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# Cost-effectiveness and budget impact analysis of peritoneal dialysis and haemodialysis in South Africa

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## Abstract

**Background** More than 800 million people are affected by chronic kidney disease (CKD) worldwide. In South Africa, the prevalence of CKD increased by 67% between 1999 and 2006. Haemodialysis (HD), peritoneal dialysis (PD), and kidney transplant are the three main modalities used for managing end stage kidney disease. The cost of these therapies poses a significant burden to the health care system in South Africa. The aim of this study is to determine the cost-effectiveness and budget impact of peritoneal dialysis versus haemodialysis from the societal perspective in South Africa.

**Methods** A Markov model was constructed to estimate the cost-effectiveness of peritoneal dialysis versus haemodialysis. The model was developed in excel and populated with clinical evidence and cost data synthesized from the literature. The costs and outcomes were estimated over a 5-year time-horizon. The outcomes were presented as quality-adjusted life years. Cost effectiveness was estimated using the incremental cost-effectiveness ratio and the incremental net monetary benefit (INMB). Probabilistic sensitivity analysis was also conducted to assess the robustness of the results. A budget impact model was constructed to estimate the impact of PD and HD over a 5 year period.

**Results** The total discounted costs per patient over 5 years were R788 384 for PD versus R1 227 708 for HD. The incremental cost for providing PD was estimated at -R438 875. The net QALYs for delivering PD compared to HD were estimated at -0.09. Cost effectiveness ratio for PD versus PD was R5 096 154/QALY. At a threshold of R38 500, PD provision has a 79% probability of being cost-effective relative to HD. The INMB was estimated at R328 574 for PD and R322 194 for HD indicating the cost-effectiveness of PD. The budget impact analysis showed that it would cost government approximately R25 billion over 5 years to treat all individuals eligible for KRT under the current scenario of 88% HD and 12% PD.

**Conclusions** In South Africa, PD is shown to be cost-effective at a willingness to pay threshold of less than R38 500. A PD-preferred policy that considers clinical appropriateness and patients' values should be considered.

**Keywords** Peritoneal dialysis, Haemodialysis, End-stage renal disease, Cost-effectiveness, Budget impact

## Introduction

The global burden of chronic kidney disease (CKD) has been increasing over the past two decades. Between 1990 and 2017, the prevalence of CKD increased by 33% [1], affecting approximately 850 million people globally in 2017 [2]. It is estimated that the mortality rate increased by 42% between 1990 and 2017 resulting in 1.2 million

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deaths [3, 4]. In sub-Saharan Africa, the prevalence of CKD is estimated between 10.7 and13.9% [5]. In South Africa, CKD prevalence is estimated between 6.4 and 8.7% [6]. The prevalence is said to have increased by 67% between 1999 and 2006 [7]. Obesity, hypertension, diabetes, dyslipidaemia, and environmental factors such as dietary salt intake have been shown to contribute to the development and progression of CKD [8]. In South Africa, poorly controlled diabetes and infection with the human immunodeficiency virus (HIV) have been shown to increase the risk of developing both acute kidney injury and CKD [5, 9]. Advanced CKD has been shown to increase cardiovascular mortality and morbidity [10].

The Kidney Disease: Improving Global Outcomes (KDIGO) organization defines CKD *as abnormalities of kidney structure or function for a minimum of 3 months with implications for health* [11]. The disease is managed through control of the underlying disease and delay in progression of the disease [12]. Where the disease progresses to glomerular filtration rate of less than 15mL/1.73m$^2$ (end stage kidney disease (ESKD)) kidney replacement therapy (KRT) is initiated as a replacement for the poor functioning kidneys [13]. Haemodialysis (HD), peritoneal dialysis (PD), and kidney transplant (KT) are the three modalities used for KRT [1]. Current estimates show that 32% and 45% of patients residing in low-income and low-middle income countries respectively have access to KRT [8, 14]. In Africa, the situation is even worse with less than 16% of people in need of KRT receiving treatment [15] due to unaffordable treatment and lack of access to KRT [13].

In South Africa, access to KRT is also limited. In 2018, there were 301 centres offering KRT. Approximately 89.4% of these centres are privately owned with the highest number in the Gauteng and Kwazulu-Natal Provinces [16]. In the public sector, most of the centres are hospital based as compared to a mixture of hospitals and free-standing centres in the private sector. In 2020, 2 290 patients were treated in the public sector as compared to 6 576 in the private sector.

HD was the most predominantly used KRT in the private at 82.8% as compared to 33.9% in the public sector. In the private sector, only 4.4% of patients received PD as compared to 22.8% in the public sector with the rest of the patients receiving transplant [16].

The cost of managing ESKD has been shown to be high globally. Expenditure related to KRT is estimated at 5 to 7% of total health care budgets even though ESKD affects 0.1 – 0.2% of the general population [13]. In South Africa, CKD has the second highest expenditure per patient per month in the private sector [17]. In the public sector, the annual cost of treating ESKD was estimated at USD31 993 per patient for HD and compared to USD25 282 for PD in 2017 [18]. Whilst the cost of managing ESKD in both sectors is known, the cost-effectiveness of the different interventions has not been examined. Given the increasing burden and costs associated with the management of CKD, it is crucial that the cost-effectiveness of the different treatment modalities is determined.

In Taiwan, Chang et.al have shown that PD is more cost effective than HD using cross-sectional data from 12 dialysis unit. The cost-effectiveness ratio was estimated at USD13 681 and USD16,643 per quality-adjusted life year for PD and HD, respectively. The results also showed similar estimated life expectancy for HD and PD [19]. Findings from Malaysia based on Markov modelling showed that commencement of 50% of ESKD patients on PD was cost-effective [5]. The analysis also showed that reducing PD increased costs of health care and reduced quality adjusted life years in patients [20].

Whilst the evaluations of these modalities have been conducted in other countries, such findings are not generalisable to South Africa due to contextual factors that might influence delivery of health care services. Under the National Health Insurance Scheme (NHI), which was promulgated into law in May 2024, government would provide needed services to all citizens without any contribution at the point of care. The increased burden of ESKD in South Africa has the potential to impact the NHI scheme and the allocation of scarce resources. This study seeks to provide local evidence by establishing the cost-effectiveness and budget impact of haemodialysis and peritoneal dialysis as treatment modalities for ESKD in the public sector in South Africa. Such analysis is important to assist decision-makers in making choices that ensures value for money in the use of scarce resources.

## Methods

### Study design

A Markov model (Fig. 1) was constructed to estimate the cost-effectiveness of peritoneal dialysis versus haemodialysis for a hypothetical population in South Africa. We modelled the cost-effectiveness of PD (Continuous Ambulatory Peritoneal Dialysis (CAPD)) versus HD using a hypothetical cohort of ESKD patients. The two modalities were chosen because most patients with ESKD are offered either PD or HD in the public sector. The target population comprised adults aged 40 years and older. We assumed that patients with ESKD would receive either PD or HD as their treatment modality. Patients were considered to remain in their chosen modality (PD or HD) or transition to the exit state, defined as death. Additionally, we assumed that patient characteristics, apart from age, remained constant throughout each cycle.

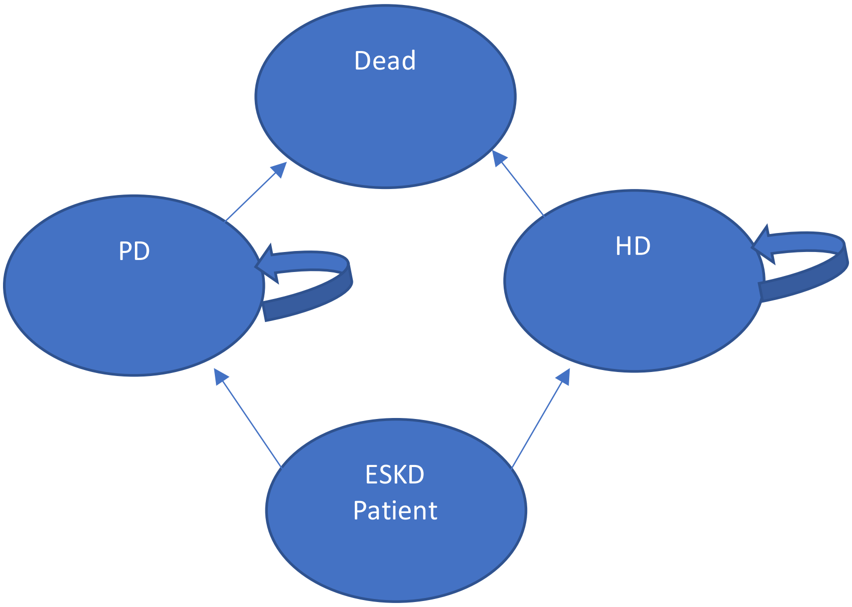

**Fig. 1** Markov model for dialysis modalities

A one-year cycle length for health state was used for the analysis. A 5-year time horizon from the government perspective was adopted. We adopted the 5-year time horizon due to the short survival rate of patients on dialysis. The input parameters included costs, transitional probabilities, and utilities for the different modalities. Both costs and effectiveness (health outcomes) were discounted at a rate of 5%, consistent with recommendations for low- and middle-income countries and South African guidelines. All costs were inflated to 2023 prices using the consumer price index for South Africa. Microsoft Excel was used to develop the model.

## Parameters and data sources

Table 1 presents the model parameters and their sources. Grey and published studies formed the sources of our input parameters.

### *Costs*

The mean costs per patient per year were obtained from the literature. Makhele, et.al estimated the direct costs of HD and PD for the management of ESKD at an academic hospital in South Africa in 2017 [18]. In this study, professionals (i.e., human resources), consumables, laboratory, equipment, drugs and maintenance costs were used to estimate annual costs of managing ESKD. In another study, Moalosi, et al. estimated the indirect costs of managing ESKD using PD and HD. In this study, time spent per visit, travel time, time employed to pick up drugs and average wage rate was used to calculate productivity loss associated with PD and HD in managing ESKD [22]. These costs (in 2017 and 2021 USD values) were converted to 2023 values using the consumer price index (CPI). The USD values were converted to the South African Rand (R) values by using the conversion factor of 1 USD = R14.79 (2021) and R13.31 (2017) .

### *Transitional probabilities*

Transitional probabilities of moving across states were estimated using mortality rates from a study which estimated a 5-year survival of patients on HD and PD in South Africa [23, 24]. The annual transition probabilities from HD to death and from PD to death were determined based on the observed mean death rates over the five-year period. The rates were converted into an annual transition probability by using the formula [27]:

$$p = 1 - e^{(-rt)} \tag{1}$$

where p is the per cycle probability, r is the per-cycle rate, and t is the number of cycles.

### *Utility estimates*

Given lack of South Africa-specific utility weights among ESKD patients, a literature search was conducted on studies measuring quality of life in patients with ESKD. Utility values were obtained from a systematic review conducted by Cooper et al. This study was deemed appropriate because it identified utility weights for a range of kidney disease states using the ISPOR Task Force Guidance [28]. The review included 17 studies conducted in various countries including UK, USA, Canada, China, and Spain. Ten of the included studies used EQ-5D-3L,

**Table 1** Model input parameters

| Parameters | Values | Distribution | Description | Source |
|---|---|---|---|---|
| Prevalence | 0.0001 | | Prevalence of patients on KRT | [21] |
| Incidence | 0.00001 | | Incidence of patients on KRT | [21] |
| HD utilisation | 0.88 | | Proportion of patients on HD treatment | [21] |
| PD utilisation | 0.12 | | Proportion of patients on PD treatment | [21] |
| **Costs (ZAR)** | | Gamma | | |
| ***Haemodialysis*** | | | | [18] |
| Fixed | 281 260 | | Cost of dialysis machine, maintenance, equipment | |
| Medication | 12 863 | | Cost of medication, e.g erythropoietin, furosemide | |
| Semi-variable cost | 131 585 | | Cost of professional services, nurses, doctors, social workers, dieticians, phlebotomist | |
| Variable | 128 672 | | Cost of laundry, consumables, lab tests | |
| Indirect | 184 317 | | Productivity loss | [22] |
| ***Peritoneal dialysis*** | | | | [18] |
| Medication | 66 527 | | Cost of medication, e.g erythropoietin, furosemide | |
| Semi-variable cost | 16 537 | | Cost of professional services, nurses, doctors, social workers, dieticians, phlebotomist | |
| Variable | 355 032 | | Cost of lab tests, and consumables | |
| Indirect | 76 319 | | Productivity loss | [22] |
| **Transitional probabilities PD** | | Beta | | [23] |
| Year 1 | 0,033 | | Annual transitional probabilities from HD to death | Estimated using reference [23, 24] |
| Year 2 | 0,070 | | | |
| Year 3 | 0,070 | | | |
| Year 4 | 0,070 | | | |
| Year 5 | 0,147 | | | |
| **Transitional probabilities HD** | | Beta | | |
| Year 1 | 0,013 | | Annual transitional probabilities from PD to death | Estimated using reference [23, 24] |
| Year 2 | 0,018 | | | |
| Year 3 | 0,018 | | | |
| Year 4 | 0,018 | | | |
| Year 5 | 0,139 | | | |
| **Utilities** | | Beta | | [25] |
| HD | 0.67 | | Patient's utility when treated with HD | |
| PD | 0.57 | | Patient's utility when treated with PD | |
| **Discount rate** | | | | [26] |
| Cost | 5% | | | |
| Utility | 5% | | | |

*PD* Peritoneal dialysis, *HD* Haemodialysis, *RRT* Renal Replacement Therapy four SF-6D, one HUI2/HUI3 whilst 2 used a combination of instruments. The review showed a decrease in utility with disease progression. Quality adjusted life years (QALYs) were calculated by multiplying the utilities with the time spent in a health state.

### Cost-effectiveness analysis

A Markov model was used to measure the cost-effectiveness of the 2 interventions. The model was used to quantify the costs and effects of the 2 interventions for managing ESKD. The main outcome were healthcare costs, QALYs, incremental cost-effectiveness ratio (ICER) and the incremental net monetary benefit (INMB). The ICER was estimated by dividing the incremental costs by the incremental QALYs. The INMB was estimated by multiplying the cost-effectiveness threshold by the health gain (total QALYs) and subtracting the total cost of the intervention. A country specific threshold of R38 500 per QALY was used [29]. All costs were reported in 2023 South African Rand and may be converted to United States Dollar using the R-US dollar exchange rate (1USD: R18,45).

### Uncertainty analysis

To test uncertainty surrounding the different model parameters, a probabilistic sensitivity analysis was conducted. Uncertainty in the results was examined with 1000 Monte-Carlo simulations across the respective probability distributions of costs, utilities, and transitional probabilities.

### Budget impact

We estimated the budget impact of HD and PD over 5 years. The 5-year period was chosen to align with the South African government's medium-term planning which occurs over a period of 5 years. We estimated the budget impact of business as usual which is the current scenario of 88% HD and 12% PD. We then estimated the budget impact of four hypothetical scenarios. In the first scenario we estimated the cost of treating 70% of patients with HD and 30% with PD. The second scenario was treatment with HD for all KRT patients. The third scenario was treatment with PD for all KRT patients. The fourth scenario was reducing treatment with HD to 50% and increasing PD to 50%.

## Results

Table 2 shows the results of the cost-effectiveness analysis. The total discounted costs per patient over a 5-year time horizon were R788 834 for PD versus R1 227 708 for HD. The incremental cost for providing PD was estimated at -R438 875. The net QALYs in PD compared to HD were estimated at −0.09. The incremental cost-effectiveness ratio for HD versus PD was R5 096 154/QALY. The INMB was estimated at R328 574 for PD and R322 194 for HD indicating the cost-effectiveness of PD.

**Table 2** Cost and cost-effectiveness of PD versus HD over a 5-year time horizon

| Time Horizon | Strategy | Total Cost | Incremental Cost | QALYs gained | Incremental QALYs | ICER/QALY | INMB |
|---|---|---|---|---|---|---|---|
| **5 years** | | | | | | | |
| | PD | 788 834 | −438 875 | 1.03 | -0.09 | 5 096 154 | 328 574 |
| | HD | 1 227 708 | | 1.11 | | | 322 194 |

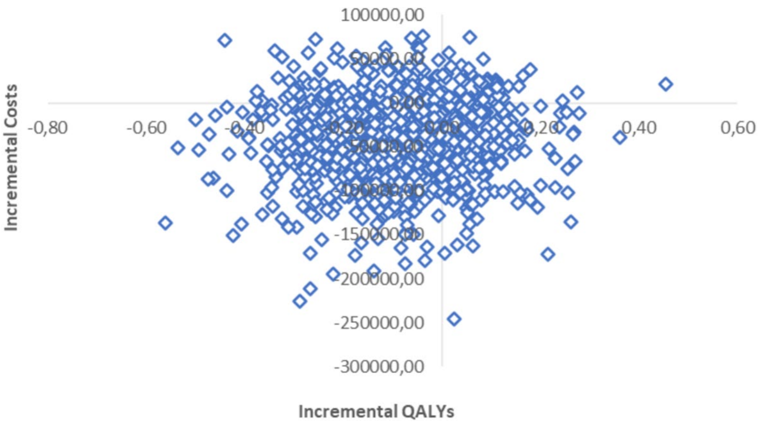

**Fig. 2** Cost-effectiveness plane over 5 years

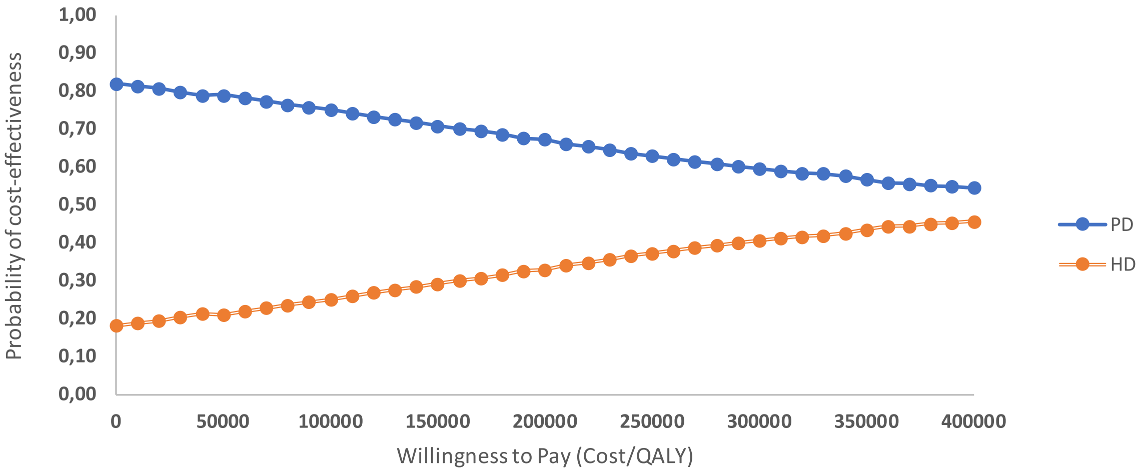

**Fig. 3** Cost-effectiveness acceptability curve for HD versus PD over 5 years

**Table 3** Budget impact

| Year | 88% HD and 12% PD | 70% HD and 30% PD | HD only | PD only | 50% HD and 50% PD |
|---|---|---|---|---|---|
| 1 | 4 544 659 926 | 4 355 173 124,21 | 4 670 984 460 | 3 618 280 008 | 4 144 632 234 |
| 2 | 4 839 927 666 | 4 602 946 120,01 | 4 997 915 363 | 3 681 351 219 | 4 339 633 291 |
| 3 | 5 129 621 138 | 4 845 380 786,58 | 5 319 114 706 | 3 740 001 642 | 4 529 558 174 |
| 4 | 5 413 865 949 | 5 082 640 420,15 | 5 634 682 969 | 3 794 541 140 | 4 714 612 054 |
| 5 | 5 194 147 912 | 4 872 221 201,83 | 5 408 765 718 | 3 620 283 997 | 4 486 884 014 |
| Total | 25 122 222 591 | 23 758 361 652,79 | 26 031 463 216 | 18 454 458 006 | 22 215 319 768 |

### Sensitivity analysis

The results of the probabilistic sensitivity analysis drawing from 1 000 random probability distributions are shown in Figs. 2 and 3. Figure 2 is the cost-effectiveness plane which shows that most of the plots appear in the lower left quadrant of the quadrant implying lower costs and outcomes as a result of the intervention. Transforming the CE plane to cost-effectiveness acceptability curve in Fig. 3 shows that at a threshold of R38 500, PD provision has a 79% probability of being cost-effective relative to HD.

### Budget impact

Table 3 shows the budget impact of the two treatment modalities over a 5-year period. The results show that it would cost government around R4.5 billion to treat all individuals eligible for KRT with the current distribution of 88% HD and 12% PD in the first year. Over 5 years this would amount to R25.1 billion. In a scenario where only HD is provided, it would cost government R26 billion over 5 years as compared to R18 billion when only PD is offered. When treatment is evenly distributed between the 2 modalities, the total budget need would be R22 billion over 5 years.

## Discussion

Our findings indicate a potential for PD to be cost-effective in the management of ESKD in the public sector in South Africa. Our study's perspective was societal using both direct and indirect costs data. The analysis showed that the costs of providing HD were higher as compared to PD. The QALYs were, however, shown to be better in HD as compared to the PD modality.

Assuming that patients do not switch between the two modalities, the analyses showed an incremental cost effectiveness ratio of R5 096 154 per quality adjusted life years over 5 years. The robustness of the model was tested using a probabilistic sensitivity analysis with 1000 iterations. At a willingness to pay of R38 500, PD was shown to be cost-effective. This finding was reinforced by the INMB which was significantly higher for PD as compared to HD.

Our findings on cost and cost-effectiveness of PD are similar to previous studies that have shown PD to be cost-effective when compared to HD in different settings. In Taiwan, Chang et al. found that PD is more cost-effective than HD using a national cohort of PD and HD patients. The study also found that the average lifetime costs were higher in HD than in PD [19]. Aroza et al. also found that the total cost was lower among patients receiving PD as compared to patients receiving HD. The analysis also showed that PD was cost-effective as compared to HD at a WTP of $50 000 after calculating the incremental net benefit [30]. Similar results were also observed in studies that investigated the cost-effectiveness of providing PD as the first option in the management of ESKD [19, 31, 32].

Regarding QALYs, our analysis showed HD to be better as compared to PD. Previous studies conducted in other countries have however shown that PD patients may have better QALYs than patients receiving HD. These differences in QALYs results could be explained by the utility values which we used in our analysis. For our study we relied on the results of a systematic review which showed a decrease in utility in PD patients as compared to HD patients [25]. The results of this review we deemed appropriate as local studies have shown poor quality of life in PD patients as compared to HD patients. Tannor et al. conducted a study in Cape Town South Africa where they showed that PD patients experienced more severe symptoms and greater limitations (diet, occupations, social interactions, body image and sexual health) as compared to HD. PD patients recorded lower scores for symptoms, energy/fatigue and sleep and higher scores for work status and dialysis staff encouragement. The overall quality of life was however not different between the two groups [33]. In another study, PD patients under a PD-First programme in Cape Town, scored worse in health-related quality of life as compared to HD patients [34]. Similar findings were observed in another hospital in Cape Town [35]. In that study, survival probability was shown to be higher in HD patients as compared to PD with better survival probability for patients who switched from PD to HD [35].

With regards to the budget impact of the 2 modalities. Our analysis showed that it would cost government over R25 billion to provide KRT to all eligible patients with the current distribution of 12% PD and 88% HD. When treatment is equally distributed between the 2 modalities government would save about R3 billion when compared to the baseline. When only HD is offered, government would need to budget over R26 billion for all eligible patients. Similar results were observed in Malaysia where it was shown that increasing the proportion of patients on PD could reduce dialysis associated costs [36].

Our study has policy implications. CKD is costly disease that would cost government over R20 billion to treat all eligible patients. CKD is also preventable. Policymakers should therefore implement policies that would reduce the underlying modifiable risk factors for CKD. Hypertension, proteinuria, obesity, poorly controlled diabetes and HIV have been linked to CKD. The cost of CKD could be reduced by preventing these risk factors through policies that have been shown to be cost-effective [37–39]. Our analysis shows that it costs government more to treat patients with HD than with PD. Policymakers should therefore invest in more PD resources. This would allow clinicians to make use of PD where it is clinically appropriate. Increasing treatment with PD would reduce the total costs of KRT which could free up resources that would allow more patients to be treated. Policymakers should also have explicit priority setting mechanisms that would also allow considerations of other factors such as equity, benefits and harms, dignity, and the impact of interventions on personal relationships. To improve health related quality of life for PD patients, additional psychological and social support should also be considered [34]. This is important as government seeks a patient centred approach to universal health coverage.

Our study has some strengths and limitations. The strength of our study is in the use of local data to estimate transitional probabilities. We used published studies to estimate transitional probabilities from treatment modality to death. The second strength is the use of locally generated evidence (direct and indirect costs) to estimate the lifetime costs of treating PD and HD. The main limitation of this study was in the use of utility values from other countries. Our choice of utility values was however guided by local studies that have compared quality of life between PD and HD patients. To account for this, we also conducted sensitivity analysis to determine the robustness of the results. The other limitation was the exclusion of complication states in our analysis which could underestimate the lifetime costs of patients. Despite the limitations stated, our study provides valuable information to guide efficient use of resources in the health sector. Future studies should therefore estimate utility values in the local setting and consider co-morbidities and complications that are common in ESKD.

## Conclusion

Chronic kidney disease poses a significant health and economic challenge globally. Access to KRT is a challenge in many low-income and low-middle income countries. Our study found that PD was more cost-effective than HD at a willingness to pay threshold of R38 500 in South Africa. Our budget impact analysis also showed that increasing PD could save government billions of Rands over a period of 5 years. This study is relevant to policymakers as the country prepares for the implementation of the NHI. A PD-preferred policy that considers clinical appropriateness and patients' values should be considered as a mechanism to free up resources that could be used for other services.

**Abbreviations**

| | |
|---|---|
| CE | Cost-effectiveness |
| CKD | Chronic kidney disease |
| ESKD | End-Stage Kidney Disease |
| HD | Haemodialysis |
| ICER | Incremental Cost-Effectiveness Ratio |
| INMB | Incremental Net Monetary Benefit |
| PD | Peritoneal dialysis |
| QALYs | Quality Adjusted Life Years |
| R | Rand |
| KRT | Kidney Replacement Therapy |
| USD | United States Dollar |

**Authors' contributions**

Conceptualization, ET; Methodology, ET; Validation, MKB; Formal analysis, ET; Writing- Original draft, ET; Writing- review and editing, ET, MKB, SG. All authors have read and approved the final manuscript.

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w and editing, ET, MKB, SG. All authors have read and approved the final manuscript.

**Data availability**

No datasets were generated during the current study.

## Declarations

**Ethics approval and consent to participate**

The study received an ethics waiver from the University of the Witwatersrand's Research Ethics Committee.

**Consent for publication**

Not applicable.

**Competing interests**

The authors declare no competing interests.

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