

Cost-Utility Analyses of Hemodialysis, Peritoneal Dialysis, and Kidney Transplantation in Patients with End-Stage Kidney Disease: A Systematic Review

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Abstract: The global burden of end-stage kidney disease (ESKD) is rising, compelling patients to increasingly confront the choice of initiating kidney replacement therapy (KRT). Cost-utility analysis (CUA) has the advantage of incorporating patient-reported outcomes regarding KRT. The aim of this study is to summarize the CUA of hemodialysis (HD), peritoneal dialysis (PD), and kidney transplantation in patients with ESKD. A systematic search was conducted to identify relevant articles in three primary databases (PubMed, SCOPUS, and ProQuest). CUA studies of dialysis for ESKD patients from 2000 to 2023 in all countries were included. Non-full-text, non-English language, review articles, systematic reviews, and studies that did not compare distinct dialysis methods were excluded. All the information was summarized narratively. Out of the 130 studies identified, 13 met the inclusion criteria and were included in this review. Most studies demonstrated good reporting quality, with CHEERS checklist scores ranging from 75% to 96%. Kidney transplantation was consistently found to be the most cost-effective KRT, offering the highest quality-adjusted life years (QALYs) and the lowest cost per QALY in the long term, despite higher initial expenses. PD showed better cost-effectiveness than HD in several studies. HD generally incurred the highest costs with lower QALY gains. Cost-effectiveness trends varied depending on regional context, healthcare perspective, and patient comorbidities. This study found that kidney transplantation is consistently the most cost-effective kidney replacement therapy, with lower cost per QALY and improved quality-adjusted life years (QALY) in most settings. In particular, transplantation showed favorable long-term outcomes despite higher initial costs, whereas peritoneal dialysis emerged as a more cost-effective alternative to hemodialysis, especially in resource-limited settings. These findings offer practical implications for treatment prioritization and policy-making in both high- and low-resource countries.

Keywords: low-income countries, middle-income countries, quality of life, kidney disease, hypertension

Introduction

End-stage kidney disease (ESKD) is the final stage of chronic kidney failure.¹ The global prevalence is increasing with some region recorded faster growth than the general population.² Peritoneal dialysis (PD), hemodialysis (HD), and kidney transplantation (KT) are the three primary kidney replacement therapies for (ESKD).³ Each treatment modalities, however, requires different intensity of resources and results in variety of outcomes that posed significant prioritization challenge for decision makers. For example, PD requires fewer dietary restriction and increased mobility compared to HD. However, it also has higher risk of infection and risk of weight gain. The gold standard treatment for patients

suffering from ESKD is KT. However, the waiting list for transplants continues to grow despite kidney transplants from living donors due to organ scarcity.⁴

Non-medical factors, including financial and reimbursement policy, influence kidney replacement therapy (KRT) modality selection in various countries.⁵ HD is the most widely used kidney replacement therapy modality in ESKD patients.⁶ In 2017, Indonesia reached 30,831 new patients undergoing HD therapy, with active patients of 77,892.⁷ By comparison, in the USA, only 19,849 patients received KT in 2017, with 40% aged 50–64 and 18% over 65 years.⁸ Although life expectancy can be accordingly increased with KRT, either treatment must be maintained for a long time, which has a severe impact on patient costs.⁹

ESKD has significant economic consequences, such as loss of gross domestic product (GDP) for its management. In developed countries, the expenses for KRT provision were 2–3% of total healthcare expenditure. ESKD patients accounted for just 0.02–0.03% of the total population.¹⁰ Nowadays, non-communicable diseases pose a significant cost burden to health systems worldwide. Non-communicable diseases are ranked number one among the top global threats to economic development, according to the World Economic Forum.¹¹

Cost-utility analysis (CUA) is generally the preferred economic evaluation method used to inform resource allocation decisions.¹² Compared to other economic evaluation methods, CUA has the advantage of being able to incorporate patient-reported outcomes. The primary outcome in CUA is the ratio of change to total costs by change to total health benefits, measured by quality-adjusted life years (QALYs). The incremental cost–effectiveness ratio (ICER) can be used to compare the value of different interventions.¹³

Despite the growing number of economic evaluations related to kidney replacement therapies, existing literature often focuses on individual treatment modalities or limited regional comparisons, lacking a comprehensive synthesis of cost-utility outcomes across diverse healthcare settings.^{14,15} Many prior studies either exclude kidney transplantation or fail to directly compare all three primary treatment options; HD, PD, and KT; within a unified analytical framework.^{16,17} This systematic review fills that gap by providing a comparative analysis of cost-utility outcomes across the three modalities, drawing on data from multiple countries and healthcare perspectives. This systematic review aims to analyze and compare the cost-effectiveness of HD, PD, and KT for patients with ESKD. By evaluating the costs and QALYs of each treatment, this study provides valuable insights to help healthcare providers and policymakers make informed decisions about resource allocation and patient care.

Methods

The systematic review was conducted and reported to determine the cost-utility in ESKD patients who performed HD, PD, or KT as KRT. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guideline was used in this systematic review.¹⁸

Search Strategy

We conducted a systematic search of PubMed, SCOPUS, and ProQuest for studies published between 2000 and 2023 using a combination of keywords related to “dialysis”, “hemodialysis (HD)”, “peritoneal dialysis (PD or CAPD)”, “kidney transplantation (KT)”, “kidney replacement therapy (KRT)”, and “end-stage kidney disease (ESKD)”. Two investigators (WW and NZ) independently screened the titles and abstracts using pre-defined inclusion criteria. Two investigators (WW and NZ) independently screened titles and abstracts, followed by full-text screening of potentially eligible articles. Any disagreements were resolved through discussion or consultation with a third party (MA, AAW and AAS). Additional relevant studies were identified by manually reviewing the reference lists of included articles. The complete search strategy is provided in [Supplementary File 1](#).

Study Selection

Inclusion criteria were constructed based on patient (P), interventions (I), comparator (C), and outcomes (O) as follows: P: ESKD patient who underwent a kidney replacement therapy; I/C: had any KRT modalities including PD, HD, or KT and; O: had any cost-utility comparison between interventions. The exclusion criteria were: (i) study patients with acute kidney injury, (ii) duplicate reports, (iii) insufficient data for pooling, and (iv) non-full-text review articles, (v) systematic

Table 1 Inclusion and Exclusion Criteria

PICOS Elements	Inclusion Criteria	Exclusion Criteria
P (Population)	ESKD patients who underwent a KRT	Studies were excluded if they did not involve ESKD patients undergoing KRT, focused on conditions other than ESKD (eg, acute kidney injury), did not analyze hemodialysis, peritoneal dialysis, or kidney transplantation, included non-human or pediatric populations, or lacked clarity about the patient population's KRT status.KRT
I (Intervention)	KRT, HD or CAPD	Studies were excluded if they did not focus on KRT interventions such as hemodialysis (HD) or continuous ambulatory peritoneal dialysis (CAPD), or if they analyzed interventions outside of these KRT modalities, such as conservative management or other non-KRT treatments.
C (Comparator)	KRT, including KT	
O (Outcome)	- Cost-utility comparison between two interventions - Cost-utility comparison between two interventions and KT - Cost-utility, including cost per QALY and 5-year survival rate	
Study Design	Comprehensive economic evaluations that compare both the cost and outcomes (such as effectiveness and benefits) of two or more interventions; including cost-effectiveness analyses, must specifically include a cost-utility analysis.	Articles were excluded if they were not full economic evaluations (eg, reviews, systematic reviews, clinical effectiveness studies, or costing studies), did not include a clear cost-effectiveness analysis (no incremental cost per outcome), lacked a cost-utility analysis (no utility measure in the outcomes), were conference abstracts, study protocols, or not written in English or Indonesian.

review studies, and (vi) studies that did not comprise a comparison. The retrieved articles' titles and abstracts were scanned for potential relevance and review inclusion eligibility. All titles and abstracts were screened according to strict criteria, as listed in [Table 1](#).

Data Collection

Two authors (WW and NZ) independently extracted data from the included studies, ensuring the accuracy and reliability of the data. Any disagreements were resolved through discussion and adjudication with a third party (MA, AAW and AAS). For each included article, a comprehensive set of information was extracted, including the author of the study, country, QALY, cost per life year (LY), cost per QALY, 5-year survival rate, comorbidities, and outcome of the study.

All costs were reported in United States (US) Dollar (\$) 2023. These values were either directly obtained from the reviewed papers when originally reported in US \$ or, when reported in local currencies, were converted into US \$ using the exchange rate corresponding to the time period when the cost data were collected. The converted values were then adjusted for inflation using US inflation rates or, when possible, commodity-specific price change rates to ensure consistency and comparability across studies.

Quality of Reporting

The quality of reporting for each study was evaluated using the CHEERS (Consolidated Health Economic Evaluation Reporting Standards) checklist.¹⁹ This checklist consists of 28 items, with each item scored as 1 point if the criterion is met and 0 points if it is not fully satisfied, resulting in a maximum possible score of 28 (equivalent to 100%). Based on these scores, studies were categorized into four quality levels: excellent (100%), good (75–99%), moderate (50–74%), and low ($\leq 49\%$).²⁰ Although this method assigns a reporting quality score to each study, it does not determine the overall quality of the study. A lower score does not necessarily mean the study is of poor quality; it may simply indicate that certain details were not reported. The CHEERS checklist was mainly used to provide extra information rather than to rank the importance of each study.

Results

Study Selection

The search yielded 130 published studies. Five articles were excluded due to duplication, resulting in 125 articles to be screened based on titles and abstracts. Following the screening, 98 articles were excluded because they reported on patients with acute kidney injury, did not conduct economic evaluations, were systematic review studies, or did not include comparisons. A total of 27 articles were further assessed, and 14 were excluded: 9 articles did not report specific outcomes related to ESKD, 3 articles were non-full-text, and 2 articles were classified as partial economic evaluations containing only cost descriptions. The final screening resulted in 13 studies being included. The process of study selection and identification is illustrated in Figure 1.

Characteristics of Included Studies

Table 2 presents the characteristics of the included studies. Among the 13 studies published between 2011 and 2023, 2 studies originated from Europe (Denmark and Austria),^{21,22} 2 studies from North and South America (Colombia and Canada),^{23,24} 8 studies from the Asia-Pacific region (Malaysia, Iran, Singapore, the Philippines, Indonesia, China, and Japan),^{5,25–31} and 1 study from Africa (Ethiopia).³² More than half of the studies evaluated quality of life using EQ-5D-5L, reporting results in terms of QALY. One study assessed quality of life using SF-36 instrument; however, it did not report QALY values, nor did it apply utility mapping to derive them. One study used cost per LY and cost per QALY to describe the outcome. Regarding the perspective used, 4 studies adopted the healthcare system perspective,^{21,22,24,29} 2 studies took the healthcare provider perspective,^{21,30} 5 studies used the societal perspective,^{14,23,27,29,32} and 2 studies combined both the healthcare system and societal perspectives.^{14,21} All studies included direct costs, such as treatment and medication expenses for both outpatient and inpatient care. However, the inclusion of indirect cost components especially among those using the societal perspective. For instance, Surendra et al, 2013⁵ and Widiana et al, 2013³⁰ included patient family costs as indirect costs. Conversely, Bayani et al, 2021²⁷ and Wu et al, 2020²⁹

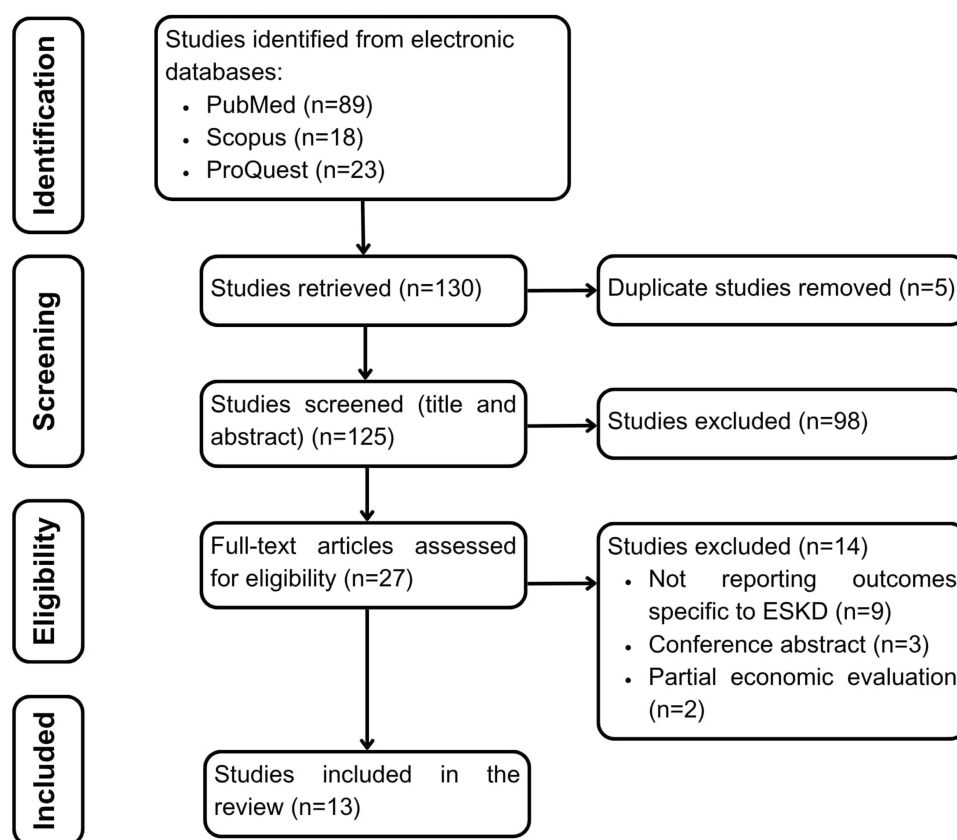


Figure 1 The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flowchart of the study selection process.

Table 2 General Characteristics of Included Studies

Study Characteristics	Number of Studies (n=13)	Study
Year of publication		
2011-2015	4	Jensen et al, 2014; ²² Haller et al, 2011; ²¹ Rosselli et al, 2015; ²³ and Shimizu et al, 2012 ³¹
2016-2020	8	Afiatin et al, 2017; ²⁸ Moradpour et al, 2020; ²⁵ Bayani et al, 2021; ²⁷ Yang Fan et al, 2016; ²⁶ Wu et al, 2020; ²⁹ Widiani et al, 2020; ³⁰ Surendra et al, 2019; ⁵ and Shimels et al, 2019 ³²
2021-2023	1	Ferguson et al, 2021 ²⁴
Region		
Europe	2	Jensen et al, 2014; ²² and Haller et al, 2011 ²¹
North and South America	2	Ferguson et al, 2021; ²⁴ and Rosselli et al, 2015 ²³
Asia Pacific	8	Afiatin et al, 2017; ²⁸ Moradpour et al, 2020; ²⁵ Bayani et al, 2021; ²⁷ Yang Fan et al, 2016; ²⁶ Wu et al, 2020; ²⁹ Widiani et al, 2020; ³⁰ Surendra et al, 2019; ⁵ and Shimizu et al, 2012 ³¹
Africa	1	Shimels et al, 2019 ³²
Type of economic evaluation		
Cost-utility analysis	13	Afiatin et al, 2017; ²⁸ Moradpour et al, 2020; ²⁵ Bayani et al, 2021; ²⁷ Ferguson et al, 2021; ²⁴ Yang Fan et al, 2016; ²⁶ Wu et al, 2020; ²⁹ Jensen et al, 2014; ²² Widiani et al, 2020; ³⁰ Surendra et al, 2019; ⁵ Shimels et al, 2019; ³² Haller et al, 2011; ²¹ Rosselli et al, 2015; ²³ and Shimizu et al, 2012 ³¹
Perspective		
Healthcare system	4	Ferguson et al, 2021; ²⁴ Haller et al, 2011; ²¹ Rosselli et al, 2015; ²³ and Surendra et al, 2019 ⁵
Healthcare provider	2	Jensen et al, 2014; ²² and Widiani et al, 2020 ³⁰
Societal	5	Moradpour et al, 2020; ²⁵ Yang Fan et al, 2016; ²⁶ Wu et al, 2020; ²⁹ Shimizu et al, 2012; ³¹ and Shimels et al, 2019 ³²
Healthcare system and societal	2	Afiatin et al, 2017; ²⁸ and Bayani et al, 2021 ²⁷
Study type		
Model based	11	Afiatin et al, 2017; ²⁸ Moradpour et al, 2020; ²⁵ Bayani et al, 2021; ²⁷ Ferguson et al, 2021; ²⁴ Yang Fan et al, 2016; ²⁶ Jensen et al, 2014; ²² Haller et al, 2011; ²¹ Surendra et al, 2019; ⁵ Rosselli et al, 2015; ²³ Shimizu et al, 2012; ³¹ and Shimels et al, 2019 ³²
Randomized control trial	2	Wu et al, 2020; ²⁹ and Widiani et al, 2020 ³⁰
Outcome measures		
Quality-adjusted life years	12	Afiatin et al, 2017; ²⁸ Moradpour et al, 2020; ²⁵ Bayani et al, 2021; ²⁷ Ferguson et al, 2021; ²⁴ Yang Fan et al, 2016; ²⁶ Jensen et al, 2014; ²² Haller et al, 2011; ²¹ Surendra et al, 2019; ⁵ Rosselli et al, 2015; ²³ Shimizu et al, 2012; ³¹ Widiani et al, 2020; ³⁰ and Shimels et al, 2019 ³²
Other effects	1	Wu et al, 2020 ²⁹

either excluded or did not explicitly specify indirect costs like productivity losses or caregiver time. This inconsistency may affect the comparability of cost estimates across studies using different perspectives. Among the 13 studies, 10 studies employed a model-based approach, while 2 studies were conducted alongside randomized controlled trials. The methods used for cost and outcome data collection were generally appropriate and aligned with the economic evaluation designs employed.

Cost-Utility Analysis of Hemodialysis, Peritoneal Dialysis, and Kidney Transplantation

CUA was conducted using the Markov model simulation cohort. Five studies compared the CUA of three modalities: KT, HD, and PD.^{21,25,27,29,31} Four studies determined the CUA by comparing HD and PD.^{5,24,26,28} Four other studies analyzed the CUA in HD and RT.^{22,24,27,28} Geographically, these studies were conducted across diverse settings including Asia (Malaysia, Indonesia, China, Singapore, Philippines, and Iran), America (Canada and Colombia), Europe (Austria and Denmark), and Africa (Ethiopia). Based on the findings from 13 included studies assessing the cost-utility of kidney replacement therapies, the majority (9 studies, 69%) concluded that kidney transplantation (KT) was the most cost-effective option compared to hemodialysis (HD) and peritoneal dialysis (PD). These studies reported that KT not only yielded the highest QALY values—up to 35.26 in Malaysia²⁹—but also demonstrated the lowest cost per QALY, such as in Iran,³² where KT cost \$1,744 per QALY compared to HD (\$2,227) and PD (\$1,850). Additionally, several studies in Philippines, Indonesia, and Ethiopia^{27,30,32} showed KT offering the highest 5-year survival rates, reaching up to 94%, highlighting its superior clinical and economic value.

In comparisons between HD and PD, 4 studies (31%) favoured PD as the more cost-effective dialysis modality. For example, a study from Malaysia reported a lower cost per QALY for PD (\$9,000.22) compared to HD (\$10,098.61),

concluding that initiating dialysis with continuous ambulatory peritoneal dialysis (CAPD) was a cost-effective approach.⁵ Similarly, research from Indonesia demonstrated a slightly higher QALY for PD (4.40) versus HD (4.34), alongside lower total costs, thereby supporting a PD-first policy.²⁸ Additionally, findings from Singapore highlighted CAPD as the most cost-effective strategy, despite the relatively high treatment costs associated with both dialysis modalities in the country.²⁸ Most of the included studies reported cost per QALY values that fall below the commonly accepted willingness-to-pay (WTP) threshold, typically set at 1–3 times a country's GDP per capita, as recommended by WHO-CHOICE.²⁸ **Table 2** summarizes the detailed information about the cost elements of the included studies.

Model Based Economic Evaluations

All 13 studies included in this review applied model-based economic evaluations to assess the cost-effectiveness of KRT options for ESKD. The most commonly used model structure was the cohort-based Markov model, which was applied in eleven of the studies.^{5,14,21–25,27–31} In these models, patient cohorts transitioned between health states over time, enabling estimation of cumulative costs and health outcomes. In contrast, two studies employed decision tree models, which are more suitable for short- to medium-term evaluations.^{22,32} The health states modeled across studies commonly included initiation of dialysis, either HD or PD, post-kidney transplantation, graft failure, dialysis-related complications, and death. While these states were consistent in most studies, some incorporated additional health states to enhance clinical and contextual relevance. For instance, Wu et al included hospitalization as a separate health state to account for the burden of acute care episodes.²⁹ Shimizu et al modeled the progression of comorbidities, particularly cardiovascular events, which are highly prevalent among dialysis patients.³¹ Surendra et al and Bayani et al included modality switching, such as transitions from PD to HD, to reflect clinical practice where PD dropout rates are high and treatment changes are common.^{5,27} These variations in model structure and health state definitions were considered appropriate and justified, reflecting differences in clinical practice patterns, resource availability, healthcare system configurations, and the perspectives adopted in each analysis. Across all models, transitions between health states were used to estimate long-term costs and health outcomes—including life years (LYs) and quality-adjusted life years (QALYs), which are standard metrics in health economic evaluations.^{5,21–23,25–28,30}

Kidney Transplantation: The Most Cost-Effective Option

Across all studies, KT consistently emerged as the most cost-effective or cost-saving KRT strategy. This finding was observed across both high-income and low-to-middle-income countries. This conclusion was reported in both high-income and low- to middle-income countries. For example, in Colombia, KT provided more quality-adjusted life years (QALYs) than dialysis (2.98 vs 2.10) at a slightly lower cost over five years (\$76,718 vs \$76,891).²³ In Iran, KT resulted in 9.43 QALYs, compared to 6.95 for PD and 6.04 for HD, with an incremental cost-effectiveness ratio (ICER) of \$1,744 per QALY compared to PD.²⁵ In Austria, increasing the use of living donor transplants was estimated to save €38 million and provide 2,242 additional QALYs over a 10-year period.²¹ Similarly, a study in Denmark showed that KT was both cost-saving and more effective than dialysis, with a 99.93% probability of being the most cost-effective option at any willingness-to-pay threshold.²² Findings from Indonesia also confirmed that KT offered better survival rates and quality of life at acceptable cost levels compared to HD.³⁰

PD-First Policies: A Cost-Effective Alternative

In settings where KT access is limited, several studies highlighted the value of PD-first strategies as a cost-efficient alternative to HD. In Indonesia, a PD-first policy produced similar life years to HD (5.93 vs 5.93), slightly higher quality-adjusted life years (QALYs) (4.40 vs 4.34), and lower costs (IDR 700 million vs IDR 735 million).³⁰ In the Philippines, PD-first strategies were found to be more cost-effective, yielding an incremental cost-effectiveness ratio (ICER) of PHP 570,029 per QALY compared to PHP 1.5 million per QALY for expanded HD coverage.²⁷ Similarly, in Singapore, continuous ambulatory peritoneal dialysis (CAPD) was shown to be more cost-effective than HD, with an ICER of SGD 96,447 per QALY.²⁶ A study in Malaysia reported that increasing PD uptake to 50% of new dialysis patients would generate significant cost savings while maintaining comparable health outcomes to current practice.⁵

Quality of Reporting

Table 3 presents the quality assessment of the 13 included studies using the Consolidated Health Economic Evaluation Reporting Standards (CHEERS) checklist. The total CHEERS scores ranged from 16 to 27 out of 28. Of the 13 studies, 11 (85%) were rated as having *good* reporting quality (scores between 75% and 96%),^{5,24–28} and 3 studies (23%) were rated as *moderate* quality (scores between 57% and 71%).^{29,33} The average score across all studies was 23 out of 28 (81%). A detailed item-by-item breakdown of CHEERS scoring for each included study is provided in [Supplementary File 2](#).

The degree of adherence to the reporting criteria in the CHEERS checklist varied across sections. Some items, including title and abstract, background and objectives, comparators, perspective, time horizon, measurement and valuation of resources and costs, source of funding, and conflicts of interest were adequately reported by nearly all studies ($\geq 93\%$).^{5,24–29,33} In particular, the measurement and valuation of resources and costs was reported in 100% of studies,^{5,24–29,33} perspective, setting and location in 92%.^{21–25,27–29,32,34} However, several items were reported less frequently. Only 2 studies (15%) characterized heterogeneity,^{21,24} 1 study (8%) addressed distributional effects,²³ and 2 studies (15%) reported an approach to stakeholder engagement,^{5,26} with none discussing its impact on outcomes. These gaps suggest that while core elements of economic evaluations were well reported, aspects related to equity, heterogeneity, and stakeholder involvement were often overlooked.

Discussion

The purpose of this review was to summarize the CUA of HD, PD, and KT in patients with ESKD, highlighting the economic impact and QALY outcomes associated with each treatment modality across various regions and study designs. The main results indicate a high overall quality of the studies, with significant variation in cost-effectiveness between the modalities, which were influenced by regional healthcare settings and the methodologies employed.

Kidney replacement therapy is the most effective intervention in end-stage kidney failure. However, further economic evidence regarding the potential benefits of the expanded economy must be reviewed to determine the most effective therapy for development in a particular country. Economic evaluation studies conducted in several countries applied a modeling approach to predict the economic impact of KRT. A CUA is an economic analysis that compares the relative costs and health outcomes in QALY of different management options and enables a judgment on the more cost-effective option. They aim to minimize costs for the greatest possible justified increase in patient-reported health outcomes.³⁵ The QALY is an outcome measure that expresses the duration and quality of life (QoL). It is widely used to assess several disease treatments' clinical and economic value.³⁶ A QALY is the product of the number of LY affected and the quality of any one life year.³⁷ A QALY accounts for survival and QoL benefits of using a healthcare technology. The QoL component of the QALY is measured using a metric known as a health utility. Given that the QALY can be used to measure the survival and QoL benefits of healthcare technology, the QALY can serve as a standard metric from which to compare the benefits of very different healthcare technologies.³⁸

All studies in this study have a target population with end-stage kidney failure. In particular, the cost-effectiveness value is calculated by comparing the use of CAPD, HD, and KT to determine the best scenario or strategy for cost-effectiveness (cost per DALY or cost per QALY). Regarding sensitivity analysis, several studies have considered the average disease burden, the total cost, the benefit–cost ratio of each therapy, and the health-related quality of life (HRQoL) patients receive.

Our study showed that KT and PD perform better when compared to HD. In particular, HD has the highest expense of the three options and shows the magnitude of the burden borne by the patient. The fact that KT yields more favorable cost-effectiveness than dialysis therapies has been previously demonstrated in several studies. 16,19,21–24,26–28 In patients awaiting their turn for RT, CAPD may be performed first.²⁸ According to Bayani (2021), in terms of QoL, there was no significant difference between twice-weekly and thrice-weekly HD patients. The utility values for all modalities highly depend on the number of comorbidities each patient has, such as hypertension and diabetes mellitus.³⁹ It is inappropriate to look only at the annual cost of each option without considering long-term viability. KT will have the highest total cost in the first year but decrease in the following years. In contrast, dialysis costs are consistently high and

Table 3 Summarize of the Included Studies

Author and Year	Country	Cost (\$)/LY	Cost (\$)/QALY	ICER (In 2023 US\$)	WTP Threshold (In 2023 US \$/QALY)	5-Year Survival Rates	Comorbidities	Outcome	Quality of Reporting (CHEERS Checklist)
Surendra et al, 2019 ⁵	Malaysia	HD: 8623.97 PD: 8143.91	HD: 10098.61 PD: 9000.22	1,473	6,480	HD: 53% PD: 39%	NA	Increasing PD as initial dialysis modality is cost-effective	Good (score 27/28, 96%)
Moradpour et al, 2020 ²⁵	Iran	HD: 13477 PD: 12865 RT: 16450	HD: 2227 PD: 1850 RT: 1744	2,160	15,340	NA	NA	RT is a better option over HD and PD	Good (score 23/28, 82%)
Rosselli et al, 2015 ²³	Colombia	HD: 21488 RT: 33108	HD: 76891 RT: 76718	2,626	17,950	DeathHD: 474 RT: 270	Diabetes mellitus, hypertension	RT can improve the overall survival rates and QoL. It is a cost-saving alternative	Good (score 25/28, 89%)
Yang Fan et al, 2016 ²⁶	Singapore	HD: 228344.87 PD: 126421.07	HD: 79095.78 PD: 452295.89	9,385	13,860	NA	Diabetes mellitus	Starting dialysis with PD is the most cost-effective option	Good (score 21/28, 75%)
Bayani et al, 2021 ²⁷	Philippines	HD: 11695.97 PD: 4458.18 RT: 8253.34	HD: 27147.69 PD: 10164.60 RT: 10306.54	6,100	7,500	HD: 0.46 PD: 0.81 RT: 0.94	NA	RT is a cost-saving alternative	Good (score 25/28, 89%)
Afiatin et al, 2017 ²⁸	Indonesia	HD: 7415.07 PD: 5972.67	HD: 13902.93 PD: 12962.63	4,269	11,130	5.93 of both	Hypertension	PD-first policy is more cost-effective than HD-first policy.	Good (score 23/28, 82%)
Wu et al, 2020 ²⁹	China	HD: 2021.20 PD: 1373.89 RT: 599.86	NA	3,178	9,470	NA	NA	RT is the most cost-effective intervention	Moderate (score 16/28, 57%)
Ferguson et al, 2021 ²⁴	Canada	NA	HD: 108526.79 PD: 87126.59	5,067	50,000	HD: 26.39% PD: 40.37%	NA	PD is more cost-effective than HD	Good (score 24/28, 85%)
Widiana et al, 2020 ³⁰	Indonesia	HD: 39056.75 RT: 49773.69	RT: 2217	3,045	11,130	HD: 18.9% RT: 45%	NA	RT is more cost-effective than HD	Moderate (score 16/28, 57%)
Shimels et al, 2019 ³²	Ethiopia	HD: 25902.08 RT: 42623.74	HD: 71860.00 RT: 13414.67	5,383	2,418	HD: 49% RT: 78%	NA	RT is more cost-effective than HD	Good (score 23/28, 82%)
Haller et al, 2011 ²¹	Austria	HD: 43659.21 PD: 22044.67 RT: 13872.02	NA	NA	NA	NA	Diabetes, HT, liver disease, HF, neoplasia, COPD, vascular disease	Live donor RT is more cost-effective than dialysis	Good (score 26/28, 92%)
Shimizu et al, 2012 ³¹	Japan	NA	HD: 6508 PD: 5441 RT: 3890	27,068	129,240	NA	NA	Live donor RT is more cost-effective than dialysis	Good (score 24/28, 85%)
Jensen et al, 2014 ²²	Denmark	NA	HD: 149003.06 RT: 116918.76	13,851	cost-saving strategy	NA		RT is more favorable than dialysis	Good (score 23/28, 82%)

Abbreviations: QALY, quality-adjusted life year; LY, life year; HD, hemodialysis; PD, peritoneal dialysis; KT, kidney transplantation; CAPD, continuous ambulatory PD; NA, not applicable.

will decrease depending only on modality-specific survival.²⁷ This is mainly due to the high cost and long duration of treatment, with most patients needing dialysis for the rest of their life or until they undergo transplantation.²⁹

HD households spent more on transportation costs than PD since they require more hospital visits, which is \$604.48 vs \$134.44.⁴⁰ PD can be considered a superior treatment choice to HD in a country with geographical variation, such as Indonesia, since it requires less household traveling expenses. Besides that, for healthcare providers, it also can reduce the need to build new facilities, buy expensive machines, and employ more highly trained staff. Budget impact analyses in Indonesia have shown that PD-first policies place a lower financial burden on payers compared to HD first approaches. While the study projected potential savings assuming full dialysis coverage (beyond the 53% coverage reported at the time of the study), these findings remain relevant for informing future policy given ongoing efforts to improve access to dialysis in Indonesia.²⁸ However, it should be emphasized that the term “PD first” does not exclude HD or other modality options, and vice versa. It is recognized that age, physical condition, comorbidities, and lifestyle influence the patient’s choice of dialysis modality.⁴¹ Despite its advantages, PD has certain limitations, including the need for patients to be adequately trained to perform the procedure at home, the potential for peritoneal infections, and the requirement for regular monitoring to prevent complications. Furthermore, PD may not be suitable for all patients, particularly those with severe abdominal conditions or those who lack support for home care.

However, a study from Wu showed that the mean unit of direct medical expenses, non-medical direct expenditures, and total economic expenses of kidney transplantation were higher than other KRT. The reasons are that the costs of surgery operations and immunosuppressive therapy of KT are higher than the costs of dialysis. On the other hand, HD patients underwent HD in the centers near their homes, while PD received home-based treatment. Therefore, the KT group’s transportation and accommodation costs were still the highest. Nevertheless, their findings indicated the highest quality of life in the KT group, followed by PD and HD.²⁹ Though KT’s economic burden is the highest, it results in optimal quality of life and utility costs. Previous studies suggested KT over dialysis because it results in a better QoL and higher life expectancy. The KT group receives the highest utility costs.⁴²

A study conducted by Ferguson showed that patients who were selected to initiate with facility-based HD were treated at a cost-effectiveness ratio of \$104,879.66/QALY, and patients who were chosen to begin with home PD were treated at a ratio of \$83,762.00/QALY. This finding is also related to transportation costs that must be incurred by HD patients who have to go to the HD center every two to three times a week. Meanwhile, PD can be done independently at home by those patients.²⁴ Another CUA from Shimels stated that transplantation is cost-effective compared to HD. While the results were computed based on patients’ perspectives, overall costs per patient in the five-year follow-up and incremental HD costs were lower than KT.³² QoL is a significant predictor of clinical outcomes for ESKD patients. It stated that poor QoL predicts death and hospitalization.⁴³ The cost-effectiveness value of KT is higher than that of dialysis due to the higher contribution to QALY in quality and life expectancy of KT than HD.⁴⁴ In developing countries, a study in Malaysia stated that the annual mortality rate in ESKD patients was higher in CAPD (0.134) than in HD (0.125). CAPD patients had a higher dialysis modality replacement rate (0.067) than HD patients (0.007). In Malaysia, the apparent difference in the risk of death between HD and CAPD was partly attributed to adverse PD patient selection. The significant increase in health utility does not compensate for the lower LY obtained in CAPD. Unlike in other countries, utilities do not differ significantly in Malaysia. This situation causes HD in developing countries to be more frequently demanded by patients. Moreover, the cost per QALY for both modalities exceed RM40,000, implying that the two modalities could be more cost-effective. This result does not reflect the real scenario as Malaysia is a country where the cost per QALY is low, and GDP increases yearly.^{5,45}

Table 2 shows KT generally provides higher QALY compared to PD and HD. In terms of both quantity (life expectancy) and quality (health-related quality of life), KT is associated with better cost-effectiveness in many settings.^{21–23,25,27,29–32,46} However, this does not imply that KT is always the dominant strategy, as it tends to incur higher initial costs. A higher QALY indicates the choice with the most significant benefit in population health and can also be considered in overall social decision-making. In Iran, the cost per LY that must be spent to carry out HD measures is \$ 13477, while for PD, it is \$ 12865, while for KT, it is \$ 16450. The costs incurred for KT are relatively higher than those of other therapies. However, the price per QALY in KT is lower, namely \$ 1744, compared to different types of therapy.²⁵ In the previous study, the effectiveness of QALY is determined by several conditions. It stated that lower life

expectancy in the old population causes lower QALY gains; an equal value of one QALY is used regardless of age; a poorer average health state, such as the patient has many comorbidities, causes lower QALY gains; and inadequate QoL measurement instruments can reduce the effectiveness of QALY.⁴⁷ A previous study by Heldal showed that KT improves health (proven by higher QALY) but has higher costs per QALY at 1-year post-transplant compared with no transplantation in ESKD patients >65 years of age. However, the mean age of the transplant population in that study was 43.7 ± 12.5 years, indicating that a small number of older patients were included.⁴⁸

It took a lot of work to compare the three KRT. Most studies compare the cost-effectiveness of HD vs PD or dialysis vs KT. However, KT has the highest cost-effectiveness value than other KRTs; long waiting lists make KT challenging to perform, especially in developing countries with limited health facilities. So, the most widely used KRT today is PD. More than 80% of Hong Kong patients chose PD.⁴⁹ Many studies have suggested that PD, particularly CAPD, is an effective KRT for patients with ESKD.^{50–52} Based on economic suitability, PD has good cost-effectiveness value, a higher early survival rate, and better protection of residual kidney function.⁵³ The experience of Thailand showed that the need for HD did not decline even after implementing a PD-First policy since the access to PD increased, and many of these patients were required to shift when they developed complications. Therapy in developing countries is advising a gradual transition to PD, starting with newly diagnosed patients who are not readily available for transplant.²⁷ Patients with PD benefited from home-based treatment and have a superior social function than HD patients. Moreover, the demand for trained medical staff and technical support in PD was not high, thus making it more suitable for application in developing countries and economically disadvantaged.⁵⁴ However, it is important to note that access to PD is not evenly distributed across socioeconomic and geographic settings. Even in countries that promote PD-First or home dialysis policies, disparities in access persist, with lower-income populations and rural areas facing greater barriers to adoption and continuation of PD.⁵⁵

Another limitation of this review is that no formal statistical comparison was performed across cost-utility estimates. Because the included studies used heterogeneous model structures, time horizons, cost inputs, and WTP thresholds, it was not feasible to perform inferential statistical analyses to test for significance of cost differences among modalities. Therefore, our comparisons are descriptive and intended to highlight general patterns across studies rather than statistically verified differences. Additionally, most of the included cost-utility analyses were model-based and did not report actual patient sample sizes for each modality. As such, it was not possible to quantitatively assess whether the observed cost-utility differences were associated with the income level of the study setting. However, general trends indicate that KT is consistently the most cost-effective strategy in high-income countries, whereas PD often emerges as the most cost-efficient option in low- and middle-income contexts with limited access to transplantation.

Even though this systematic review had several limitations, such as its inability to account for prevalence rates in strategy search and the high heterogeneity among the included studies, policymakers in developing countries can consider this study to make comprehensive policy recommendations. In this study, KT is the most cost-effective compared with HD and PD in patients suffering from ESKD. However, PD was suitable for application in developing countries and as an initial KRT before receiving KT.

Conclusion

This systematic review highlights the comparative cost-utility of KT, PD, and HD as treatment modalities for patients with ESKD. KT consistently emerged as the most cost-effective option, offering the highest QALYs and the lowest cost per QALY over the long term, despite its higher initial costs. These findings were consistent across both high-income and low- and middle-income countries, reinforcing KT's value in improving survival and quality of life. PD also showed favorable cost-effectiveness in many studies, particularly compared to HD, due to its lower direct and indirect costs and its suitability for home-based care, an advantage in resource-limited or geographically dispersed settings. In contrast, HD was often the least cost-effective, associated with higher recurring costs and lower improvements in quality of life. While KT remains the ideal option clinically and economically, its accessibility is constrained by donor shortages and infrastructural limitations, especially in developing countries. In such cases, PD offers a practical and scalable alternative, and PD-first policies, when supported by adequate training and healthcare infrastructure, may help bridge the treatment gap. These findings underscore the need for context-specific economic evaluations to guide policy decisions, with

a strategic focus on expanding access to KT while leveraging PD as a cost-effective interim solution tailored to national healthcare capacities.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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