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(REVIEW ARTICLE)

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Cost minimization analysis of chronic kidney disease management: Evaluating economic strategies for early intervention and treatment optimization

GREESHMA GIREESH * and MANJU CS

College of pharmaceutical sciences government medical college, affiliated to Kerala university of health sciences, Calicut, Kerala, India.

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Abstract

Chronic kidney disease is a common global health condition characterized by progressive loss of kidney function and significant cost burden on the healthcare system worldwide. The disease often coexists with conditions such as diabetes and hypertension, further complicates its management and increasing associated costs. Effective economic management, particularly in the early stages of CKD, is crucial for reducing long-term healthcare expenses and improving patient outcomes. This review examines the utility of cost minimization analysis (CMA) as a strategic tool for evaluating economic options in CKD management. CMA is an economic evaluation method that compares the costs of different therapeutic interventions that have demonstrated equivalent clinical effectiveness, thereby aiding healthcare providers and policymakers in identifying the most cost-efficient options to optimize resource utilization. This review highlights the economic impact of CKD, focusing on the increasing costs linked to advanced disease management and the essential role of early diagnosis and intervention in reducing these costs and explores various cost-effective strategies for CKD management, including pharmacological treatments, lifestyle modifications, and patient education, to identify approaches that are both clinically and economically advantageous. Additionally, the broader implications of cost minimization for healthcare policy, clinical decision-making, and resource allocation are discussed for their significance in a resource-limited healthcare setting. Evidence indicates that prioritizing cost-effective CKD management through early intervention and preventive care can significantly lower healthcare expenditures, slow the disease progression, and enhance patient's quality of life. By adopting such strategies, healthcare systems can achieve better clinical outcomes and ensure financial sustainability.

Keywords: Chronic kidney disease; Cost minimization analysis; Economic strategies; Early intervention; Healthcare cost; Treatment optimization

1. Introduction

Chronic kidney disease is a long-term disorder in which kidney function gradually declines. It affects millions of people worldwide and places significant financial strain on healthcare systems due to the high expenses of treatment and management particularly in the advanced stages [1]. Chronic kidney disease is frequently associated with comorbidities like diabetes and hypertension, complicates its management, and escalates healthcare expenses[2]. Due to limited healthcare resources, there is a pressing need for cost-effective strategies that emphasize early intervention and treatment optimization to manage kidney disease more efficiently[3]. This review offers a detailed examination of cost minimization analysis within chronic kidney disease management, highlighting the economic advantages of early intervention and the optimization of treatment strategies. By focusing on these aspects, the review aims to underscore how cost minimization analysis can contribute to more efficient and economical management of chronic kidney disease[4].

* Corresponding author: GREESHMA GIREESH

2. The economic implications of chronic kidney disease

Chronic kidney disease (CKD) incurs significant healthcare costs, particularly in its late stages. End-stage renal disease (ESRD), the most severe form of CKD, requires costly treatments such as dialysis or kidney transplantation[5]. The financial impact of CKD extends beyond direct medical expenses to encompass indirect costs, including diminished productivity, disability, and reduced quality of life. These indirect costs can significantly affect both patients and the broader economy. Addressing CKD early and effectively can help mitigate these expenses and improve overall health outcomes.[6,7]

2.1. Direct and Indirect Costs of CKD

Direct costs of chronic kidney disease (CKD) encompass expenses related to hospitalizations, outpatient visits, medications, and renal replacement therapies, such as dialysis and kidney transplantation. Direct costs can be substantial, as the disease progresses. Indirect costs, on the other hand, include productivity losses stemming from disability, early retirement, and absenteeism from work, with broader economic implications[8].

Our recent study entitled "Evaluation of Pharmacoeconomic status in patients with chronic kidney disease" conducted in the outpatient department of Nephrology in a tertiary care teaching hospital provides a quantitative measure of both direct and indirect costs related to CKD interventions. The direct costs of interventions are found to be 23838.15 INR and the indirect cost was found to be 5226.67 INR which indicates that the direct costs of CKD management are higher than that of its indirect costs.

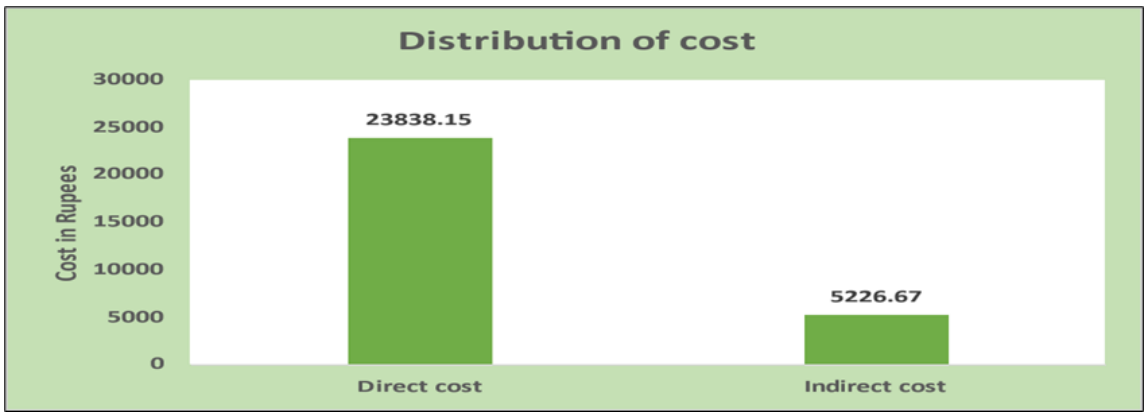

Figure 1 Cost of illness of CKD

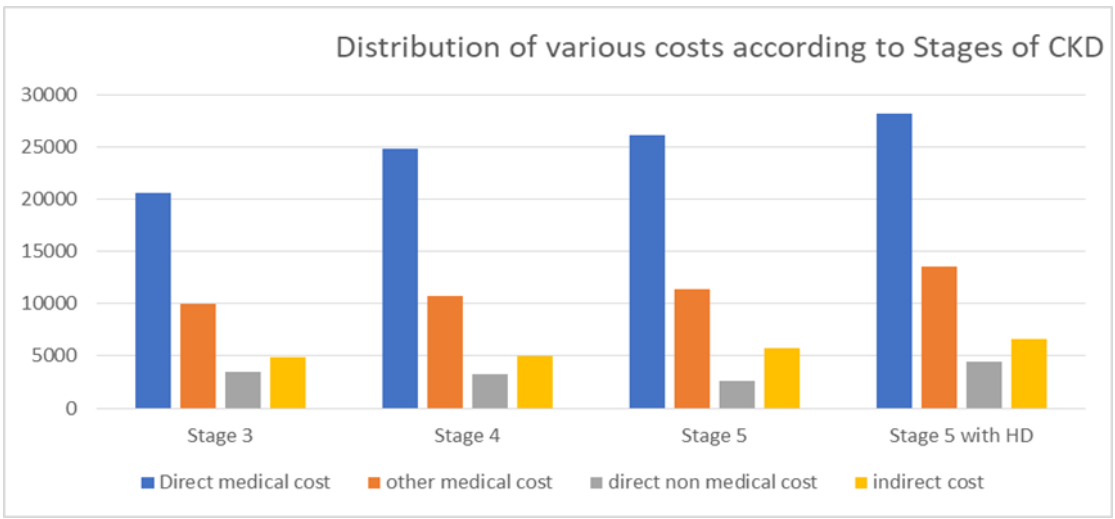

Figure 2 Cost of illness of CKD according to stages

As CKD advances, patients typically require more intensive and frequent care, significantly escalating overall costs. Implementing strategies focused on delaying disease progression such as early detection, lifestyle modifications, and

effective management of risk factors can substantially reduce both direct and indirect expenses associated with CKD[9]. By prioritizing preventive measures and timely interventions, it is possible to lower the financial impact on both individuals and the healthcare system. Additionally, investing in these strategies can improve patient quality of life and outcomes, further contributing to cost savings[10].

2.2. Cost Drivers in CKD Management

The key cost drivers in the care of CKD include the expense of drugs, frequent hospitalizations, and the necessity for kidney replacement therapies, such as renal dialysis or renal transplantation, particularly in the advanced stages of the disease.11 Comorbid conditions such as diabetes and cardiovascular diseases, which are common among CKD patients, contribute to overall costs due to the need for concurrent treatments and management. Identifying and understanding these cost drivers is crucial for developing strategies aimed at minimizing expenses by targeting interventions at the early stages of CKD12. Early-stage interventions, including lifestyle modifications, proactive management of risk factors, and effective medication use, are often more cost-effective and can prevent the need for more expensive treatments later on. By focusing on these early interventions, healthcare systems can reduce both the direct and indirect costs associated with CKD, improving overall cost-efficiency and patient outcomes13.

3. Cost minimization analysis (cma) in health-care

Cost minimization analysis (CMA) is an economic evaluation method designed to compare the costs of various therapeutic interventions that have demonstrated equal effectiveness[14]. Unlike cost-effectiveness analysis, which assesses both the costs and outcomes of different interventions to determine the most efficient option, CMA concentrates exclusively on identifying the least expensive alternative while ensuring that the level of effectiveness remains consistent[15]. This technique is useful in the management of CKD because the costs of multiple treatment alternatives with similar clinical outcomes vary greatly. By focusing solely on cost, CMA helps in identifying the most economically efficient treatment options, thereby facilitating better resource allocation and cost control in CKD management. This approach is crucial for healthcare systems aiming to optimize their budgets while providing effective care to patients with CKD[16].

3.1. Relevance of CMA in CKD Management

In managing chronic kidney disease (CKD), cost minimization analysis (CMA) is employed to compare various treatment approaches, such as conservative management versus early initiation of dialysis, comparing the use of angiotensin II receptor blockers (ARBs) against angiotensin-converting enzyme inhibitors (ACEIs) for blood pressure control.[17] CMA focuses on evaluating the cost differences between these treatment options while ensuring that clinical outcomes remain equivalent. This method is essential for identifying the most economically efficient strategies for CKD management, particularly in scenarios where healthcare resources are limited and the prevalence of CKD is increasing globally. By prioritizing cost-effectiveness, CMA helps healthcare systems allocate resources more wisely and manage CKD more efficiently, ultimately contributing to better financial and clinical outcomes.[18]

A study conducted by **Jarupala et al** on Cost minimization analysis of medications used in the management of end-stage renal failure indicates that substituting the branded medication with a generic alternative could help patients to reduce the economic burden, especially in patients with ESRD. This will help in better patient compliance, treatment adherence, and treatment outcomes. Healthcare practitioners may adopt prescribing the generic alternatives with least price without compromising the efficacy of the drug for the benefit of the ESRD patients.[19]

3.2. Methodological Considerations for Conducting CMA in CKD

Performing a cost minimization analysis (CMA) involves a comprehensive understanding of the costs linked to each treatment option, including both direct medical expenses (such as medications and hospitalizations) and indirect costs (such as transportation and caregiver time)[20]. Chronic kidney disease (CKD) is a long-term ailment, therefore cost comparisons must take the time horizon into account. A short-term perspective might overlook the full benefits of early intervention strategies, designed to delay disease progression and reduce overall long-term costs[21]. By accounting for both immediate and extended costs, CMA provides a more accurate evaluation of the economic efficiency of different CKD management strategies, highlighting the potential financial advantages of early and proactive treatments[22].

4. Early intervention strategies and cost minimization in ckd

Early intervention in chronic kidney disease (CKD) encompasses strategies aimed at early detection, lifestyle changes, and pharmacological management to decelerate disease progression and minimize complications. Addressing CKD in

its early stages is generally more cost-effective compared to managing the disease once it has advanced[23]. By adopting cost-effective approaches, significant savings can be realized, primarily by postponing the progression into end-stage renal disease (ESRD) and reducing the reliance on costly treatments like dialysis or kidney transplantation. These proactive measures not only enhance patient outcomes but also alleviate the economic burden on the healthcare system by avoiding the high costs associated with advanced CKD care[24].

4.1. Early Detection and Diagnosis

Early detection and diagnosis of chronic kidney disease (CKD) through regular screening and monitoring of individuals having risk factors, such as diabetes, hypertension, or a family history of kidney disease, is critical for enabling timely interventions that can significantly slow disease progression. Routine testing, such as haematological tests to assess renal function (e.g., serum creatinine, estimated glomerular filtration rate) and urine tests to find out proteinuria or albuminuria, can aid in detecting CKD in its early stages when it is more controllable.

Table 1 Stages of CKD with description[25]

Stage	Description of stage	GFR (mL/min/1.73m^2)	Action
1	Kidney damage (e.g., proteinuria, structural abnormalities) with normal or increased GFR. No symptoms may be present at this stage.	Greater than 90	Diagnosis, Treatment, and Risk Reduction: Early detection, management of comorbidities (hypertension, diabetes), lifestyle interventions, and monitoring for cardiovascular disease (CVD) risk. Delay progression.
2	Mild reduction in GFR with evidence of kidney damage (e.g., abnormal urine tests or imaging studies).	Between 60 and 89	Estimation of Progression: Regular monitoring of kidney function, control of blood pressure, glucose, and other comorbidities. Adjust medication to avoid nephrotoxicity and maintain CVD prevention efforts.
3	Moderate reduction in GFR, with or without symptoms like fatigue, swelling, and changes in urination.	Between 30 and 59	Complication Management: Screening and treating anaemia, bone disease, electrolyte imbalances (e.g., hyperkalaemia), and acidosis. Continue controlling blood pressure and diabetes, with preparation for more frequent monitoring.
4	Severe reduction in GFR. Symptoms may become more pronounced, such as fatigue, swelling, loss of appetite, and nausea.	Between 15 and 29	Preparation for Renal Replacement: Referral to a nephrologist for the discussion of dialysis and transplantation options, continued management of complications, and planning for vascular access for dialysis, if necessary.
5	Kidney failure or ESRD -The kidneys can no longer maintain necessary body functions without intervention.	Less than 15	Kidney Replacement (if uraemia is present): Initiation of dialysis or preparation for kidney transplantation. Palliative care may also be considered if the patient chooses to forego dialysis. Continued symptom management.

Table 2 Diagnostic Criteria For Chronic Kidney Disease (CKD)[26]

Indicators of kidney damage (one or more may be present):
• Abnormalities in urine sediment
• Presence of albumin in the urine (AER ≥ 30 mg/24 hours or ACR ≥ 3 mg/mmol)
• Histological abnormalities identified through tissue analysis
• Structural abnormalities observed in imaging studies
• Electrolyte imbalances and other disruptions caused by tubular dysfunctions
• Previous history of kidney transplantation
• Reduced GFR

- GFR below 60 mL/min/1.73 m^2 (GFR stages G3a to G5)

When CKD is detected early, management strategies frequently centre on lifestyle changes, such as eating a balanced diet with limited protein, sodium, and phosphorous intake, as well as engaging in regular exercise to control blood pressure, maintain a healthy weight, and improve overall cardiovascular health. Pharmacological therapies, such as the use of angiotensin II receptor blockers (ARBs) or angiotensin-converting enzyme (ACE) inhibitors, are also critical for managing hypertension and preventing further kidney damage. Additionally, maintaining optimal blood glucose levels through medication and diet is critical for diabetic patients to reduce the risk of CKD progression[27].

The economic advantage of early detection lies in its cost-effectiveness. Managing CKD in its early stages through preventive measures and relatively low-cost interventions, such as lifestyle modifications and medication, is far less expensive than the extensive costs associated with treating patients having end-stage renal disease (ESRD). ESRD management often requires renal dialysis or renal transplantation, both of which are highly resource-intensive and place a significant economic burden on healthcare systems and patients. Therefore, investing in regular screening programs and early-stage interventions not only improves patient outcomes by delaying or preventing the progression to ESRD but also serves as a cost-minimizing strategy for healthcare providers[28].

4.2. Pharmacological Interventions

Pharmacological interventions, including angiotensin II receptor blockers (ARBs), angiotensin-converting enzyme inhibitors (ACEIs), and sodium-glucose co-transporter-2 (SGLT2) inhibitors, are effective in slowing the progression of chronic kidney disease (CKD) and lowering the risk of cardiovascular events in CKD patients.[29] Comparing the costs and benefits of these medications is essential to determine the most cost-effective options for managing CKD, especially in patients with coexisting conditions like diabetes and hypertension. For example, SGLT2 inhibitors not only help manage blood sugar levels but also provide additional benefits, such as reducing cardiovascular mortality and hospitalization rates for heart failure, which may justify their higher cost relative to other drug classes. Moreover, incorporating these agents into treatment plans can optimize patient outcomes by targeting multiple pathways involved in CKD progression. Cost-benefit analyses of these medications are vital for tailoring treatment strategies to achieve both clinical effectiveness and economic efficiency[30].

4.3. Lifestyle Modifications and Patient Education

Lifestyle modifications and patient education are keys to preventing chronic kidney disease (CKD), particularly for patients with hypertension and diabetes. Essential strategies include a low-sodium diet rich in fruits, vegetables, whole grains, and lean protein. Daily exercise, such as 150 minutes of moderate activity weekly, helps manage weight, blood pressure, and blood sugar[29]. As smoking harms blood vessels and kidney function suggesting that quitting smoking may be a modifiable factor in delaying kidney disease progression[31]. Maintaining a healthy weight, staying hydrated, and effectively managing blood pressure and blood sugar with lifestyle changes and medications are also vital. Educating patients on CKD risk factors, the need for regular screenings, medication adherence, and recognizing early symptoms like fatigue and changes in urination can lead to early intervention. Self-management programs and community support groups further enhance patient skills, motivation, and adherence to these preventive measures, significantly reducing CKD risk[32].

5. Implications for healthcare policy and clinical practice

The results from cost-minimization analyses (CMAs) can profoundly influence healthcare policy and clinical practices. By pinpointing the most cost-effective approaches to managing chronic kidney disease (CKD), policymakers can more efficiently allocate resources and develop guidelines that emphasize early intervention and optimized treatment strategies. This can lead to enhanced patient outcomes, lower overall healthcare expenditures, and more strategic use of limited healthcare resources[33]. Additionally, evidence from CMAs supports the implementation of preventive measures and cost-effective treatments that benefit both patients and the healthcare system. Ultimately, integrating these findings into policy decisions ensures that resources are used wisely and that CKD management is both effective and sustainable[34].

6. Conclusion

Cost minimization analysis (CMA) is an essential tool for assessing economic strategies for the treatment of long-term renal impairment, especially early intervention and treatment optimization. The economic impact of CKD is

considerable, but implementing early detection and cost-effective management strategies can lead to significant reductions in overall costs and enhance patient outcomes. By concentrating on minimizing costs, healthcare providers and policymakers can devise approaches that deliver high-quality care while alleviating the financial strain on healthcare systems. Ongoing research is crucial to further investigate the economic effects of various CKD management strategies and to pinpoint the most cost-effective interventions tailored to different patient populations. This continued exploration will help refine treatment protocols and optimize resource allocation, ultimately improving both the efficiency and effectiveness of CKD management.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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