adequate dialysis is associated with improved clinical outcomes, whereas inadequate removal of urea is linked to poor prognosis and increased risk of complications [4].

Despite advances in dialysis technology, variability in urea levels among patients remains a significant clinical challenge. Several factors influence urea levels in CKD patients, including dietary protein intake, residual renal function, dialysis adequacy, and individual metabolic characteristics. Among these

factors, age and sex have been identified as important determinants that may affect both urea production and clearance. Age-related physiological changes, such as reduced muscle mass and altered protein metabolism, can influence urea generation, while sex differences in body composition and hormonal regulation may contribute to variations in urea levels [5,6]. Age is a well-established factor affecting CKD progression and outcomes. The prevalence of CKD increases significantly in older populations, with a substantial proportion of patients aged over 60 years . Aging is associated with structural and functional changes in the kidneys, including decreased glomerular filtration rate (GFR), renal fibrosis, and vascular alterations [7]. Additionally, elderly patients often present with multiple comorbidities, such as hypertension and diabetes, which further accelerate renal decline and influence biochemical parameters, including urea levels [8]. In contrast, younger CKD patients may exhibit different metabolic profiles, including higher protein turnover and greater muscle mass, which can lead to increased urea production. However, younger patients may also demonstrate better physiological reserve and response to dialysis therapy [9].

The comparison of urea levels across different age groups (<50 years, 51–60 years, and >61 years) is therefore important to understand age-related variations in CKD patients undergoing hemodialysis. Sex differences in CKD have also been widely reported. Although CKD prevalence is often higher in women, disease progression tends to be faster in men, potentially due to differences in hormonal influences, lifestyle factors, and comorbid conditions [10]. Men generally have higher muscle mass compared to women, which may result in increased production of nitrogenous waste products such as urea [11]. On the other hand, women may exhibit better treatment adherence and dialysis adequacy, which can influence urea clearance [12]. Recent studies have highlighted the importance of considering sex-specific differences in dialysis outcomes. For instance, dialysis adequacy parameters such as Kt/V may differ between men and women due to variations in body composition and volume distribution [3]. Additionally, some evidence suggests that female patients may achieve better dialysis adequacy despite having similar or lower urea levels compared to males [13]. These findings indicate that sex-related factors should be taken into account when evaluating urea levels and dialysis effectiveness.Another critical aspect in CKD management is the frequency of hemodialysis. Standard hemodialysis is typically performed two to three times per week; however, the optimal frequency may vary depending on individual patient characteristics.

Increasing the frequency of dialysis sessions has been shown to improve urea clearance, reduce toxin accumulation, and enhance patient outcomes [14]. Nevertheless, higher frequency dialysis may also be associated with increased burden, including vascular access complications and reduced quality of life [15].The relationship between urea levels and hemodialysis frequency is complex and influenced by multiple factors, including age and sex. Older patients may require more frequent dialysis due to reduced residual kidney function, while younger patients may maintain adequate urea control with fewer sessions [16]. Similarly, sex differences in dialysis response may contribute to variations in treatment requirements and outcomes [17].Despite the growing body of evidence, studies examining the combined effects of age, sex, urea levels, and hemodialysis frequency remain limited, particularly in specific populations. Most previous studies have focused on isolated factors rather than integrating these variables into a comprehensive analysis. Furthermore, variability in findings across different populations highlights the need for context-specific research.Understanding the interplay between urea levels, age, sex, and hemodialysis frequency is essential for optimizing CKD management. Such knowledge can contribute to the development of individualized treatment strategies, improve dialysis adequacy, and ultimately enhance patient outcomes. Therefore, this study aims to analyze urea levels and hemodialysis frequency among CKD patients based on sex and age groups (<50 years, 51–60 years, and >61 years), providing insights into demographic and clinical factors influencing urea dynamics.

II. METHODS

This study is an observational research utilizing existing data obtained from medical records at PKU Muhammadiyah Gamping Hospital from 2021 to 2023. A descriptive quantitative approach with a cross-sectional survey design was applied to examine the relationship between dependent and independent variables simultaneously. The inclusion criteria consisted of hospitalized patients at PKU Gamping Hospital

who were diagnosed with chronic kidney disease and had comorbid conditions. The medical records included both surviving and deceased inpatients. The exclusion criteria included patients with incomplete medical record data. Data collection was conducted using secondary data derived from the medical records of chronic kidney disease patients who underwent hemodialysis therapy at PKU Muhammadiyah Gamping Hospital from January to September 2023. Out of a total of 181 medical records of chronic kidney disease patients, 78 records were considered complete, containing data on total urinary protein levels and frequency of hemodialysis.An independent t-test analysis was performed to determine whether there was a significant difference in urea levels between male and female patients.This study received ethical approval from the Ethics Committee of PKU Muhammadiyah Gamping Hospital with approval number 061/EC-EXEM-KEPK FKIK UMY/VI/2024.

III. RESULT AND DISCUSSION

1. Analysis of Urea Levels Based on Sex and Age

a. Male Patients (Tables 1 and 2)

In male patients (Tables 1 and 2), the 51–60 years age group exhibited the highest mean urea level, reaching 111.731 mg/dL. The ≤50 years group had a lower mean value (85.227 mg/dL), while in the ≥61 years group, the mean slightly decreased (94.2 mg/dL). The standard deviation in the ≥61 years group was notably high (±88.716), indicating substantial variability in urea levels among patients in this age group.

Table 1. Mean Urea Levels in Male Patients with Kidney Failure

Age (years)	Mean Urea (mg/dL)	Hemodialysis Frequency
≤50	85.227 ±23.299	2.000±0.000
51-60	111.731 ± 47.744	1.923 ± 0.272
≥61	94.2 ± 88.716	1.909 ± 0.301

Extreme values (Table 2) show that the lowest urea levels were relatively similar across age groups (approximately 34–38 mg/dL). However, the highest values increased markedly with age, particularly in the ≥61 years group (332.5 mg/dL), suggesting more severe clinical conditions in some elderly patients. Hemodialysis frequency remained relatively stable at approximately twice per week, with a slight decrease in older patients.

Table 2. Minimum and Maximum Urea Levels by Age Group in Male Patients

Age (years)	≤50	51-60	≥61
Minimumurea (mg/dL)	38.4	35.2	34.3
Maximum urea (mg/dL)	125.2	238	332.5
Hemodialysis frequency	2	2	2

b. Female Patients (Tables 3 and 4)

In female patients (Tables 3 and 4), there was a progressive increase in urea levels with advancing age, indicating a more consistent pattern compared to male patients.

Table 3. Mean Urea Levels in Female Patients with Kidney Failure

Age (years)	Mean Urea (mg/dL)	Mean Hemodialysis Frequency
≤50	92.337 ±47.898	1.947±0.524
51-60	101.4 ± 42.478	1.954 ± 0.428
≥61	108.19 ± 63.938	2.00± 0.471

Extreme values (Table 4) indicate that the lowest urea level was observed in the ≥61 years group (5 mg/dL), which may represent an outlier or a specific clinical condition. The highest urea levels were elevated across all age groups but did not reach the extreme values observed in elderly male patients.

Table 4. Minimum and Maximum Urea Levels by Age Group in Female Patients

Age (years)	≤50	51-60	≥61
Minimumurea (mg/dL)	31.1	30	5
Maximum urea (mg/dL)	195.3	165.8	208.7
Hemodialysis frequency	1	2	2 and 3

Hemodialysis frequency in female patients tended to increase with age (up to 2–3 times per week), suggesting a need for more intensive therapy in older patients.

2. Comparison Between Male and Female Patients

a. Mean Urea Levels

In the ≤50 years group, females had slightly higher mean urea levels than males. In the 51–60 years group, males exhibited substantially higher levels. In the ≥61 years group, females had higher mean values; however, males showed more extreme maximum values.

b. Data Variability

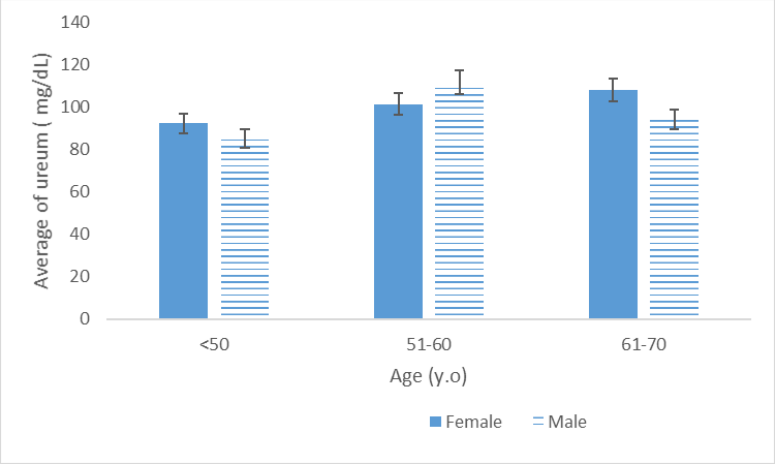
Male patients demonstrated greater variability, particularly in the ≥61 years group. In contrast, female patients showed a more consistent pattern, although variability was still present.

c. Hemodialysis Frequency

Male patients: relatively stable (~2 sessions per week). Female patients: increased with age (up to 3 sessions per week). This finding suggests that elderly female patients may require more frequent dialysis therapy.

3. Interpretation of the T-Test (Independent Samples T-Test)

The independent t-test results indicated that there was no statistically significant difference in urea levels between male and female patients ($p = 0.919 > 0.05$). The mean urea level in female patients was 100.38 ± 54.32 mg/dL, while in male patients it was 99.35 ± 47.53 mg/dL.



Picture of the Independent Samples T-Test of urea number based on age between male and female patient kidney failure.Thus, sex does not have a significant effect on urea levels in patients with kidney failure in this study. The t-test was conducted to determine whether there was a significant difference between male and female urea levels. Based on the observed data patterns:A potential difference may exist in certain age groups, particularly 51–60 years, where the difference appears relatively large. However, in other age groups, the difference is likely not significant, due to overlapping values and high variability.

Discussion

This study aimed to analyze urea levels in patients with chronic kidney disease (CKD) based on age and sex, as well as their association with hemodialysis frequency. Overall, the findings indicate that urea levels vary across age groups within each sex; however, no statistically significant difference was observed between male and female patients. These results highlight that urea levels in CKD patients are influenced by multiple factors beyond sex alone.

1. Urea Level Patterns in Male Patients

In male patients, the highest mean urea level was observed in the 51–60 years age group, followed by a decline in patients aged ≥61 years. This finding appears to contrast with the general assumption that renal function continuously deteriorates with advancing age. One possible explanation is the reduction in muscle mass among older individuals, which may lead to decreased urea production. Physiologically, urea is the end product of protein metabolism; therefore, its production is closely related to muscle mass and dietary protein intake. In elderly individuals, conditions such as sarcopenia may reduce urea production despite declining renal excretory function. Previous studies have demonstrated that urea levels reflect not only kidney function but also an individual's metabolic and nutritional status [1].Additionally, elderly patients are

more likely to follow stricter dietary protein restrictions or receive more intensive treatment, including well-regulated hemodialysis. These factors may contribute to relatively lower urea levels in older age groups [2]. The very high standard deviation observed in the ≥61 years group suggests substantial clinical heterogeneity. This indicates that patients within this age category differ considerably in terms of disease severity, comorbidities, and treatment response. Similar findings have been reported in previous studies, which describe greater variability among elderly CKD populations compared to younger groups [3]. The extremely high maximum urea level (up to 332.5 mg/dL) in older male patients suggests the presence of severe uremia in certain individuals. This condition may result from delayed treatment, poor adherence, or complications that exacerbate renal dysfunction. Elevated urea levels have been associated with increased risks of systemic complications and mortality [4].

2. Urea Dynamics in Female Patients

In contrast to males, female patients demonstrated a progressive increase in urea levels with advancing age, indicating a more consistent pattern. This suggests that renal function decline in females may occur in a more gradual and predictable manner.The increase in urea levels among older women may be associated with physiological changes, particularly those related to menopause. The decline in estrogen levels is known to reduce its protective effects on renal and vascular systems, thereby accelerating kidney damage [6]. Furthermore, the prevalence of comorbid conditions such as hypertension and diabetes increases with age, contributing to CKD progression.The extremely low urea value (5 mg/dL) observed in the ≥61 years group likely represents an outlier and may not reflect the general population trend. This value could be attributed to conditions such as severe malnutrition, altered protein metabolism, or excessive dialysis. Therefore, such extreme values should be interpreted cautiously to avoid bias in the analysis.Overall, the relatively consistent increase in urea levels among female patients suggests a more homogeneous clinical profile compared to males.

3. Comparison Between Male and Female Patients

Although differences in urea distribution patterns were observed between sexes, statistical analysis revealed no significant difference between male and female patients. This is supported by the p-value, which exceeded the significance threshold ($p > 0.05$).These findings suggest that sex is not a primary determinant of urea levels in CKD patients. This is consistent with previous studies indicating that after adjusting for confounding factors such as age, nutritional status, and treatment, the effect of sex becomes negligible [7]. However, other studies have reported higher urea levels in males, potentially due to greater muscle mass and higher protein metabolism [8]. These discrepancies indicate that urea levels are influenced by complex interactions among multiple physiological and clinical factors.

4. Variability of Urea Levels

Greater variability in urea levels among male patients, particularly in older age groups, suggests broader differences in clinical conditions within this population. Factors such as dietary habits, treatment adherence, and comorbidities may contribute to this variability.In contrast, female patients exhibited a more stable pattern, although variability was still present. This relative stability may be associated with better adherence to long-term treatment. Previous research has shown that female patients tend to demonstrate higher compliance with chronic disease management compared to males [9].

5. Role of Hemodialysis Frequency

Hemodialysis frequency plays a crucial role in controlling urea levels. In this study, the frequency remained relatively constant in male patients, whereas it increased in older female patients.The increased frequency of hemodialysis in elderly female patients may reflect the need for more intensive treatment to maintain metabolic balance. Evidence suggests that more frequent dialysis sessions can significantly reduce urea levels and improve patient outcomes [10].However, the effectiveness of hemodialysis depends not only on frequency but also on duration and adequacy. Therefore, evaluating dialysis adequacy remains essential to ensure optimal treatment outcomes.

6. Clinical Implications

The absence of significant differences between male and female patients indicates that clinical management of urea levels should not be based solely on sex. Instead, greater emphasis should be placed on individual patient characteristics, including age, clinical condition, and response to therapy.A personalized approach is increasingly important in the management of CKD patients. Additionally, incorporating other biomarkers beyond urea may improve the accuracy of kidney function assessment [11].

7. Study Limitations

This study has several limitations, including the absence of data on CKD staging, lack of analysis of comorbid conditions, and omission of other renal function parameters such as glomerular filtration rate (GFR). Furthermore, the presence of extreme values may have influenced the overall analysis.

IV. CONCLUSION

In summary, this study demonstrates that urea levels in CKD patients vary with age, with different patterns observed between males and females. However, no statistically significant difference was found between sexes. These findings suggest that urea levels are influenced by multiple complex factors, emphasizing the need for a comprehensive and individualized clinical approach.

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