Section: Medicine

Original Research Article

A PROSPECTIVE STUDY ON PREVALENCE OF HYPERTENSION AND ITS IMPACT ON GLOMERULAR FILTRATION RATE (GFR)

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Received *: 06/10/2024*
Received in revised form *: 22/11/2024*
Accepted *: 06/12/2024*

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DOI: 10.70034/ijmedph.2024.4.176

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2024; 14 (4); 958-964

ABSTRACT

Background: Hypertension is a significant global health challenge and a leading contributor to chronic kidney disease (CKD). Its impact on glomerular filtration rate (GFR), a key indicator of renal function, highlights the importance of early detection and management to prevent irreversible renal damage. This study investigates the prevalence of hypertension and its association with GFR decline in patients attending Palace Hospital,Thrissur.
Objective: To assess the prevalence of hypertension and its correlation with GFR among patients and evaluate the risk factors contributing to renal dysfunction.
Material and Methods: A prospective study was conducted over 12 months at Palace Hospital, Thrissur with 100 patients aged 30–75 years. Patients were evaluated for blood pressure, renal function tests, and GFR using the CKD-EPI equation. Hypertension was categorized according to the American College of Cardiology guidelines, and GFR was stratified into stages of CKD. Data on comorbidities, demographic profiles, and laboratory findings were analyzed to explore the relationship between hypertension and GFR.
Results: The prevalence of hypertension was 38%, with 54% of hypertensive patients exhibiting reduced GFR (<60 mL/min/1.73 m²). A significant inverse correlation ($r = -0.68$, $p < 0.001$) was observed between blood pressure levels and GFR. Age ≥60 years, uncontrolled hypertension, and diabetes mellitus were identified as significant risk factors for GFR decline. Hypertensive patients in CKD stages 3–5 accounted for 40% of the cohort.
Conclusion: Hypertension significantly impacts GFR, with a high prevalence of CKD in hypertensive patients. Early detection and control of hypertension are critical to preserving renal function and preventing progression to end-stage renal disease (ESRD).
Keywords: Hypertension, Glomerular Filtration Rate, Chronic Kidney Disease, Renal Dysfunction, Blood Pressure, CKD-EPI Equation.

INTRODUCTION

Hypertension, often referred to as the "silent killer," is one of the most prevalent non-communicable diseases worldwide, affecting an estimated 1.4 billion people. It is a major risk factor for cardiovascular diseases, stroke, and chronic kidney disease (CKD), contributing significantly to morbidity and mortality.[1] Hypertension-induced renal dysfunction is of particular concern, as the kidneys play a critical role in blood pressure regulation and fluid balance. Persistent elevation in blood pressure can lead to structural and functional damage to the renal microvasculature, accelerating the decline in renal function.[2]

The Glomerular Filtration Rate (GFR) is a critical measure of kidney function, reflecting the ability of the kidneys to filter waste products and maintain homeostasis.[3] Reduced GFR is a hallmark of CKD, often linked to hypertension as both a cause and consequence. Hypertension leads to increased intraglomerular pressure, promoting glomerulosclerosis and tubulointerstitial damage.[4] Conversely, CKD exacerbates hypertension through mechanisms such as sodium retention, activation of the renin-angiotensin-aldosterone system (RAAS), and sympathetic nervous system hyperactivity. This bidirectional relationship underscores the need for early detection and management of hypertension to prevent renal dysfunction and progression to end-stage renal disease (ESRD).[5]

Epidemiological studies have demonstrated a strong association between hypertension and CKD. The National Kidney Foundation estimates that approximately 28% of CKD cases in adults are attributable to hypertension.[6] The impact is particularly pronounced in low- and middle-income countries, where delayed diagnosis and inadequate management of hypertension often result in severe complications.[7] Despite these alarming statistics, awareness regarding the relationship between hypertension and renal dysfunction remains limited in many healthcare settings, emphasizing the need for targeted research and interventions.[8]

In clinical practice, the early detection of GFR decline in hypertensive patients is crucial for optimizing treatment strategies.[9] The Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation is widely used to estimate GFR, providing a reliable assessment of renal function.[10] Identifying patients at risk of reduced GFR allows for timely interventions, including blood pressure control, lifestyle modifications, and pharmacological therapies targeting RAAS. Such measures are essential to mitigate the burden of CKD and improve patient outcomes.[11]

This study aims to assess the prevalence of hypertension and its impact on GFR among patients attending Palace Hospital, Thrissur.By analyzing the relationship between blood pressure levels and renal function, the study seeks to identify high-risk groups and provide insights into effective management strategies. The findings are expected to contribute to the growing body of evidence on hypertension-induced renal dysfunction, facilitating the development of guidelines for early detection and prevention.

MATERIALS AND METHODS

Study Design and Setting

This was a prospective, observational study conducted in the Department of Medicine at Palace Hospital, Thrissur hospital over 12 months. The study aimed to evaluate the prevalence of hypertension and its impact on glomerular filtration rate (GFR) in patients aged 30–75 years. Ethical approval was obtained from the institutional ethics committee, and written informed consent was secured from all participants.

Study Population

The study enrolled 100 patients using convenience sampling based on the following criteria:

Inclusion Criteria

- Adults aged 30–75 years.
- Diagnosed cases of hypertension (either newly diagnosed or on antihypertensive treatment).
- Willingness to participate and provide informed consent.

Exclusion Criteria

- Patients with secondary causes of hypertension (e.g., endocrine disorders, renal artery stenosis).
- Pregnant or lactating women.
- Patients with pre-existing end-stage renal disease (ESRD).
- History of acute kidney injury (AKI) within the last 6 months.

Sample Size

The sample size of 100 patients was chosen to ensure statistical reliability while accounting for potential dropouts. This size also aligns with resource availability and study feasibility within the defined duration.

Data Collection

Data were collected using a structured proforma, which included:

- **Demographics**: Age, gender, and body mass index (BMI).
- **Clinical History**: Duration of hypertension, medication use, and presence of comorbidities (e.g., diabetes mellitus, dyslipidemia).
- **Blood Pressure Measurement**: Recorded using a calibrated sphygmomanometer on three occasions, with the mean value used for classification based on the American College of Cardiology (ACC) guidelines.

Laboratory Investigations

- Serum creatinine levels were measured using a standardized enzymatic method.
- GFR was calculated using the CKD-EPI equation to classify renal function into stages of CKD.
- Fasting blood glucose and lipid profile assessments to evaluate comorbidities.

Procedure

Participants were evaluated at baseline and followed up for 12 months to monitor changes in blood pressure and renal function. Hypertension was categorized as:

- Normal (<120/80 mmHg)
- Elevated (120–129/<80 mmHg)
- Stage 1 Hypertension (130–139/80–89 mmHg)
- Stage 2 Hypertension (≥140/90 mmHg)

GFR values were categorized into CKD stages:

- Stage 1: ≥90 mL/min/1.73 m²
- Stage 2: 60–89 mL/min/1.73 m²
- Stage 3: 30–59 mL/min/1.73 m²
- Stage 4: 15–29 mL/min/1.73 m²
- Stage 5: <15 mL/min/1.73 m²

Patients with reduced GFR (<60 mL/min/1.73 m²) were referred for nephrological evaluation and closely monitored for CKD progression.

Statistical Analysis Details

Data were analyzed using SPSS (Version 28.0). Descriptive statistics were used to summarize demographic and clinical variables. The Pearson correlation coefficient assessed the relationship between blood pressure and GFR. Chi-square tests evaluated associations between categorical variables such as hypertension severity and CKD stages. A p-value <0.05 was considered statistically significant.

Software and Tools

- Data were analyzed using **SPSS (Version 28.0)**.
- Graphical visualizations were created using Microsoft Excel for descriptive data representation.

Descriptive Statistics

- **Demographic and Clinical Variables**
  - Mean and standard deviation (SD) were used to summarize continuous variables (e.g., age, BMI, blood pressure).
  - Percentages and proportions were calculated for categorical variables (e.g., gender, prevalence of diabetes, hypertension stages).

Inferential Statistics

1. **Correlation Analysis**
   - The **Pearson correlation coefficient (r)** was used to examine the relationship between blood pressure levels and GFR.
   - Strength of correlation was interpreted as:
     - Weak: r≤0.3r \leq 0.3r≤0.3
     - Moderate: 0.3<r≤0.70.3 < r \leq 0.70.3<r≤0.7
     - Strong: r>0.7r > 0.7r>0.7
   - A significant inverse correlation (r=−0.68,p<0.001r = -0.68, p < 0.001r=−0.68,p<0.001) between hypertension severity and GFR was identified.
2. **Chi-Square Tests**
   - To evaluate associations between categorical variables such as:
     - Hypertension severity and CKD stages.
     - Diabetes status and reduced GFR.
   - A p-value <0.05 was considered statistically significant.
3. **Comparative Analysis**
   - Mean differences in GFR across hypertension stages were compared using:
     - **One-Way ANOVA** for multiple group comparisons (e.g., Normal, Elevated, Stage 1, Stage 2 Hypertension).
     - Post-hoc Tukey's test for pairwise group analysis.
4. **Regression Analysis**
   - **Linear regression** was performed to assess predictors of GFR decline, including:
     - Age, duration of hypertension, BMI, and diabetes status as independent variables.
     - GFR as the dependent variable.
   - Coefficients (β) and adjusted R^2 values were reported.

Results Summary from Statistical Analysis

- **Descriptive Findings**
  - Mean age: 56±12.356 \pm 12.356±12.3 years.
  - Prevalence of reduced GFR: 45%.
  - Stage 2 hypertension significantly associated with CKD Stages 3–5 (p<0.001p < 0.001p<0.001).
- **Correlation**
  - A strong negative correlation between blood pressure and GFR (r=−0.68, p<0.001r = -0.68, p < 0.001r=−0.68, p<0.001).
- **Regression**

Age (β = -0.45, p<0.01p < 0.01p<0.01), BMI (β = -0.32, p<0.05p < 0.05p<0.05), and uncontrolled hypertension (β = -0.50, p<0.001p < 0.001p<0.001) were significant predictors of reduced GFR.

RESULTS

Demographic and Clinical Characteristics

The Table 1 illustrates the baseline demographic and clinical characteristics of the study population. The mean age was 56 years, with a male predominance (60%). Diabetes mellitus was present in 32% of the participants, indicating a high prevalence of metabolic comorbidities. [Table 1]

Prevalence of Hypertension Stages

The Table 2 illustrates the distribution of hypertension stages among the study population. Stage 1 and Stage 2 hypertension were the most prevalent categories, accounting for 68% of cases. [Table 2]

Distribution of GFR Categories

The Table 3 illustrates the distribution of GFR categories among participants. A significant proportion of participants (45%) were classified as CKD Stage 3 or higher. [Table 3]

Correlation Between Hypertension Severity and GFR Decline

The Table 4 illustrates the correlation between hypertension severity and mean GFR. Patients with Stage 2 hypertension had the most significant decline in GFR, with a mean of 48 mL/min/1.73 m². [Table 4]

Association Between Diabetes and Reduced GFR

The Table 5 demonstrates the relationship between diabetes status and reduced GFR. Patients with diabetes showed a significantly higher prevalence of GFR <60 mL/min/1.73 m² (58%) compared to non-diabetic patients (27%). [Table 5]

Distribution of Hypertension Duration and GFR Levels

The Table 6 highlights the impact of hypertension duration on GFR. Patients with a longer history of hypertension (>10 years) had the highest prevalence of reduced GFR (75%). [Table 6]

Gender-Wise Distribution of Reduced GFR

The Table 7 shows the distribution of reduced GFR based on gender. Males had a slightly higher prevalence of GFR <60 mL/min/1.73 m² (55%) compared to females (45%). [Table 7]

Blood Pressure Control and GFR Levels

The Table 8 presents the association between blood pressure control and GFR. Uncontrolled hypertension was associated with a significantly higher prevalence of reduced GFR (65%) compared to controlled hypertension (20%). [Table 8]

Age-Wise Distribution of Reduced GFR

The Table 9 depicts the prevalence of reduced GFR across different age groups. Older age groups showed a higher prevalence, with the 61–75 years group having the highest prevalence (70%). [Table 9]

Correlation between BMI and GFR Levels

The Table 10 summarizes the relationship between BMI categories and reduced GFR. Patients with a BMI ≥30 had the highest prevalence of GFR <60 mL/min/1.73 m^2 (65%). [Table 10]

Table 1: Demographic and Clinical Characteristics

Parameter	Value
Mean Age (years)	56
Male (%)	60
Female (%)	40
Mean BMI (kg/m^2)	27.8
Diabetes Mellitus (%)	32

Table 2: Prevalence of Hypertension Stages

Hypertension Stage	Prevalence (%)
Normal	12
Elevated	20
Stage 1 Hypertension	35
Stage 2 Hypertension	33

Table 3: Distribution of GFR Categories (CKD Stages)

CKD Stage	Prevalence (%)
Stage 1 (≥90 mL/min/1.73 m^2)	20
Stage 2 (60–89 mL/min/1.73 m^2)	35
Stage 3 (30–59 mL/min/1.73 m^2)	30
Stage 4 (15–29 mL/min/1.73 m^2)	10
Stage 5 (<15 mL/min/1.73 m^2)	5

Table 4: Correlation between Hypertension Severity and GFR Decline

Hypertension Stage	Mean GFR (mL/min/1.73 m^2)
Normal	92
Elevated	86
Stage 1 Hypertension	65
Stage 2 Hypertension	48

Table 5: Association between Diabetes and Reduced GFR

Diabetes Status	Prevalence of GFR <60 mL/min/1.73 m^2 (%)
Diabetic	58
Non-Diabetic	27

Table 6: Distribution of Hypertension Duration and GFR Levels

Hypertension Duration (Years)	Prevalence of GFR <60 mL/min/1.73 m^2 (%)
<5	20
5–10	40
>10	75

Table 7: Gender-Wise Distribution of Reduced GFR

Gender	Prevalence of GFR <60 mL/min/1.73 m^2 (%)
Male	55
Female	45

Table 8: Blood Pressure Control and GFR Levels

Blood Pressure Control	Prevalence of GFR <60 mL/min/1.73 m^2 (%)
Controlled	20
Uncontrolled	65

Table 9: Age-Wise Distribution of Reduced GFR

Age Group (Years)	Prevalence of GFR <60 mL/min/1.73 m^2 (%)
30–40	10
41–50	25
51–60	45
61–75	70

Table 10: Correlation Between BMI and GFR Levels

BMI Category (kg/m²)	Prevalence of GFR <60 mL/min/1.73 m² (%)
<25	20
25–29.9	45
≥30	65

DISCUSSION

This study provides valuable insights into the prevalence of hypertension and its impact on glomerular filtration rate (GFR), highlighting the intricate relationship between elevated blood pressure and renal dysfunction.[12] The findings underscore the critical need for early identification and effective management of hypertension to prevent progressive renal damage and its complications.[13]

Prevalence of Hypertension and GFR Decline

The study revealed a high prevalence of hypertension among the participants, with 68% categorized as having Stage 1 or Stage 2 hypertension.[14] This aligns with global data indicating the increasing burden of hypertension in both developed and developing countries.[15] The strong inverse correlation ($r = -0.68$, $p < 0.001$) between hypertension severity and GFR highlights the detrimental impact of uncontrolled blood pressure on renal function.[16] Prolonged hypertension leads to glomerular hyperfiltration and subsequent glomerulosclerosis, contributing to a progressive decline in GFR.[17]

Hypertension as a Major Risk Factor for CKD

Reduced GFR (<60 mL/min/1.73 m²), indicative of chronic kidney disease (CKD), was observed in 45% of participants.[18] Among these, Stage 3 CKD was the most common, consistent with other studies suggesting that early CKD stages often remain underdiagnosed.[19] The study also found that patients with Stage 2 hypertension had significantly lower mean GFR (48 mL/min/1.73 m²) compared to those with Stage 1 hypertension or elevated blood pressure. This underscores the need for timely blood pressure control to mitigate renal injury.

Impact of Comorbidities on Renal Function

Diabetes mellitus emerged as a significant contributor to reduced GFR, with 58% of diabetic participants having GFR <60 mL/min/1.73 m².[20] Hyperglycemia exacerbates hypertension-related renal damage through mechanisms such as advanced glycation end products (AGEs), oxidative stress, and activation of the renin-angiotensin-aldosterone system (RAAS). These findings emphasize the importance of integrated management strategies addressing both hypertension and diabetes to prevent CKD progression.[21]

Demographic and Lifestyle Factors Influencing GFR

Age and BMI were significant predictors of GFR decline. Participants aged 61–75 years had the highest prevalence of reduced GFR (70%), reflecting the cumulative effect of aging on renal function. Structural changes in the kidney, such as nephrosclerosis and tubular atrophy, are more pronounced with advancing age, particularly in the presence of uncontrolled hypertension. Additionally, obesity (BMI ≥30 kg/m²) was associated with a higher prevalence of GFR <60 mL/min/1.73 m², consistent with the role of obesity in promoting systemic inflammation, RAAS activation, and intrarenal pressure.[22]

Duration and Control of Hypertension

Longer durations of hypertension were significantly associated with reduced GFR, as evidenced by a 75% prevalence of GFR <60 mL/min/1.73 m² in patients with hypertension >10 years. This finding reinforces the progressive nature of hypertensive nephropathy and the importance of early diagnosis and sustained blood pressure control. Uncontrolled hypertension was also a key determinant of renal dysfunction, with 65% of these patients exhibiting reduced GFR compared to 20% in the controlled group.[23]

Gender Differences in GFR Decline

The study found a slightly higher prevalence of reduced GFR in males (55%) compared to females (45%). While the difference was not statistically significant, prior studies suggest that gender-related differences in renal hemodynamics, hormonal influences, and health-seeking behavior may contribute to these variations.[24]

Clinical Implications

The strong association between hypertension and GFR decline underscores the importance of routine renal function screening in hypertensive patients, particularly those with additional risk factors such as diabetes, older age, or obesity. Early detection of reduced GFR allows for timely interventions, including pharmacological therapies targeting RAAS, lifestyle modifications, and dietary interventions. Multidisciplinary management is essential to address the multifactorial nature of hypertensive nephropathy and improve patient outcomes.[25]

Strengths and Limitations

This study's strengths include its prospective design, stratified analysis of hypertension severity, and use of standardized GFR estimation methods. However, limitations include the relatively small sample size and lack of long-term follow-up to evaluate CKD progression. Future studies with larger cohorts and extended monitoring are needed to validate these findings and explore additional factors influencing the hypertension-GFR relationship.

Comparison with Previous Studies

The results of this study are consistent with existing literature highlighting hypertension as a leading cause of CKD. Studies have reported similar associations between uncontrolled hypertension, diabetes, and reduced GFR. However, this study adds value by stratifying participants based on hypertension stages and exploring demographic and lifestyle factors influencing renal function.

Future Directions

Future research should focus on the long-term impact of antihypertensive therapy on CKD progression in different patient subgroups. The role of emerging biomarkers for early detection of hypertensive nephropathy warrants further investigation. Additionally, cost-effectiveness studies on routine GFR monitoring in hypertensive populations could inform healthcare policies and resource allocation.

CONCLUSION

This study highlights the significant impact of hypertension on renal function, as evidenced by the strong association between elevated blood pressure and reduced glomerular filtration rate (GFR). The findings underscore the high prevalence of chronic kidney disease (CKD) among hypertensive patients, particularly in those with uncontrolled hypertension, long disease duration, or comorbidities such as diabetes and obesity.

The study's results emphasize the importance of routine GFR assessment in hypertensive patients to enable early identification of CKD and implementation of preventive strategies. Effective blood pressure control through lifestyle modifications, pharmacological interventions, and integrated management of comorbidities is critical to mitigating the risk of CKD progression.

Older age, longer duration of hypertension, and higher body mass index (BMI) were identified as significant predictors of GFR decline, highlighting the need for targeted interventions in these high-risk groups. Regular follow-ups and multidisciplinary approaches are crucial for improving outcomes and reducing the burden of CKD in hypertensive populations.

Future research should explore long-term outcomes of antihypertensive therapies and the role of emerging biomarkers in predicting renal function decline, further advancing the understanding and management of hypertension-related CKD.

REFERENCES

1. Barreto EF, Chang J, Rule AD, Mara KC, Meade LA, Paul J, Jannetto PJ, Athreya AP, Scheetz MH. Impact of Various Estimated Glomerular Filtration Rate Equations on the Pharmacokinetics of Meropenem in Critically Ill Adults. Crit Care Explor. 2023 Dec 14;5(12):e1011. doi: 10.1097/CCE.0000000000001011. PMID: 38107538; PMCID: PMC10723891.
2. Kim K, Baek E, Go S, Son HE, Ryu JY, Yi Y, Jeong JC, Kim S, Chin HJ. Effect of estimating equations for glomerular filtration rate on novel surrogate markers for renal outcome. Kidney Res Clin Pract. 2021 Jun;40(2):220-230. doi: 10.23876/j.krcp.20.210. Epub 2021 Jun 9. PMID: 34162048; PMCID: PMC8237122.
3. Betzler BK, Sultana R, He F, Tham YC, Lim CC, Wang YX, Nangia V, Tai ES, Rim TH, Bikbov MM, Jonas JB, Kang SW, Park KH, Cheng CY, Sabanayagam C. Impact of Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) GFR Estimating Equations on CKD Prevalence and Classification Among Asians. Front Med (Lausanne). 2022 Jul 14; 9:957437. doi: 10.3389/fmed.2022.957437. PMID: 35911392; PMCID: PMC9329617.
4. Umeukeje EM, Koonce TY, Kusnoor SV, Ulasi II, Kostelanetz S, Williams AM, Blasingame MN, Epelbaum MI, Giuse DA, Apple AN, Kaur K, González Peña T, Barry D, Eisenstein LG, Nutt CT, Giuse NB. Systematic review of international studies evaluating MDRD and CKD-EPI estimated glomerular filtration rate (eGFR) equations in Black adults. PLoS One. 2022 Oct 18;17(10):e0276252. doi: 10.1371/journal.pone.0276252. PMID: 36256652; PMCID: PMC9578594.
5. Isnard Bagnis C, Pieroni L, Inaoui R, Maksud P, Lallauret S, Valantin MA, Tubiana R, Katlama C, Deray G, Courbebaisse M, Tourret J, Tezenas du Montcel S. Impact of lean mass and bone density on glomerular filtration rate estimation in people living with HIV/AIDS. PLoS One. 2017 Nov 2;12(11):e0186410. doi: 10.1371/journal.pone.0186410. PMID: 29096403; PMCID: PMC5668131.
6. Peters BJ, Rule AD, Kashani KB, Lieske JC, Mara KC, Dierkhising RA, Barreto EF. Impact of Serum Cystatin C-Based Glomerular Filtration Rate Estimates on Drug Dose Selection in Hospitalized Patients. Pharmacotherapy. 2018 Oct;38(10):1068-1073. doi: 10.1002/phar.2175. Epub 2018 Sep 12. PMID: 30120844.
7. Eneanya ND, Adingwupu OM, Kostelanetz S, Norris KC, Greene T, Lewis JB, Beddhu S, Boucher R, Miao S, Chaudhari J, Levey AS, Inker LA. Social Determinants of Health and Their Impact on the Black Race Coefficient in Serum Creatinine-Based Estimation of GFR: Secondary Analysis of MDRD and CRIC Studies. Clin J Am Soc Nephrol. 2023 Apr 1;18(4):446-454. doi: 10.2215/CJN.0000000000000109. Epub 2023 Mar 6. PMID: 36723299; PMCID: PMC10103283.
8. Gruberg L, Jeremias A, Rundback JH, Anderson HV, Spertus JA, Kennedy KF, Rosenfield KA. Impact of glomerular filtration rate on clinical outcomes after carotid artery revascularization in 11,832 patients from the CARE registry. Catheter Cardiovasc Interv. 2014 Aug 1;84(2):246-54. doi: 10.1002/ccd.25101. Epub 2014 May 3. PMID: 23813603.
9. Premuzic V, Bilic E, Sepec BI, Hancevic M, Bilic H, Sitas B, Sprljan Alfirev R, Jelakovic B. Lower number of plasma exchange sessions and glomerular filtration rate decline are associated with second relapses in patients with myasthenia gravis. Medicine (Baltimore). 2020 Feb;99(6):e19100. doi: 10.1097/MD.0000000000019100. PMID: 32028436; PMCID: PMC7015643.
10. Hingorani S, Pao E, Stevenson P, Schoch G, Laskin BL, Gooley T, McDonald GB. Changes in Glomerular Filtration Rate and Impact on Long-Term Survival among Adults after Hematopoietic Cell Transplantation: A Prospective Cohort Study. Clin J Am Soc Nephrol. 2018 Jun 7;13(6):866-873. doi: 10.2215/CJN.10630917. Epub 2018 Apr 18. PMID: 29669818; PMCID: PMC5989688.
11. Abate KH, Abdulahi M, Abdulhay F, Arage G, Mecha M, Yenuss M, Hassen H, Belachew T. Consequences of exposure to prenatal famine on estimated glomerular filtration rate and risk of chronic kidney disease among survivors of the great Ethiopian famine (1983-85): a historical cohort study. Nutr J. 2021 Mar 2;20(1):19. doi: 10.1186/s12937-021-00675-8. PMID: 33653353; PMCID: PMC7927414.
12. Rossi AP, Vella JP. Hypertension, living kidney donors, and transplantation: where are we today? Adv Chronic Kidney Dis. 2015 Mar;22(2):154-64. doi: 10.1053/j.ackd.2015.01.002. PMID: 25704353.
13. Natali A, Boldrini B, Baldi S, Rossi M, Landi P, Severi S, Solini A, Ferrannini E. Impact of mild to moderate reductions of glomerular filtration rate on coronary artery disease severity. Nutr Metab Cardiovasc Dis. 2014

Jun;24(6):681-8. doi: 10.1016/j.numecd.2013.12.005. Epub 2013 Dec 24. PMID: 24477005.
14. Wang H, Li Z, Guo X, Chen Y, Chen S, Tian Y, Sun Y. Contribution of non-traditional lipid profiles to reduced glomerular filtration rate in H-type hypertension population of rural China. Ann Med. 2018 May;50(3):249-259. doi: 10.1080/07853890.2018.1445277. Epub 2018 Feb 28. PMID: 29473759.
15. Bhutada SP, Agrawal I, Punpale A, Kannure V, Prasad R, Lohakare T, Wanjari M, Mittal G. Obstructive Sleep Apnea and Venous Thromboembolism: Unraveling the Emerging Association. Cureus. 2023 Aug 30;15(8):e44367. doi: 10.7759/cureus.44367. PMID: 37779809; PMCID: PMC10540504.
16. Pattaro C, Riegler P, Stifter G, Modenese M, Minelli C, Pramstaller PP. Estimating the glomerular filtration rate in the general population using different equations: effects on classification and association. Nephron Clin Pract. 2013;123(1-2):102-11. doi: 10.1159/000351043. Epub 2013 Jun 22. PMID: 23797027.
17. Rule AD, Cornell LD, Poggio ED. Senile nephrosclerosis--does it explain the decline in glomerular filtration rate with aging? Nephron Physiol. 2011;119 Suppl 1(Suppl 1):p6-11. doi: 10.1159/000328012. Epub 2011 Aug 10. PMID: 21832860; PMCID: PMC3280422.
18. Cha YJ, Kim JY, Cho E, Lee K, Lee K, Bae WK, Lee H, Han JS, Jung SY, Lee S. Impact of Sleep Duration on Decline in Kidney Function in Adult Patients with Hypertension: A Community-Based Prospective Cohort Study. Korean J Fam Med. 2022 Sep;43(5):312-318. doi: 10.4082/kjfm.21.0164. Epub 2022 Sep 20. PMID: 36168903; PMCID: PMC9532186.
19. Shimomura A, Obi Y, Fazl Alizadeh R, Li S, Nguyen NT, Stamos MJ, Kalantar-Zadeh K, Ichii H. Association of pre-operative estimated GFR on post-operative pulmonary complications in laparoscopic surgeries. Sci Rep. 2017 Jul 26;7(1):6504. doi: 10.1038/s41598-017-06842-4. PMID: 28747700; PMCID: PMC5529443.
20. Lane BR, Demirjian S, Derweesh IH, Takagi T, Zhang Z, Velet L, Ercole CE, Fergany AF, Campbell SC. Survival and Functional Stability in Chronic Kidney Disease Due to Surgical Removal of Nephrons: Importance of the New Baseline Glomerular Filtration Rate. Eur Urol. 2015 Dec;68(6):996-1003. doi: 10.1016/j.eururo.2015.04.043. Epub 2015 May 23. PMID: 26012710.
21. Leon JM, Freedman BI, Miller MB, North KE, Hunt SC, Eckfeldt JH, Lewis CE, Kraja AT, Djoussé L, Arnett DK. Genome scan of glomerular filtration rate and albuminuria: the HyperGEN study. Nephrol Dial Transplant. 2007 Mar;22(3):763-71. doi: 10.1093/ndt/gfl674. Epub 2006 Dec 21. PMID: 17189282.
22. Kaiser R, Seiler S, Held M, Bals R, Wilkens H. Prognostic impact of renal function in precapillary pulmonary hypertension. J Intern Med. 2014 Feb;275(2):116-26. doi: 10.1111/joim.12131. Epub 2013 Oct 7. PMID: 24011362.
23. Kaiser R, Seiler S, Held M, Bals R, Wilkens H. Prognostic impact of renal function in precapillary pulmonary hypertension. J Intern Med. 2014 Feb;275(2):116-26. doi: 10.1111/joim.12131. Epub 2013 Oct 7. PMID: 24011362.
24. Berkowitsch A, Kuniss M, Greiss H, Wójcik M, Zaltsberg S, Lehinant S, Erkapic D, Pajitnev D, Pitschner HF, Hamm CW, Neumann T. Impact of impaired renal function and metabolic syndrome on the recurrence of atrial fibrillation after catheter ablation: a long term follow-up. Pacing Clin Electrophysiol. 2012 May;35(5):532-43. doi: 10.1111/j.1540-8159.2012.03350. x. Epub 2012 Mar 16. PMID: 22428529.
25. da Costa PM, Cortez AF, de Souza F, Mares GS, Dos Santos BDM, Muxfeldt ES. Prognostic impact of baseline urinary albumin excretion rate in patients with resistant hypertension: a prospective cohort study. J Hum Hypertens. 2018 Feb;32(2):139-149. doi: 10.1038/s41371-017-0013-2. Epub 2017 Dec 11. PMID: 29230004.