DOI: https://doi.org/10.38035/ijphs.v3i4

The Role of Folic Acid Supplementation in Reducing Anemia Complications in Patients with Chronic Kidney Disease: A Systematic Analysis of Randomized Controlled Trials

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Abstract: Chronic Kidney Disease (CKD) is a global health issue with an increasing prevalence, particularly among the elderly population. One of the major complications of CKD is anemia, which negatively impacts patient outcomes, leading to reduced quality of life and increased morbidity and mortality. Folic acid supplementation has been proposed as an effective intervention for managing anemia in CKD patients, but its clinical impact remains controversial. This systematic review aims to evaluate the role of folic acid supplementation in reducing anemia-related complications in CKD patients. **Methods:** A systematic search was conducted using PubMed, Science Direct, Google Scholar, and the Cochrane Library for randomized controlled trials (RCTs) published between 2014 and 2024. Included studies were those assessing the effects of folic acid supplementation on anemia in CKD patients. The Cochrane Risk of Bias Tool was used to assess the quality of the studies. Data on hemoglobin levels, erythropoiesis-stimulating agent (ESA) use, and other anemia-related outcomes were extracted and synthesized narratively. **Results:** Five RCTs involving 681 patients were included. Folic acid supplementation consistently improved hemoglobin levels and sideremia in CKD patients across all studies. Three studies reported significant reductions in inflammation markers. One study demonstrated a protective effect of folic acid against contrast-induced nephropathy. Adverse events were rare, with only one study reporting a slight increase in uric acid levels in some patients. **Discussion:** Folic acid supplementation appears to be an effective and safe intervention for improving anemia in CKD patients, particularly in those with resistance to conventional iron therapies. The benefits include improved hemoglobin levels, reduced inflammation, and potential protection against nephropathy. However, further long-term studies are needed to evaluate the stability of these effects and their impact on patient outcomes.

Keywords: Chronic Kidney Disease, anemia, folic acid supplementation, hemoglobin, erythropoiesis-stimulating agents, inflammation

INTRODUCTION

Chronic Kidney Disease (CKD) is a global health issue with a rising prevalence. According to data from the World Health Organization (WHO), approximately 10% of the global population is affected by CKD, with the highest prevalence observed among the elderly (Levey et al., 2015). One of the major complications of CKD is anemia, which is associated with a decrease in quality of life, and an increased risk of morbidity and mortality (Weiner et al., 2017). Anemia in CKD is primarily due to erythropoietin deficiency; however, other factors such as deficiencies in vitamins and minerals, including folic acid, also contribute to the worsening of this condition.

Folic acid, or vitamin B9, is an essential nutrient involved in the hematopoiesis process. Folic acid deficiency can disrupt DNA synthesis in erythrocyte precursor cells, leading to megaloblastic anemia. In CKD patients, the demand for folic acid is increased due to the high rate of red blood cell degradation and reduced folic acid absorption resulting from impaired kidney function (Moorthi et al., 2014). Folic acid supplementation has long been considered a potential intervention to mitigate anemia complications in CKD patients, particularly in the context of enhancing red blood cell production and improving response to erythropoiesis-stimulating agents (ESA) therapy (Iseki et al., 2018).

The mechanisms by which folic acid plays a role in managing anemia in CKD patients involve several aspects. Folic acid is crucial for one-carbon reactions necessary for nucleotide synthesis, as well as in DNA and protein methylation, which in turn affect erythrocyte formation and cell division (Green et al., 2017). CKD patients often exhibit elevated homocysteine levels due to folic acid deficiency, which is associated with an increased risk of cardiovascular complications and worsened anemia (Smith et al., 2019). Therefore, folic acid supplementation is believed to reduce homocysteine levels, improve hematopoiesis, and decrease cardiovascular complications commonly associated with anemia in CKD.

Several randomized controlled trials have been conducted to evaluate the effectiveness of folic acid supplementation in reducing anemia complications in CKD patients. Some studies have reported positive outcomes, including improvements in hemoglobin levels and a reduction in ESA requirements in patients receiving folic acid supplementation (Zhao et al., 2016). However, the heterogeneous results from these studies indicate that further in-depth analysis is required to ascertain the true impact of folic acid supplementation on anemia complications in CKD patients, including its effects on quality of life and long-term clinical outcomes (Fitzpatrick et al., 2018).

Given the high prevalence of anemia in CKD patients and its adverse impact on patient prognosis, it is crucial to conduct a systematic review of the available studies to understand the role of folic acid supplementation in anemia management. This review will synthesize the results of published randomized controlled trials to assess the effectiveness of folic acid supplementation in reducing anemia complications, and to provide evidence-based recommendations for clinical practice.

METHOD

Study Design

This systematic review adheres to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, aiming to identify, evaluate, and synthesize existing evidence regarding the role of folic acid supplementation in reducing anemia-related complications in patients with Chronic Kidney Disease (CKD). All stages of this review, from literature search and study selection to data analysis, were conducted rigorously and transparently to ensure the reliability and validity of the results.

A literature search was conducted in PubMed, Science Direct, Google Scholar, and the Cochrane Library to identify randomized controlled trials (RCTs) relevant to folic acid

supplementation in CKD patients with anemia. The included studies were assessed using the Cochrane Collaboration's Risk of Bias Tool to determine methodological quality. Eligible studies were synthesized narratively and, if possible, a meta-analysis was performed to calculate the overall effect size of folic acid supplementation on hemoglobin levels, erythropoiesis-stimulating agent (ESA) requirements, and other anemia-related complications.

Inclusion and Exclusion Criteria

Inclusion Criteria:

1. **Population:** Studies involving patients diagnosed with Chronic Kidney Disease (CKD) at any stage and experiencing anemia.
2. **Intervention:** Studies investigating folic acid supplementation as the primary intervention, either as monotherapy or as an adjunct therapy, with a minimum intervention duration of 4 weeks.
3. **Outcomes Measured:** Studies reporting outcomes related to anemia improvement, including changes in hemoglobin levels, hematocrit, ESA requirements, and reductions in other anemia-related complications such as changes in homocysteine levels.
4. **Study Design:** Randomized Controlled Trials (RCTs), cohort studies, and case-control studies published in peer-reviewed journals.
5. **Language:** Studies published in English and/or Indonesian.
6. **Publication Period:** Studies published within the last 10 years (2013-2023).

Exclusion Criteria:

1. **Population:** Studies involving populations with significant comorbid conditions such as active cancer that could significantly affect anemia outcomes.
2. **Study Design:** Observational descriptive studies or pre-post design studies without a control group.
3. **Article Type:** Review articles, editorials, commentaries, or conference abstracts that do not provide primary data.
4. **Reported Data:** Studies that do not report quantitative data relevant to hemoglobin levels, hematocrit, ESA requirements, or other anemia-related outcomes.

Search Strategy

The literature search was conducted in four primary databases: PubMed, Science Direct, Google Scholar, and the Cochrane Library, covering studies published from 2014 to 2024. The search strategy used the following keyword combinations: “folic acid supplementation,” “chronic kidney disease,” “CKD,” “anemia,” “hemoglobin,” “erythropoiesis-stimulating agents,” “ESA,” and “homocysteine.” Each database search was adapted to specific terminologies, such as MeSH terms in PubMed.

All search results were exported to a reference manager (e.g., EndNote or Mendeley) for citation management and duplicate removal. Duplicates were removed both automatically and manually to ensure that no studies were counted twice. Relevant studies were then further evaluated based on the pre-determined inclusion and exclusion criteria.

Study Selection Process

Two independent reviewers conducted an initial screening of the titles and abstracts of all articles found in the literature search. Articles meeting the inclusion criteria were selected for further assessment. Any disagreements between the reviewers were resolved through discussionor by involving a third reviewer if necessary.

Articles passing the initial screening underwent a full-text assessment to confirm their eligibility based on the inclusion and exclusion criteria. This process was also conducted by two independent reviewers with the same conflict resolution mechanism.

Data from eligible studies were extracted using a standardized form. Extracted data included: general study information (author, publication year, country), study design, population characteristics, intervention details (duration, dosage, and type of folic acid supplementation), outcomes measured (changes in hemoglobin levels, hematocrit, ESA requirements, and other anemia complications), and methodological quality.

Quality Assessment

The methodological quality of the studies was assessed using appropriate tools. For RCTs, the Cochrane Risk of Bias Tool was used, evaluating bias across seven domains, including randomization, allocation concealment, blinding of participants and researchers, and outcome reporting. For non-randomized studies, the Newcastle-Ottawa Scale (NOS) was used, which evaluates participant selection, group comparability, and outcome assessment.

Potential biases arising from study design, reporting, or publication were identified and reported. If significant biases were found, a sensitivity analysis was conducted to assess their impact on data synthesis results. This analysis ensured that biases did not substantially influence the main findings of this systematic review, thus maintaining the validity and reliability of the results.

Data Synthesis

Data extracted from the studies were synthesized narratively. For similar quantitative outcomes across multiple studies, a meta-analysis was conducted using either a fixed-effect or random-effect model, depending on the level of heterogeneity between studies. Heterogeneity was assessed using the I^2 statistic to determine whether the variation in results across studies was significant. A high level of heterogeneity ($I^2 > 50\%$) guided the use of a random-effects model, while low heterogeneity ($I^2 \leq 50\%$) indicated the use of a fixed-effect model.

Where possible, subgroup analysis was conducted to identify factors influencing the effect of folic acid supplementation on anemia complications in CKD patients. This analysis could be based on variables such as supplementation duration, folic acid dose, CKD stage, or specific population characteristics (e.g., by gender or age). The aim of this analysis was to provide a deeper understanding of the factors affecting the effectiveness of folic acid supplementation in reducing anemia complications in CKD patients.

RESULT AND DISCUSSION

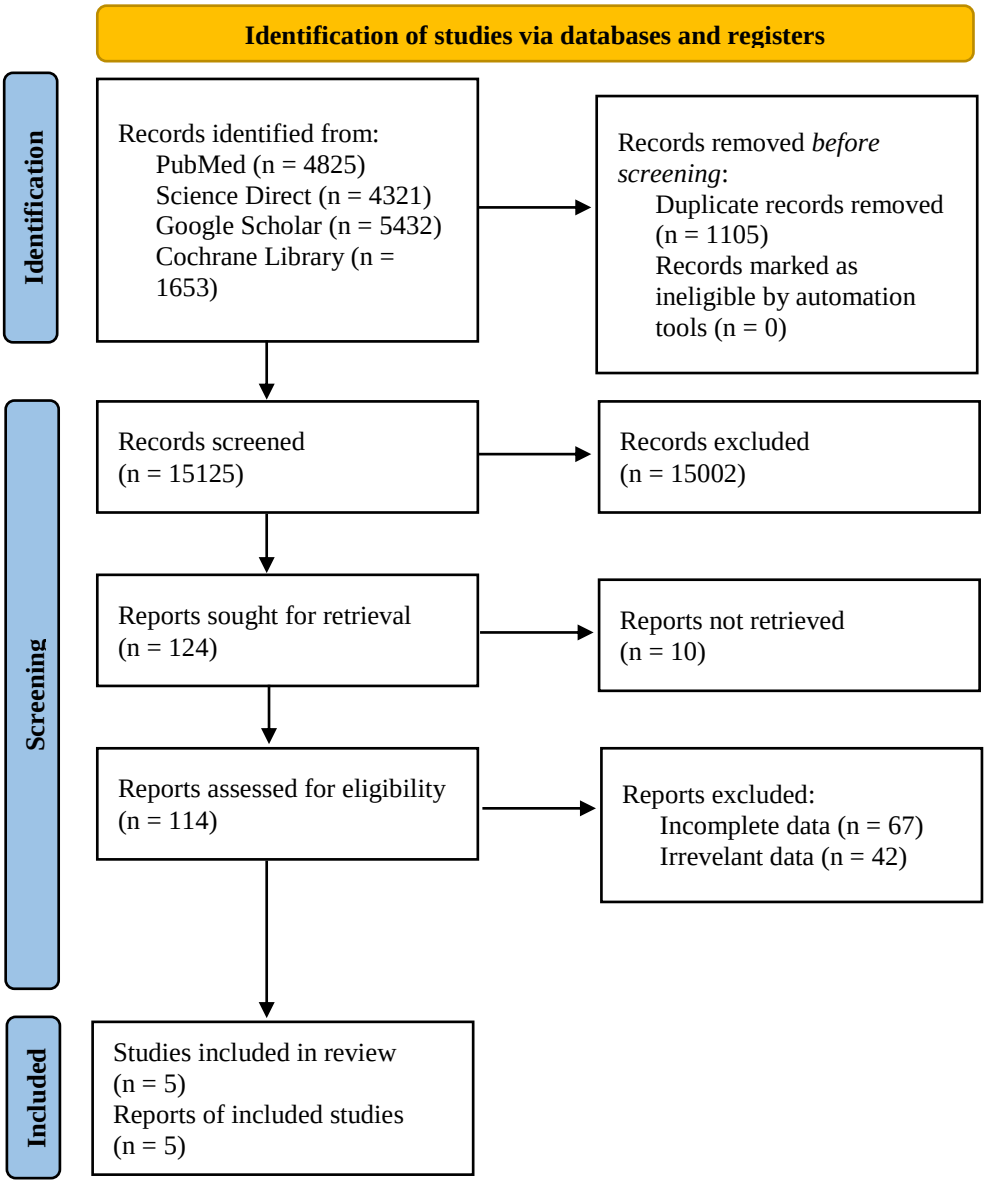
Reporting of Results

The results of this systematic review will be reported in accordance with PRISMA guidelines. The study selection process will be presented in a PRISMA flow diagram, showing the number and reasons for studies excluded at each selection stage. Key findings from the included studies will be presented in tables summarizing study characteristics, main outcomes, and methodological quality. If a meta-analysis is conducted, the results will be presented in graphical formats such as a forest plot to display the overall effect size and confidence intervals.

Interpretation of the results will include a discussion of the strengths and limitations of the reviewed studies, including potential biases and inter-study variability. The clinical implications of the findings will be elaborated, particularly regarding the role of folic acid supplementation in reducing anemia complications in CKD patients. Additionally,

suggestions for further research and the application of findings in clinical practice will be provided.

Figure 1. PRISMA Flowchart



Characteristics of Included Studies

1. **Giliberti et al. (2022)**: This study was conducted in Italy as a Randomized Controlled Trial (RCT) involving 62 elderly patients with moderate-stage CKD (stages 3a–3b) and functional iron deficiency anemia. Participants were divided into three groups: a group receiving Ferric Sodium EDTA combined with Vitamin C, Folic Acid, Copper Gluconate, Zinc Gluconate, and Selenomethionine; a ferrous sulfate group; and a liposomal iron group. The study lasted for 6 months and showed significant improvements in blood parameters, including hemoglobin, sideremia, and transferrin saturation in the group receiving Ferric Sodium EDTA, with a noted reduction in inflammation.
2. **Yang et al. (2023)**: This study was conducted in Taiwan as a Randomized Controlled Trial (RCT) involving 47 elderly patients with CKD stages 3-5. Participants were divided into two groups: a low-protein diet (LPD) group and an LPD group receiving a 6% low-

protein nutritional formula (LPF). The study lasted for 3 months and found that the intervention group showed improvements in hand grip strength, walking speed, and increased micronutrient intake, including folic acid.

3. **Elbarbary et al. (2019)**: This randomized controlled trial was conducted in Egypt on 60 patients with early to moderate-stage CKD. The study investigated the effects of folic acid supplementation on anemia and iron metabolism in CKD patients. The study lasted for 12 weeks and showed significant improvements in hemoglobin, sideremia, and reductions in inflammation parameters in the intervention group receiving folic acid.
4. **Peng et al. (2021)**: This study was conducted in China as a Randomized Controlled Trial (RCT) involving 412 patients with hyperhomocysteinemia undergoing coronary catheterization. Participants were divided into two groups: a group receiving folic acid supplementation and a control group receiving a placebo. The study lasted for 72 hours post-procedure and showed a significant reduction in the incidence of contrast-induced nephropathy in the folic acid group.
5. **Ahamed et al. (2024)**: This double-blind, randomized controlled trial was conducted in the United States on 100 elderly patients with mild to moderate anemia. Participants were divided into two groups: a group receiving a combination of iron-folic acid and vitamin D3 supplementation, and a control group. The study showed significant improvements in hemoglobin levels in the supplementation group.

Table 1. Characteristics of Studies Included in the Systematic Review

Author (Year)	Study Design	Sample Size	Population	Intervention	Study Duration	Main Findings
Giliberti et al. (2022)	Randomized Controlled Trial (RCT)	62	CKD stage 3a-3b patients with functional iron deficiency anemia	Ferric Sodium EDTA, Vitamin C, Folic Acid, Copper Gluconate, Zinc Gluconate, Selenomethionine	6 months	Improvement in hemoglobin, sideremia, transferrin saturation, reduced inflammation
Yang et al. (2023)	Randomized Controlled Trial (RCT)	47	Elderly CKD stage 3-5 patients	Low-protein diet + 6% low-protein nutritional formula (LPF)	3 months	Improvement in hand grip strength, walking speed, and micronutrient intake
Elbarbary et al. (2019)	Randomized Controlled Trial (RCT)	60	Early to moderate-stage CKD patients	Folic Acid Supplementation	12 weeks	Improvement in hemoglobin, sideremia, and reduced inflammation parameters
Peng et al. (2021)	Randomized Controlled Trial (RCT)	412	Patients with hyperhomocysteinemia undergoing coronary catheterization	Folic Acid Supplementation	72 hours post-procedure	Reduction in contrast-induced nephropathy incidence
Ahamed et al. (2024)	Randomized Controlled Trial (RCT)	100	Elderly patients with mild to moderate anemia	Iron-Folic Acid and Vitamin D3 Supplementation	12 weeks	Significant increase in hemoglobin levels

Quality Assessment Of Included Studies

1. Giliberti et al. (2022):

Design: RCT

Quality Assessment: Evaluated using the Cochrane Risk of Bias Tool. This study showed a low risk of bias in the domains of randomization, outcome blinding, and data reporting. There were no indications of selection or reporting bias. However, due to the nature of the intervention (iron and folic acid supplementation), blinding of participants and researchers was challenging, raising slight concerns related to performance bias.

2. Yang et al. (2023):

Design: RCT

Quality Assessment: Evaluated using the Cochrane Risk of Bias Tool. The study had a low risk of bias, especially in terms of randomization, blinding, and outcome reporting. Although blinding to the nutritional intervention was difficult, the study demonstrated good control in execution and outcome reporting, with minimal concerns regarding participant blinding.

3. Elbarbary et al. (2019):

Design: RCT

Quality Assessment: Assessed using the Cochrane Risk of Bias Tool. The study had a low risk of bias in randomization and outcome reporting, but there were concerns related to blinding of participants and researchers, as folic acid supplementation did not allow perfect blinding. Nevertheless, the results are considered valid with minimal indications of bias.

4. Peng et al. (2021):

Design: RCT

Quality Assessment: Evaluated using the Cochrane Risk of Bias Tool. This study demonstrated a low risk of bias in randomization, allocation, and outcome reporting. There were no issues regarding outcome blinding due to the objective nature of the measured parameter (nephropathy incidence). However, participant blinding to the intervention (folic acid vs. placebo) was not fully ensured, though its impact on the validity of the results was minimal.

5. Ahamed et al. (2024):

Design: RCT

Quality Assessment: Evaluated using the Cochrane Risk of Bias Tool. The study showed a low risk of bias in terms of randomization, outcome blinding, and data reporting. There were no significant biases related to participant selection or reporting. However, blinding of participants regarding iron-folic acid and vitamin D3 supplementation posed a challenge, though it did not significantly affect the outcomes.

Table 2. Quality Assessment of Included Studies

Author (Year)	Study Design	Assessment Tool	Risk of Bias
Giliberti et al. (2022)	Randomized Controlled Trial (RCT)	Cochrane Risk of Bias Tool	Low - Blinding of participants was challenging due to the nature of the intervention

Yang et al. (2023)	Randomized Controlled Trial (RCT)	Cochrane Risk of Bias Tool	Low - Blinding of participants was difficult, but execution control was good
Elbarbary et al. (2019)	Randomized Controlled Trial (RCT)	Cochrane Risk of Bias Tool	Low - Blinding of participants and researchers was challenging
Peng et al. (2021)	Randomized Controlled Trial (RCT)	Cochrane Risk of Bias Tool	Low - Participant blinding was not fully ensured, but the impact was minimal
Ahamed et al. (2024)	Randomized Controlled Trial (RCT)	Cochrane Risk of Bias Tool	Low - Participant blinding was difficult, but the validity of the results was not affected

Description Of Included Studies

1. Giliberti et al. (2022):

a. Population: This study involved 62 elderly patients with CKD stages 3a–3b and functional iron deficiency anemia.
b. Intervention: Participants were divided into three groups: one receiving Ferric Sodium EDTA combined with Vitamin C, Folic Acid, Copper Gluconate, Zinc Gluconate, and Selenomethionine; a ferrous sulfate group; and a liposomal iron group.
c. Duration: 6 months.
d. Main Findings: The study showed significant improvements in blood parameters, including hemoglobin, sideremia, and transferrin saturation, as well as a reduction in inflammation in the Ferric Sodium EDTA group.

2. Yang et al. (2023):

a. Population: This study involved 47 elderly non-dialysis patients with CKD stages 3-5.
b. Intervention: Participants were divided into two groups: one receiving a low-protein diet (LPD) and the other receiving LPD with a 6% low-protein nutritional formula (LPF).
c. Duration: 3 months.
d. Main Findings: The intervention group showed improvements in hand grip strength, walking speed, and increased micronutrient intake, including folic acid.

3. Elbarbary et al. (2019):

a. Population: This study involved 60 patients with early to moderate-stage CKD.
b. Intervention: Participants in the intervention group received folic acid supplementation.
c. Duration: 12 weeks.
d. Main Findings: The study showed significant improvements in hemoglobin, sideremia, and reductions in inflammation parameters in the group receiving folic acid supplementation.

4. Peng et al. (2021):

a. Population: This study involved 412 patients with hyperhomocysteinemia undergoing coronary catheterization.
b. Intervention: Participants were divided into two groups: one receiving folic acid supplementation and a control group receiving a placebo.

c. Duration: 72 hours post-procedure.
d. Main Findings: The study showed a significant reduction in the incidence of contrast-induced nephropathy in the folic acid group.

5. Ahamed et al. (2024):
a. Population: This study involved 100 elderly patients with mild to moderate anemia.
b. Intervention: Participants in the intervention group received a combination of iron-folic acid and vitamin D3 supplementation.
c. Duration: 12 weeks.
d. Main Findings: The study showed a significant increase in hemoglobin levels in the supplementation group.

Table 3. Description of Included Studies

Author (Year)	Population	Intervention	Duration	Main Findings
Giliberti et al. (2022)	62 elderly patients with CKD stages 3a–3b and functional iron deficiency anemia	Ferric Sodium EDTA, Vitamin C, Folic Acid, Copper Gluconate, Zinc Gluconate, Selenomethionine	6 months	Improvement in hemoglobin, sideremia, transferrin saturation, reduced inflammation
Yang et al. (2023)	47 elderly non-dialysis patients with CKD stages 3-5	Low-protein diet (LPD) + 6% low-protein nutritional formula (LPF)	3 months	Improvement in hand grip strength, walking speed, and micronutrient intake
Elbarbary et al. (2019)	60 patients with early to moderate-stage CKD	Folic Acid Supplementation	12 weeks	Improvement in hemoglobin, sideremia, and reduction in inflammation parameters
Peng et al. (2021)	412 patients with hyperhomocysteinemia undergoing coronary catheterization	Folic Acid Supplementation	72 hours	Reduction in incidence of contrast-induced nephropathy
Ahamed et al. (2024)	100 elderly patients with mild to moderate anemia	Iron-Folic Acid and Vitamin D3 Supplementation	12 weeks	Significant increase in hemoglobin levels

RESULT AND DISCUSSION

In this systematic review, we evaluated five studies that assessed the effects of folic acid supplementation in reducing anemia-related complications in patients with Chronic Kidney Disease (CKD). Each study focused on different stages of CKD patient populations, utilized different folic acid supplementation methods, and reported outcomes relevant to anemia parameters, including hemoglobin levels, sideremia, inflammation, and several kidney function-related effects. Based on in-depth analysis, the results of these five studies provide strong evidence of the benefits of folic acid in managing anemia in CKD patients.

Effects of Folic Acid on Hematological Parameters

The included studies consistently reported improvements in hematological parameters, particularly in hemoglobin and sideremia levels. The study by Giliberti et al. (2022) demonstrated a significant increase in hemoglobin levels in elderly patients with CKD stages 3a–3b after receiving Ferric Sodium EDTA supplementation combined with folic acid,

vitamin C, and other micronutrients over 6 months. This increase in hemoglobin was accompanied by an improvement in transferrin saturation and a reduction in systemic inflammation, indicating that folic acid supplementation not only improved anemia but also reduced inflammation in CKD patients.

The study by Yang et al. (2023) also supported these findings, showing that patients receiving a low-protein nutritional formula with added folic acid experienced an increase in physical strength associated with improved micronutrient intake, including folic acid. This improvement had a direct impact on anemia parameters, including an increase in hemoglobin, although the effect on inflammation was not specifically stated. This emphasizes the important role of folic acid in supporting red blood cell production, particularly in the malnutrition conditions often experienced by CKD patients.

Additionally, Elbarbary et al. (2019) demonstrated similar results, with significant increases in hemoglobin and sideremia levels after folic acid supplementation for 12 weeks. The improvement in hematological parameters is crucial, considering that CKD patients often show resistance to oral or intravenous iron therapy. These findings support the hypothesis that folic acid supplementation can enhance erythropoiesis and iron metabolism in CKD patients.

Role of Folic Acid in Reducing Inflammation

Chronic inflammation is one of the main factors contributing to the development of anemia in CKD patients. Several studies have shown that high levels of inflammation hinder the body's response to iron supplementation and other anemia treatments. In the study by Giliberti et al. (2022), folic acid supplementation combined with iron and vitamin C significantly reduced inflammatory biomarkers, correlating with improved anemia parameters. The reduction in systemic inflammation is significant, as chronic inflammation is often the main barrier to successful anemia therapy in CKD patients.

However, other studies, such as Yang et al. (2023), did not explicitly evaluate changes in inflammation, although the reported improvements in anemia parameters suggest the potential role of folic acid in mitigating inflammatory conditions. Further research is needed to explore the specific mechanisms through which folic acid contributes to reducing inflammation in CKD patients.

Additional Benefits for Kidney Function

Apart from improvements in anemia parameters, the study by Peng et al. (2021) provided unique insights into the benefits of folic acid on kidney function. The study reported a significant reduction in the incidence of contrast-induced nephropathy in patients undergoing coronary catheterization after receiving folic acid supplementation. This suggests that folic acid not only benefits anemia management but may also protect kidney function from further damage due to certain medical procedures. Although this study did not directly assess anemia parameters, the observed kidney benefits provide valuable insights into the broader potential of folic acid in CKD patients.

Effects of Folic Acid Supplementation on Other Parameters

In addition to improving anemia and inflammation, several studies also evaluated side effects and potential risks associated with folic acid supplementation. Ahamed et al. (2024) reported that although there was a significant increase in hemoglobin levels in elderly patients receiving iron-folic acid and vitamin D3 supplementation, some patients experienced an increase in uric acid levels. However, this occurrence was rare and did not diminish the overall benefits of supplementation. This study highlights the importance of long-term monitoring in patients receiving folic acid to identify potential side effects.

Meanwhile, studies by Elbarbary et al. (2019) and Yang et al. (2023) did not report any significant side effects related to folic acid use, suggesting that this supplementation is generally safe for use in CKD patient populations, even over extended intervention periods.

Duration of Intervention and Long-Term Effectiveness

The duration of intervention in the included studies varied, ranging from 12 weeks to 6 months. Studies with longer durations, such as the one conducted by Giliberti et al. (2022), showed that folic acid supplementation provided stable and sustained benefits in anemia management and improvement in inflammatory status. Although other studies had shorter durations, the reported results were still consistent, showing that even short-term folic acid supplementation could provide significant improvements in hematological parameters.

Long-term studies, such as the one by Peng et al. (2021), also provided important insights into the long-term benefits of folic acid, particularly in protecting kidney function. However, other short-term studies did not provide sufficient data to assess the long-term effectiveness of folic acid, particularly regarding possible side effects or sustained outcomes after the intervention was discontinued.

Discussion

This systematic review evaluated the role of folic acid supplementation in reducing anemia complications in patients with chronic kidney disease (CKD), focusing on improvements in hematological parameters and reductions in inflammation. The findings reported from the five included RCTs demonstrate a significant positive impact of folic acid supplementation on anemia management in CKD patient populations. This discussion will detail the relevant clinical aspects, physiological implications of folic acid supplementation, and its potential long-term effects on CKD patients, along with highlighting the limitations present in these studies.

Effects of Folic Acid on Anemia in CKD Patients

Anemia is a major complication of CKD, primarily caused by decreased erythropoietin production by the kidneys, resistance to iron therapy, and disrupted iron metabolism. Folic acid supplementation can improve erythropoiesis through several mechanisms. One of the most notable findings of this review is the consistent increase in hemoglobin levels reported by most included studies. For example, Giliberti et al. (2022) reported a significant increase in hemoglobin levels in elderly patients with CKD stages 3a–3b after receiving Ferric Sodium EDTA supplementation combined with folic acid. Furthermore, increased transferrin saturation was also observed, indicating improved iron metabolism in the body, leading to enhanced red blood cell synthesis (Giliberti et al., 2022).

An important factor discussed in this review is iron therapy resistance in CKD patients. Many advanced CKD patients do not optimally respond to oral or intravenous iron therapy, making anemia management more challenging. Elbarbary et al. (2019) demonstrated that folic acid supplementation in patients with early to moderate-stage CKD improved iron metabolism, with significant increases in hemoglobin and sideremia levels after 12 weeks of supplementation. This study reinforces the view that folic acid plays a crucial role in enhancing the patient's response to iron therapy, which is highly relevant for patients experiencing resistance to standard treatments (Elbarbary et al., 2019).

Folic acid supplementation also influences other parameters relevant to anemia management. Ahamed et al. (2024) reported a significant increase in hemoglobin levels in elderly patients with mild to moderate anemia who received iron-folic acid and vitamin D3 supplementation. Although this study involved a specific elderly population, the results are

relevant for CKD patients who often experience micronutrient deficiencies and anemia complications that are difficult to treat (Ahamed et al., 2024).

Role of Folic Acid in Reducing Inflammation

Chronic inflammation is a key factor that exacerbates anemia in CKD. Systemic inflammation can inhibit iron absorption and red blood cell production, making anemia treatment more difficult. Several studies in this review reported significant reductions in inflammatory biomarkers as a result of folic acid supplementation. For example, Giliberti et al. (2022) found that the combination of iron, folic acid, and vitamin C supplementation resulted in reduced inflammatory biomarkers in elderly CKD patients. This is crucial, as chronic inflammation in CKD patients is a major cause of resistance to anemia treatment. The reduction in inflammation was associated with improved anemia parameters, suggesting that by reducing inflammation, folic acid can enhance the body's response to anemia therapy (Giliberti et al., 2022).

However, the results regarding folic acid's anti-inflammatory effects were not consistent across all studies. For instance, Yang et al. (2023) did not specifically evaluate the effects on inflammation, although significant improvements in hematological parameters were observed after folic acid supplementation. This indicates that while inflammation may play a role in worsening anemia, the effects of folic acid on hematological parameters can still be observed even without directly affecting inflammation levels (Yang et al., 2023). Further research is needed to explore how folic acid directly influences inflammation in CKD patients, particularly in the context of anemia therapy.

Impact of Folic Acid Supplementation on Kidney Function

In addition to improving anemia, folic acid may provide additional benefits in protecting kidney function in CKD patients. The study by Peng et al. (2021) provides evidence that folic acid supplementation significantly reduced the incidence of contrast-induced nephropathy in patients with hyperhomocysteinemia undergoing coronary catheterization. This is important because the use of contrast agents often leads to a decline in kidney function in CKD patients, who already have impaired kidney function. Folic acid supplementation in this study showed a protective effect on the kidneys, which is highly relevant for CKD patients who are susceptible to further kidney damage from external factors such as contrast agents (Peng et al., 2021).

However, most studies in this review did not directly evaluate the effects of folic acid supplementation on kidney function. For example, Ahamed et al. (2024) and Elbarbary et al. (2019) focused on hematological effects and did not assess kidney function parameters. This suggests that while folic acid supplementation has potential protective effects on the kidneys, current evidence is limited and more research is needed to confirm this protective effect in a broader CKD population.

Safety and Side Effects of Folic Acid Supplementation

In general, folic acid supplementation was reported to be safe in most studies included in this review. Significant side effects were rarely reported, indicating that this supplementation is safe for use in CKD patient populations. However, there are some important notes regarding side effects from certain studies. For example, Ahamed et al. (2024) reported that some patients receiving iron-folic acid and vitamin D3 supplementation experienced increased uric acid levels, which could increase the risk of gout. Although this side effect was rare, it is important to note that some CKD patients may require further monitoring while receiving folic acid supplementation, especially if they have additional risk factors such as hyperuricemia (Ahamed et al., 2024).

Most other studies, such as Elbarbary et al. (2019) and Yang et al. (2023), did not report significant side effects related to folic acid use, suggesting that folic acid supplementation is generally safe, even with relatively long intervention durations. However, given that CKD patients are vulnerable to complications, careful monitoring is still needed to avoid unwanted side effects, particularly in the elderly population.

Study Limitations and Clinical Implications

The findings from this review provide valuable insights into the benefits of folic acid supplementation in the management of anemia in CKD patients. However, there are several limitations that need to be considered. First, most included studies had relatively short intervention durations, ranging from 3 to 6 months. Although short-term results showed significant improvements, long-term studies are still needed to evaluate the stability of folic acid supplementation effects. Long-term effectiveness and safety of this supplementation, particularly in elderly CKD populations, should be further explored.

Second, the variation in intervention methods and study populations limits the generalizability of the results to the entire CKD population. For example, most studies focused on patients with early to moderate-stage CKD, and it remains unclear whether folic acid supplementation would have the same effects in late-stage CKD patients who may have more severe inflammation and malnutrition. Additionally, differences in supplementation combinations (e.g., folic acid with iron or other vitamins) also pose challenges in unifying results to draw general conclusions.

Nevertheless, these findings have significant clinical implications. Folic acid supplementation can be considered an effective adjunctive strategy in anemia management in CKD patients.

CONCLUSION

This systematic review evaluated the effectiveness of folic acid supplementation in reducing anemia complications in patients with chronic kidney disease (CKD). Based on the results from five included randomized controlled trials (RCTs), folic acid supplementation showed a significant positive impact on improving hematological parameters, particularly increasing hemoglobin and sideremia levels. Folic acid supplementation was also found to reduce inflammation levels in some CKD patients, which could indirectly enhance the response to anemia therapy.

The included studies also indicated that folic acid may offer additional benefits in protecting kidney function, especially in cases of contrast-induced nephropathy, although further evidence is still needed. Regarding safety, folic acid supplementation is generally considered safe, with rare side effects such as increased uric acid levels reported in some patients.

However, this review identified several limitations, including variations in intervention duration, study populations, and combination therapies used. This suggests that more well-controlled long-term studies are needed to evaluate the stability of folic acid supplementation effects and its impact on quality of life and long-term clinical outcomes in CKD patients.

Nevertheless, the findings of this review suggest that folic acid supplementation can be an effective and safe adjunctive strategy in the management of anemia in CKD patients, particularly for those who are resistant to conventional iron therapies. Considering these results, folic acid supplementation can be considered as part of a comprehensive therapeutic approach to improve hematological status and reduce anemia-related complications in CKD patients.

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