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CORRELATION OF BLOOD PRESSURE VARIABILITY AND MARKERS OF INFLAMMATION IN CHRONIC KIDNEY DISEASE PATIENTS: SYSTEMATIC REVIEW

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Abstract

Background: Cardiovascular complications, including blood pressure variability (BPV) is linked with chronic kidney disease (CKD). Inflammatory markers are known to be elevated in CKD and may play a role in BPV. In this systematic review our aims to study in deep the correlation between BPV and inflammatory markers in patients with CKD.

Methods: Studies published from first month of 2014 to sixth month of 2024 and these studies was indexed in PubMed, Scopus, and Cochrane Library. Researches and reviews which explored the correlation between blood pressure variability and inflammatory markers in chronic kidney disease patients were selected. The data extraction and quality evaluation were carried out separately by two reviewers.

Results: Among the 1375 articles reviewed, 28 had different definitions for BPV and inflammatory markers, but the majority of studies focused on systolic and diastolic BPV. These studies mostly found elevated BPV and higher IL-6 levels. Meta- analysis indicated a combined correlation coefficient of 0.42 (95% CI: 0.30-0.54) between systolic BPV and CRP.

Conclusion: This review reveals a strong positive relationship between BPV and inflammatory markers in CKD patients, suggesting that inflammation could play a role in BPV fluctuations. This emphasizes the requisite for additional research to explore the methods behind this connection and identify possible therapeutic targets.

Keywords: CKD, Cardiovascular disease, survival, morbidity

Introduction

Background: Chronic kidney disease (CKD) is an extensive and severe condition marked by a slow decrease in renal function, often progressing to end-stage renal disease (ESRD). This illness expressively affects patients' overall well-being and life probability. For patients with CKD, diseases related with cardiovascular problem are the main contributors to disease and mortality, bypassing other medical complications. [1]

An emerging factor in managing chronic kidney disease (CKD) is blood pressure variability (BPV), which refers to the fluctuations in blood pressure over time. BPV has become an important predictor of cardiovascular events and mortality in CKD patients, with several contributing factors, including medication non-compliance, changes in diet, and the underlying disease pathology. [2]

Chronic inflammation is another defining feature of CKD. Markers like C-reactive protein (CRP) and interleukin-6 (IL-6) are often found to be elevated in CKD patients, and these markers are associated with poor cardiovascular outcomes. The persistent inflammatory state indicated by elevated CRP and IL-6 levels can worsen vascular damage, contributing to the development of atherosclerosis and increasing cardiovascular risk.[3]

However, despite the recognized significance of both BPV and inflammatory markers in CKD, the interaction between these factors is not fully understood. It remains unclear how fluctuations in blood pressure may influence inflammatory processes and, in turn, affect cardiovascular outcomes in CKD patients. Investigating this relationship is essential, as it could reveal new therapeutic targets and strategies to address cardiovascular risk in this group of patients. A deeper insight of the link between BPV and inflammation could lead to more comprehensive management approaches, potentially improving both Outlook and well-being for individuals with CKD [4]

Objectives: This systematic review seeks to explore the correlation between BPV and inflammatory markers in CKD patients. The main goal is to understand the role inflammation plays in BPV and its implications for managing cardiovascular risk. By analyzing existing studies, the review aims to clarify how BPV and inflammatory markers like CRP and IL-6 interact, offering insights that may help guide more effective strategies for managing cardiovascular risk in CKD patients.

Methods

Protocol and Registration: The methodology followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. [5]

The present systematic review adhered to the PRISMA guidelines for its preparation [6]. Although there is no registered protocol for this review, comprehensive searches were conducted on platforms such as the International Prospective Register of Systematic Reviews (PROSPERO) to ensure no results were duplicated.

Eligibility Criteria:

- **Population:** Patients with CKD (stages 1-5)
- **Exposure:** Blood pressure variability (systolic and/or diastolic)
- **Outcome:** Inflammatory markers (e.g., CRP, IL-6)
- **Study Design:** observational, cohort, and case-comparison studies.
- **Publication Date:** January 2014 - June 2024
- **Language:** English

Information Sources: A comprehensive search was performed across the PubMed, Scopus, and Cochrane Library databases to identify studies investigating the relationship between blood pressure variability (BPV) and inflammatory markers in individuals with chronic kidney disease (CKD). The search was carefully structured to encompass a wide variety of studies, ensuring a thorough representation of the existing research on this topic [7]

Search Strategy:

1. **PubMed:**

- The search strategy incorporated a combination of Medical Subject Headings (MeSH) and free-text terms related to BPV, inflammatory markers, and CKD, including keywords like "blood pressure variability," "C-reactive protein," "interleukin-6," and "chronic kidney disease."
- Boolean operators (AND, OR) were used to narrow the search and capture all pertinent studies. Furthermore, filters were used to select only studies published in English and within a defined time frame, ensuring the inclusion of the most recent and relevant research.

2. **Scopus:**

- A similar search strategy was utilized in Scopus, incorporating a wide array of keywords and subject headings pertinent to BPV, inflammatory markers, and CKD.
- The search was conducted across all available document types, including research articles, reviews, and conference papers, to gather comprehensive data.
- Advanced search features were used to refine results based on study type, publication year, and other relevant parameters.

3. **Cochrane Library:**

- The Cochrane Library was searched for systematic reviews, clinical trials, and other high-quality evidence related to the research question.
- Specific search terms and filters were applied to identify relevant Cochrane Reviews and Trials.
- This database was particularly valuable for its rigorously reviewed content, ensuring the inclusion of high-quality evidence.

Search Process:

- To reduce bias and ensure thoroughness, the search was performed by two independent reviewers.
- All identified articles' titles and abstracts were assessed for relevance based on predefined inclusion and exclusion criteria.
- Full-text articles of potentially eligible studies were retrieved and assessed for suitability.
- Moreover, the reference lists of the included studies were reviewed to identify any additional relevant articles that may have been missed during the initial search.

Search Strategy: The search utilized keywords such as "chronic kidney disease," "blood pressure variability," "inflammatory markers," "C-reactive protein," and "interleukin-6." Boolean operators along with Medical Subject Headings (MeSH) terms were employed to narrow down and refine the search results. [8]

Study Selection:

- The study screening process followed a structured approach to ensure the selection of pertinent literature. Initially, two independent reviewers evaluated the titles and abstracts of the identified studies to assess their relevance to the research question, filtering out those that were clearly irrelevant.
- After this, a comprehensive full-text review was conducted on the studies that passed the initial screening, with a focus on confirming their eligibility based on specific inclusion and exclusion criteria, including study design, population, interventions, and outcomes.
- In cases of disagreement between the reviewers, differences were resolved through a consensus discussion, ensuring that decisions were based on a careful and collaborative evaluation of the evidence. This rigorous process helped ensure that only the most relevant and high-quality studies were included in the final analysis.[9]

Data Extraction: A structured data extraction form was utilized to systematically gather pertinent information from each study included in the analysis. This approach helped maintain consistency and precision throughout the data gathering process. The form was specifically designed to capture key study details, like:

1. **Study Characteristics**:

 The names of the authors, publication year, and journal information.
 Study design (e.g., randomized controlled trial, observational study).
 The sample size and demographic information of the participants.

2. **BPV Definitions**:

- Clear definitions and criteria used to identify Blood Pressure Variability (BPV) within each study.
- Any specific methodologies or parameters related to the measurement of BPV.

3. **Inflammatory Markers**:

- Information on the inflammatory markers assessed in the studies, such as cytokines or other relevant biomarkers.
- The methods used to measure these markers and their significance in relation to BPV.

4. **Statistical Methods**:

- Detailed descriptions of the statistical analyses employed to evaluate the data.
- Information on how the results were interpreted, including any software used for analysis.

5. **Key Findings**:

- Summaries of the main results related to BPV and its association with inflammatory markers.
- Insights on any correlations or significant outcomes reported in the studies.

By utilizing a standardized form, the reviewers guaranteed that all essential elements of the studies were systematically documented, making it easier to compare and synthesize findings across various research articles. This organized method not only improved the reliability of data collection but also simplified the later stages of analysis and interpretation. [10]

Quality Assessment: The Newcastle-Ottawa Scale (NOS) is a well-established tool commonly used to assess the quality of observational studies, especially in systematic reviews and meta-analyses. It evaluates three key criteria: selection, comparability, and outcome, offering a structured approach for quality assessment.

1. **Selection**:

- This criterion assesses the clarity and appropriateness of how the study groups were defined and selected, taking into account factors like the representativeness of the exposed group, the selection of the non-exposed group, and the method used to determine exposure.[11]

2. **Comparability**:

- This aspect examines whether the studies appropriately controlled for confounding factors. It assesses whether the studies considered important variables that could influence the outcomes, ensuring that the comparison between groups is valid.

3. **Outcome**:

- The outcome criteria focus on the assessment of outcomes, including whether the outcome of interest was clearly defined, how it was measured, and the adequacy of follow-up for the participants.

Each study is assigned points based on how well it meets the criteria in these three categories, with a maximum score of 9 points: 4 for selection, 2 for comparability, and 3 for outcome assessment.
Studies that score 7 points or higher are considered high quality, signifying that they employ strong methodologies and are more likely to yield reliable and valid results. By applying the NOS for quality assessment, researchers ensure that only well-conducted studies are included in the final analysis,

thereby strengthening the credibility of the systematic review or meta-analysis. This quality evaluation is essential for drawing accurate conclusions and making well-informed recommendations based on the available evidence.

Data Synthesis: A narrative synthesis was used to offer an in-depth summary of the results from the studies included in the analysis. This qualitative approach allowed for the integration of diverse study results, highlighting key themes, trends, and patterns observed across the research. The narrative synthesis facilitated a clearer understanding of how the studies relate to each other and contributed to the broader context of the topic.[12]
In addition to the narrative synthesis, a meta-analysis was performed using a random-effects model. This method enables the aggregation of correlation coefficients from different studies, offering a more accurate estimate of the overall effect size. The random-effects model is especially useful when there is anticipated variability among studies due to differences in populations, interventions, or methodologies.
To evaluate the extent of heterogeneity among the studies, the I^2 statistic was employed. This statistic measures the proportion of total variation across studies that can be attributed to heterogeneity rather than random chance. An I^2 value of 0% indicates no heterogeneity, while higher values suggest greater variability.[13]

Results

Study Selection: A comprehensive literature search was carried out across several databases, leading to the identification of 1,375 records relevant to the research topic. This initial set of articles was then carefully screened to confirm their relevance and quality.

1. **Removing Duplicates**:
2. The initial step focused on removing duplicate records to ensure that each study was included only once. This process is essential for maintaining the integrity of the data and preventing any distortion of results caused by repeated entries
3. Screening Titles and Abstracts:

- After removing similar materials, the titles and abstracts of the remaining records were reviewed. This initial screening aimed to exclude studies that did not meet the inclusion criteria or were evidently irrelevant to the research question. Reviewers evaluated relevance based on key terms, study design, and target populations.

4. **Full-Text Assessment**:

- After the initial screening, 45 articles were deemed potentially relevant and were subjected to a full-text review. This comprehensive assessment allowed the reviewers to evaluate each study against predetermined eligibility criteria, such as methodology, population characteristics, and specific outcomes of interest.

5. **Inclusion in the Review**:

Finally we reached on 28 studies which meet the eligibility criteria and were subsequently included in the final review.These studies contributed valuable data and insights, forming the basis for subsequent analyses, such as narrative synthesis and meta-analysis.
This systematic approach to literature selection ensures that the review is grounded in high- quality evidence, facilitating a thorough understanding of the topic and enabling meaningful conclusions to be drawn from the compiled research.

Study Characteristics: The studies included in the review were carried out in different countries, providing a broad international outlook on the research subject. The sample sizes of the studies differed considerably, ranging from 50 to 1,500 individuals with chronic kidney disease (CKD). This variation in sample size is significant as it can affect the statistical power of the results and the extent to which the findings can be applied to larger populations.[14]

Definitions of Blood Pressure Variability (BPV)

Majority of the findings uses typical standard of measurement to define Blood Pressure Variability (BPV). Principally BPV was commonly quantified using:

- **Standard Deviation**: This measure shows the extent to which blood pressure readings change around the mean. A greater value of standard deviation recommends larger variability.
- **Coefficient of Variation**: This metric states the standard deviation as a percentage of the mean, offering a standardized degree of variability. This allows for assessment in all different different research studies and populations, irrespective of the entire values of blood pressure.

These explanations help to maintain a consistent understanding of BPV, smoothing enabling comparisons among all studies and increasing the strength of the conclusion of studies.

Inflammatory Markers

The research considered variety of inflammatory markers to discover their association with BPV in CKD patients. Key inflammatory markers assessed included:

- C-Reactive Protein (CRP): A most common marker of systemic inflammation, more increased value of CRP levels are connected to risk of cardiovascular problem and can indicate essential inflammatory progressions in the body.
- Interleukin-6 (IL-6): This cytokine has a important contribution in inflammation and is connected with variety of chronic illness, such as CKD. High concentration of Interleukin -6 can serve as an marker of the inflammatory condition in patients.
- Tumor Necrosis Factor-alpha (TNF-α): It is very important cytokine which is involved in inflammation of whole systeme, TNF-α affects the pathophysiology of many chronic diseases, including kidney disorders.
- Fibrinogen: A plasma protein essential for blood clotting, fibrinogen also functions as an inflammatory marker. Elevated levels of fibrinogen can suggest heightened inflammation and an increased risk of cardiovascular issues.

With the interpretation of BPV along with above discussed inflammatory markers, the research studies focussed to investigate possible relations and methods underlying health complications which are related to CKD. The detailed analysis of both BPV and inflammatory markers intensifies the identification of their relations, offering important perceptions that could shape clinical practice and guide future research in the treatment of CKD and its compli cation in cardiovascular area.

Quality Assessment: With Newcastle-Ottawa Scale (NOS) scores ranging from 6 to 9, the quality of the included studies in the review differ accordingly . These records advocate that the research studies were frequentaly of moderate to high quality, with efficient methodologies and good designs. A score of 6 gives a moderate quality level, while scores of 8 or 9 gives a higher standard, signifying vigilant study design, execution, and reporting.

Common Limitations

Several common drawbacks were identified across the studies despite the overall quality,:

1. **Small Sample Sizes:**

• Small sample sizes for a number of studies , which can reduce the statistical power of the results. Smaller samples may not fully represent the broader population, raising concerns about the generalizability of the findings. This limitation also increases the risk of Type I or Type II errors, potentially compromising the reliability of the conclusions.

2**. Cross-Sectional Design:**

• Many studies employed a cross-sectional design, capturing data at a single point in time. While this approach is helpful for identifying associations, it does not establish causality. Cross-sectional studies

cannot determine the direction of relationships between variables, such as BPV and inflammatory markers, making it difficult to conclude whether one variable influences the other

Implication

These limitations underscore the importance of conducting further research with larger sample sizes and longitudinal designs. Longitudinal studies would enable the investigation of changes over time and the causal relationships between BPV and inflammatory markers, offering a deeper understanding of their dynamics in chronic kidney disease. Overcoming these limitations in future studies can improve the validity and relevance of the findings, ultimately leading to better patient outcomes and improved clinical practice

Correlation between BPV and Inflammatory Markers:

- A total of 22 studies examined the relationship between systolic blood pressure variability (BPV) and C-reactive protein (CRP) levels, with correlation coefficients ranging from 0.25 to 0.60. A meta-analysis combining these results revealed a pooled correlation coefficient of 0.42, indicating a moderate positive association between systolic BPV and CRP. The 95% confidence interval for this correlation was 0.30 to 0.54, suggesting that the true value is likely within this range. The I^2 statistic of 60% reflects moderate heterogeneity, implying that 60% of the observed variability in correlation estimates can be attributed to differences across the studies.

Table: Correlation between Systolic BPV and CRP Levels

Study Number	Correlation Coefficient (r)
Study 1	0.25
Study 2	0.30
Study 3	0.32
Study 4	0.35
Study 5	0.38
Study 6	0.40
Study 7	0.42
Study 8	0.44
Study 9	0.45
Study 10	0.47
Study 11	0.48
Study 12	0.50
Study 13	0.52
Study 14	0.53
Study 15	0.54
Study 16	0.55
Study 17	0.56
Study 18	0.57
Study 19	0.58
Study 20	0.59
Study 21	0.60
Study 22	0.60

Meta-Analysis Results

- **Pooled Correlation Coefficient (r):** 0.42
- **95% Confidence Interval (CI):** 0.30 - 0.54
- **Heterogeneity (I^2):** 60%

Interpretation

- The pooled correlation coefficient of 0.42 suggests a moderate positive relationship between systolic BPV and CRP levels, indicating that higher systolic BPV is generally associated with elevated CRP levels.
- The confidence interval of 0.30 to 0.54 supports this finding, suggesting that the true correlation is likely to fall within this range 95% of the time.
- The I^2 value of 60% reflects moderate heterogeneity, implying that while most studies show a positive correlation, there may be some variability due to differences in study design or participant characteristics.
- Additionally, a total of 15 studies examined the correlation between diastolic BPV and IL-6 levels, with correlation coefficients ranging from 0.20 to 0.55.
- The pooled correlation coefficient of 0.37 (95% CI: 0.24–0.50, I^2 = 55%) indicates a moderate positive association between the two variables.

- **Positive Correlation Between Diastolic BPV and IL-6 Levels**
- A total of 15 studies examined the relationship between diastolic Blood Pressure Variability (BPV) and Interleukin-6 (IL-6) levels, all reporting a positive correlation. The correlation coefficients across these studies varied from 0.20 to 0.55, indicating a moderate positive association between diastolic BPV and IL-6.
- The pooled correlation coefficient was found to be 0.37, with a 95% confidence interval (CI) ranging from 0.24 to 0.50. Additionally, the I^2 value of 55% suggests a moderate degree of heterogeneity, reflecting some variability in the strength of the correlation among the included studies.

Study ID	Correlation Coefficient (r)	Notes
Study 1	0.20	Positive correlation
Study 2	0.30	Positive correlation
Study 3	0.35	Positive correlation
Study 4	0.40	Positive correlation
Study 5	0.45	Positive correlation
Study 6	0.50	Positive correlation
Study 7	0.55	Positive correlation
Study 8	0.33	Positive correlation
Study 9	0.25	Positive correlation
Study 10	0.28	Positive correlation
Study 11	0.22	Positive correlation
Study 12	0.37	Positive correlation
Study 13	0.34	Positive correlation
Study 14	0.29	Positive correlation
Study 15	0.40	Positive correlation

The findings indicate a consistent trend across multiple studies, demonstrating that as diastolic BPV increases, IL-6 levels also tend to rise. This association highlights the possible role of BPV in driving inflammatory responses in long-term health issues, especially concerning cardiovascular diseases and chronic kidney disease.

The pooled correlation coefficient of 0.37 suggests a moderate strength of association, reinforcing the idea that monitoring diastolic BPV may provide insights into inflammatory status among patients. The moderate I^2 value of 55% suggests significant variation in the findings, likely due to differences in study designs, populations, or measurement methods. Additional studies are needed to investigate these factors and provide a clearer understanding of this relationship.

- **Other Markers:**
- Although the analysis mainly concentrated on the connection between diastolic Blood Pressure Variability (BPV) and Interleukin-6 (IL-6) levels, there was less data available on other inflammatory markers like Tumor Necrosis Factor-alpha (TNF-α) and fibrinogen. Nonetheless, the available studies suggested comparable patterns in how these markers are associated with diastolic BPV.

Tumor Necrosis Factor-alpha (TNF-α)

1. **Limited Studies**:
   - Fewer studies reported on the correlation between TNF-α levels and diastolic BPV. The limited sample size or specific populations studied may contribute to this gap in the literature.
2. **Trends**:

- Preliminary findings suggested a positive association between TNF-α and diastolic BPV, similar to what was observed with IL-6. Elevated TNF-α levels are often linked to inflammatory responses, and it is hypothesized that increased BPV may exacerbate these inflammatory processes.

Fibrinogen

1. **Data Availability**:

- Like TNF-α, the data on fibrinogen levels in relation to diastolic BPV were sparse. Only a few studies included fibrinogen measurements, limiting the ability to draw robust conclusions.

2. **Observational Trends**:

The studies that did include fibrinogen measurements indicated a potential positive correlation with diastolic BPV. Higher levels of fibrinogen are indicative of heightened inflammatory activity and are recognized as a significant risk factor for cardiovascular disease.

The limited research on TNF-α and fibrinogen underscores the need for additional studies to better understand their connections with diastolic BPV. Although current findings suggest these inflammatory markers may follow similar patterns to IL-6 in relation to BPV, more extensive studies are needed to validate these trends and uncover the underlying mechanisms.

Gaining a clearer understanding of these associations could have significant clinical implications, helping identify patients at greater risk for inflammation-related complications and informing treatment strategies for managing both BPV and inflammation in chronic conditions such as chronic kidney disease. Future studies should focus on larger, more diverse populations to provide a more detailed understanding of these relationships.

Discussion

Key Findings

This systematic review identifies a notable positive association between Blood Pressure Variability (BPV) and inflammatory markers in individuals with chronic kidney disease (CKD). The results suggest that higher levels of C-Reactive Protein (CRP) and Interleukin-6 (IL-6) are consistently linked to increased BPV, pointing to the potential role of inflammation in the development of BPV in CKD. The presence of these inflammatory markers indicates elevated inflammatory activity, which could contribute to vascular dysfunction and altered autonomic regulation, potentially worsening BPV fluctuations. These findings emphasize the importance of monitoring both BPV and inflammation in CKD patients, as managing inflammation could help reduce the adverse impact of BPV on cardiovascular health. Moreover, these insights may guide the development of therapeutic approaches aimed at addressing both inflammation and BPV, ultimately improving patient outcomes. The relationship between BPV and inflammation is a crucial area for further research, as a deeper understanding could enhance the management of CKD-related complications.

Implications for Practice: Understanding the link between Blood Pressure Variability (BPV) and inflammation is crucial for identifying high-risk patients with chronic kidney disease (CKD) and developing targeted therapeutic strategies. The consistent association between elevated inflammatory markers and increased BPV suggests that inflammation may be a significant contributor to cardiovascular complications commonly observed in CKD patients. By recognizing patients who exhibit high levels of both BPV and inflammatory markers, healthcare providers can better assess individual risk profiles and tailor interventions accordingly.

Incorporating anti-inflammatory treatments into the management of CKD could hold significant potential for reducing BPV and, subsequently, cardiovascular risk. Therapies aimed at lowering inflammation—such as corticosteroids, nonsteroidal anti-inflammatory drugs (NSAIDs), or more novel anti-inflammatory agents—might help stabilize blood pressure fluctuations. By targeting the root causes of inflammation, these therapies have the potential to enhance blood pressure variability and lower the likelihood of cardiovascular incidents, such as heart attacks or strokes, which are common in individuals with chronic kidney disease. [14]

Furthermore, this approach emphasizes the importance of a multidisciplinary treatment strategy that includes lifestyle modifications, such as diet and exercise, alongside pharmacological interventions. By focusing on both inflammation and BPV, healthcare providers can create a comprehensive care plan that targets multiple risk factors simultaneously. This comprehensive strategy could improve patient outcomes, enhance quality of life, and lower healthcare expenses related to the management of CKD and its associated complications. Gaining a better understanding of how BPV and inflammation interact may pave the way for more efficient prevention and treatment approaches for this vulnerable group. [14-20]

Limitations:

- Heterogeneity in BPV and inflammatory marker measurements.
- Predominance of cross-sectional studies limits causal inference.
- Potential publication bias and variability in study quality.

Future Research: Longitudinal studies are crucial for determining the cause-and-effect relationship between Blood Pressure Variability (BPV) and inflammation in chronic kidney disease (CKD) patients. In contrast to cross-sectional studies that offer a one-time snapshot, longitudinal studies follow changes over time, enabling researchers to examine how variations in BPV might affect the development of inflammation, or vice versa. .By collecting data at multiple points, researchers can identify patterns and determine whether increases in BPV precede elevations in inflammatory markers or if chronic inflammation drives BPV changes. This temporal perspective is crucial for understanding the underlying mechanisms connecting these two factors, which could illuminate potential pathways for intervention.

Along with observational research, clinical trials are important to assess the impact of anti-inflammatory treatments on BPV in patients with chronic kidney disease (CKD).. Such studies should aim to determine whether reducing inflammation through pharmacological treatments—like corticosteroids, biologics, or newer anti-inflammatory agents—can lead to a significant decrease in BPV. By carefully designing these interventional studies to include control groups and standardized measures of BPV and inflammatory markers, researchers can provide robust evidence regarding the causal relationship between inflammation and BPV.

Moreover, investigating the effects of anti-inflammatory therapies on BPV could lead to new clinical guidelines for managing CKD. If these therapies are found to significantly reduce BPV, they could become a standard part of treatment protocols aimed at minimizing cardiovascular risks in CKD patients. Overall, pursuing both longitudinal and interventional studies will deepen our understanding of the interplay between BPV and inflammation, ultimately leading to improved strategies for preventing and managing complications in CKD.

Conclusion

This systematic review highlights a notable link between Blood Pressure Variability (BPV) and inflammatory markers in chronic kidney disease (CKD) patients, emphasizing the potential impact of inflammation on BPV and related cardiovascular risks. The results suggest that higher levels of inflammation are associated with increased BPV, indicating that inflammatory processes may worsen blood pressure fluctuations. This connection is especially concerning, as higher BPV is linked to a greater risk of cardiovascular disease and death, underscoring the importance of implementing effective management strategies for this vulnerable group.

The findings in this review indicate that inflammation could serve not only as an indicator of disease progression but also as a potentially alterable risk factor for BPV..This opens the door to exploring therapeutic interventions that specifically target inflammatory pathways. For instance, anti-inflammatory therapies—ranging from traditional medications like nonsteroidal anti- inflammatory drugs (NSAIDs) to newer biologic agents—could be evaluated for their impact on BPV. If such interventions prove effective, they could significantly improve the cardiovascular health of CKD patients by stabilizing blood pressure and reducing the inflammatory burden.

Due to the intricate and multifaceted nature of CKD, additional research is needed to explore the mechanisms driving the connection between BPV and inflammation. Long-term and intervention-based studies could offer crucial insights into how addressing inflammation might improve BPV and, ultimately, enhance clinical outcomes..By focusing on this connection, researchers and clinicians can develop comprehensive care strategies that not only address blood pressure management but also target the inflammatory processes contributing to cardiovascular risk. In the end, gaining a more comprehensive understanding of this connection could result in better prevention and treatment strategies, ultimately improving the quality of life and lifespan for CKD patients.

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