Cost-Effectiveness Analysis of A Program to Delay Progression to Dialysis and Death Among CKD Patients in Lima, Peru

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Research

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Abstract

Background. The Renal Health Program (RHP) was implemented in 2013 as a secondary prevention strategy to reduce the incidence of patients starting dialysis and overall mortality. A previous study found that adhered patients have 58% protection against progression to dialysis compared to non-adhered.

Objective. We aim to estimate the lifetime economic and health consequences of the RHP intervention to determine its cost-effectiveness in comparison with usual care.

Methods. We use a Markov model of three health stages to simulate for 30 years the cost associated with RHP and usual care, as well as years lived free of dialysis (YL) and Quality Adjusted Life Years (QALY). Costs were estimated from the payer perspective. We conduct a Probabilistic Sensitivity Analysis (PSA) to assess the robustness of our estimates.

Results. We found that the RHP is a cost-saving alternative compared to usual care, with a per person difference of $-782.73in costs and 0.04 in QALYs. The Incremental Cost-Effectiveness Ratio (ICER) per QALY is $-21,660. From a PSA, RHP holds cost-saving under 999 out of 1,000 evaluated scenarios.

Discussion. Our results show the lifetime economic value of a case-management intervention for CKD patients to delay its progression to dialysis. The RHP is cost-saving compared to usual care, with a negative ICER per QALY robust to different scenarios. We aim these results to help in the decision-making process of scaling-up and investment of similar strategies in Peru. Our results help to increase the evidence in Latin America where there is a lack of information in the long-term consequences of prevention and early referral strategies in CKD patients.

Introduction

In Lima, Perú, the prevalence of chronic kidney disease (CKD) is 7% higher than the national mean(1,2). Each year, 51 thousand life years are lost due to CKD and associated complications(3). Patients that progress to the end stage of the renal disease (ESRD) are likely to need renal replacement therapy (RRT). In Peru, the most prevalent RRT option is hemodialysis(1) whose annual cost in low and middle-income countries ranges from $3,424 to $42,785 in United States Dollars(4). This cost creates an access barrier to the patients – only 50% of Peruvians needing hemodialysis are able to obtain treatment (5) – as a well as major financial burden for healthcare providers.

In this context, the Renal Health Unit of the Hospital E. Rebagliati, the biggest facility of the Peruvian social health insurance (EsSalud), implemented an early-detection intervention in 2013 called the Renal Health Program (RHP). The intervention focused on early detection of CKD patients to allow timely treatment early referral to nephrology for high-risk patients, and comprehensive healthcare attention to control for comorbidities. The RHP aims to reduce the incidence of needing dialysis and overall mortality. This holistic approximation to the CKD requires coordinated efforts between the primary and the specialized care and hence aligns with the evidence that this approach is an effective way to detect at-risk patients(6).

The efficacy of the RHP was evaluated in competitive-risk survival analysis(7). This study showed that, for the general sample, adhered patients are protected against starting dialysis by 58% but there was no significant effect in the overall mortality. The current analysis builds on the said epidemiological results to inform a cost-effectiveness analysis (CEA). Our study aims to provide an economic value assessment of the RHP intervention from the payer perspective.

The economic evaluation is an essential piece to inform the decision-making process in Peru. Furthermore, this information can be useful to other countries in Latin America, a region with limited coverage of CKD treatment and dialysis for which this type of intervention might be attractive(8,9).

Methods

Intervention, Population, and Setting

The RHP intervention is based on case-management of CKD patients through the frequent and regular observance of the estimated Glomerular Filtration Rate (eGFR) and microalbuminuria levels to prevent the progression of the renal disease, control of comorbidities status (diabetes and hypertension), and promotion of healthy lifestyles. The RHP was implemented in the Hospital E. Rebagliati Network, which included the hospital and primary care centers. Target patients were adults with a diagnosis of CKD. Patients were classified in 5 states of disease progression according to the KDIGO guidelines(10) which determines specific aspects of the intervention delivery. In each visit, they received attention from the physician, nurse, and nutritionist, and performed an eGFR test for microalbuminuria detection. Additionally, some patients received social assistant and psychology care. Patients were required to visit a primary care facility in a variant frequency depending on their CKD stage: once a year for stages 1 and 2, twice for stages 3a and 3b, and three times for patients in stage 4. Patients in the early stages of the CKD (1-3a) must receive attention in primary care, while late stage patients receive attention in specialized facilities.

Modelling approach

We performed a deterministic CEA comparing the cost and health consequences of RHP to the usual care. While the intervened patients follow a treatment protocol and are closely followed-up, usual care patients receive treatment based on their demand. Usual care patients do not receive regular laboratory tests nor CKD-specific case-management consultation in other clinical services beyond Nephrology. To be considered intervened, patients had to meet a threshold of attendance during the first year, defined by expert consultation and depending on CKD stage.

Our CEA used a Markov model defined by three health states: CKD (all stages), Dialysis and Death.(Figure 1) This study used the time-to-event variables from the previous RHP epidemiologic study to estimate both survival curves (to dialysis and overall mortality) in the control group, and the estimated hazard ratios to use them as treatment effects(7). The time scale in the previous study was days, in this study we used years. Due to the change in units, survival rates might suffer small changes that are negligible.

We used parametric methods that allow us to project the survival proportions beyond the five years, from 2013 to 2018, of observed data, corresponding to CKD diagnosed patients, beginning of RRT, and overall mortality. From the many potential distributions, we would select the one with the best goodness of fit using information criteria indicators the Akaike and Bayesian Information Criterion. Using the results of the selected distribution we estimate, for each outcome, lambda and gamma as: 1/(exp (*intercept*)^(1/*scale*)) and 1/*scale*, respectively. These two parameters would allow us to estimate the survival probabilities from CKD to dialysis and death for each cycle in the usual care following this formula: 1-exp ($lambda * (cycle - 1)^{gamma} - cycle^{gamma}$). This is the probability to transit from the first health state to the other ones, expressed as a function of the cycle that accounts for the increasing risk to event alongside the time. For the RHP alternative, we used the same transition probabilities in each cycle, but a treatment effect was applied to account for the effect of the intervention. The probability to transit from dialysis to death was estimated through literature review.

Since our objective was to model, the lifetime consequences of both competing alternatives and considering that the mean age of the population of interest is around 60 years old, our model ran for 30 cycles, where each cycle represents one year. Cost and outcomes were observed at the end of each cycle. We used a simulated cohort of 1,000 people for each strategy, replicating the same CKD stage distribution and diabetes prevalence as in the original dataset for representative purposes and internal validity.

Cost assessment

Costs were estimated from the payer perspective, EsSalud, considering direct medical costs for both alternatives. We considered all costs faced by the payer to provide treatment in one year. For the intervention, we considered the costs of nephroprotection treatment, outpatient visits, and laboratory tests. These costs are not homogeneous across stages of CKD but vary due to frequency of provision (hospital visits and lab tests), and type of facility (primary care facilities have cheaper provision costs than more specialized ones), and patients with diabetes receive additionally glycosylated hemoglobin tests. We also included the implementation cost of the intervention, including a first investment that includes the time utilized by the Renal Health Unit to develop the intervention, protocol, guidelines, personnel training, and a yearly operational cost that includes the time spent by the RHP team identifying, testing, referring, and keeping accurate records of the patients.

Patients on the usual care receive on-demand outpatient visits, and subject to medical indication for laboratory tests. There was not a fixed frequency for neither of those services, contrary to the intervention. Thus, healthcare utilization would depend on the patients' behavior and preferences. Given the inherent randomness of this healthcare utilization variables, we decided to base our estimates in expert consultation. The nephrologists from the Renal Health Unit provided us with their best-educated guess of the number of outpatient visits that a regular CKD patient receives in one year. We also added the cost of one laboratory test per year without differentiation for diabetes condition or facility in which it would take place. This allow us to keep the usual care costs low, to obtain conservative estimations for the Incremental Cost-Effectiveness Ratio (ICER).

Since the costs vary across CKD stages in both alternatives, and across diabetes diagnose in the RHP, but the Markov mode used one compartment in the Markov model for all CKD stages, we use a weighted average to estimate the annual treatment cost per patient in each alternative. The weight was defined by the proportion of stages and diabetic patients in the observed data. Finally, we included the annual cost of hemodialysis by considering the cost of the session and the drugs provided in each one, and the number of sessions in a year.

We used two sources of cost estimation: the EsSalud General Management Office cost report (2018), and the report of resources use specifically for the intervention from the Renal Health Unit (2014). The first one provided the unit cost per activity, while the latter gives us the number of units per activity consumed to follow and treat a regular patient in each CKD stage. We used institutional costs to reduce uncertainty around the final estimations. Data collection was conducted in local currency, Peruvian Soles (PEN), while results are presented in United States Dollars (USD, $).

Health consequences

We sought to compare the differences in health outcomes between the alternatives using years lived free of dialysis (YL) and Quality Adjusted Life Years (QALY), to obtain a measure of the number of person-years avoided in dialysis and the number of person-years of perfect health gained, associated with the adherence to the intervention. The utility scores were obtained through literature review.

Analysis

We projected the costs and health consequences of each alternative separately during 30 cycles, each one equivalent to 1 year. Cost and health outcomes would be discounted by an annual rate of 3% in order to reflect the time-preferences of the economic agents. After these calculations, we aggregated the total costs, YL and QALY from each alternative and express them in per-person units.

To address the fundamental question of which alternative poses the highest economic value we use the Incremental Cost-Effectiveness Ratio (ICER) calculated as the difference in cost between RHP and usual care over the differences in health outcomes. Then, we can interpret the ICER as the additional cost for the payer associated to avoid one person-year in dialysis and to gain one QALY. Final estimations are made in local currency but converted to USD using a fixed exchange rate of 3.3 PEN per each USD. We use the CE threshold of 1 to 3 times the gross domestic product (GDP) per capita, estimated in $6,571 for Peru, according to the World Bank.

To assess the robustness of the ICER estimation, we performed a Probabilistic Sensitivity Analysis (PSA) based on a Monte Carlo simulation of 1,000 repetitions. In each repetition, the model randomly picked a value for each pre-defined changing parameter within its range value and considering its distribution, to create a unique context in which the RHP is evaluated against the usual care. The changing parameters were treatment effects (over both dialysis and mortality), cost of treatment, costs of dialysis, utility score of CKD, utility score of dialysis, and discount rate. The range of values for each parameter was as follows: the treatment effects would take the lower and upper values of the estimated confidence interval, the costs would vary 15%, the utilities would change 10%, and the discount rate would take 0% to reflect no discounting and 5% to reflect a scenario with higher opportunity cost. We summarized the results by descriptive statistics of the ICER per QALY distribution and a figure showing the incremental costs and QALYs for each simulation.

Results

Survival curves projection

We found that the Weibull distribution has the best fits among parametric curves for both progressions to dialysis and mortality. Using the scale and intercept we estimate a lambda and gamma as 0.008 and 0.938 for the survival to dialysis, and 0.043 and 1.143 for the survival to death. The projections consistency was assessed using the observed data and the published survival rates at the end of the 5 years.

Regarding the transition probability from dialysis to death, a study reported a survival probability of 95% for the first year of dialysis, 91% for the second, and 88% for the third(11). Since our model only considers people that just started in dialysis, and the model has a memoryless property, we use a fixed rate of 5% to estimate this transition. Considering a treatment, affect associated to the adherence to the intervention of 58% (HR=0.42, 95%CI 0.21, 0.71) reduction in risk to dialysis, and no change in mortality risk (HR=1, 95%CI 0.88, 0.71), we project the proportion of people event-free in each point of time.(Fig 2)

We found that the event-free survival curve of the intervened cohort is constantly and slightly over the usual care. This is an indication that the intervention produced gains in years lived without dialysis, and QALYs. At the end of the projection, over 90% of the cohort would be death, which is consistent with a cohort mostly composed by people around 60 years old.

Cost estimation

We estimate the annual per-patient cost of treatment is $531.18 for the RHP alternative, and $45.18 in usual care.(Table 1) The annual cost of dialysis is $13,458.79 per patient, composed by 156 sessions at $79.09 each plus $6.8 for drugs in each session, and 4 medical appointments in Nephrology ($14.84 each). The initial implementation cost of RHP is $30,411.52 and the annual operation cost $4,994.8. We do not express the operational cost as per person because they are mostly composed of fixed costs with negligible marginal costs per patient. Thus, in each alternative, the costs of the provision in one year would be determined by the proportion of people remaining event-free multiplied by the cost of treatment, plus the proportion of people entering dialysis, multiplied by the cost of one year of therapy. Additionally, for the RHP we add the cost operational cost.

Utility scores

The utility for CKD patients is 0.84, and 0.65 for patients starting dialysis. In the study, these scores correspond to the stage 3, the most prevalent stage in our cohort, and to the stage 5, a close approximation to patients just starting RRT.

Incremental costs and outcomes

Table 2 shows a summary of the parameters used in the study and the values they would take in the sensitivity analysis.

Our results showed that the cost of the RHP is $782.73 less expensive than the RHP, while avoiding 0.36 per-person years on dialysis and creating 0.04 more QALYs per-person. We found an ICER per QALY of $-21,660, and $-2,173 per year avoided in dialysis. The RHP is a cost-saving alternative. It's provision costs less than the usual care and creates higher health outcomes. (Table 3)

Sensitive analysis

We performed a PSA to evaluate 1,000 different scenarios from nine changing parameters. The usual care showed consistently higher costs and similar QALYs than the RHP. Consequently, the mean ICER per QALY was $-21,341, with a standard deviation of $7,823, and a range of values of $-50,923 to $4,050. In only one, out of a thousand repetitions, the ICER per QALY was positive. Hence, we can safely assure that RHP holds cost saving across multiple scenarios. Even more, in the single case when the ICER was positive, its value ($4,050 per QALY) was lower than the willingness to pay of the payer locate between 1 and 3 times the value of a Peruvian GDP per capita of $6,571.(Fig 3)

The incremental costs showed a range of values from -5,071 to 341 with a mean of -2,1342 and a standard deviation of 891. The incremental QALYs showed much less variability with a mean of 0.035, a standard deviation of 0.004, and a range from 0.02 to 0.049. The reason is the parameters that concentrated the largest portion of the variability over the ICER - treatment effect of the intervention, cost of the program, and cost of dialysis – have a greater effect on cost than on utilities.

Discussion

Through a lifetime deterministic CEA, we found that the RHP was cost-saving compared to the usual care with an ICER per person-year avoided in dialysis of $-2,173 and per QALY gained of $-21,660, comparing the RHP to usual care. Furthermore, our results are robust against parameter uncertainty: the PSA showed that the RHP was cost-saving in 999 out of 1,000 scenarios evaluated.

There are two main reasons behind such a low ICER per QALY. First, the difference in QALYs is very small. At a 30-year projection, the RHP generates 0.036 more QALY per person than the usual care, because the speed of disease progression is slow in both alternatives. This difference constitutes the denominator of the ICER and would create a large ratio. Second, the cost of dialysis is enormous compared to the marginal cost of providing the intervention. While treating a patient in the RHP increases the cost for the payer to $486 compared to usual care, the payers save $13,458 every time a patient delays its start on dialysis. Hence, at the end of the projection, although relatively small, the differences in costs and QALYs favors the RHP.

We used utilities from a Korean study because the study context and demographic characteristics of the targeted population was very similar to ours (12). For external validity, a metanalysis that included over 100 publications from all over the world, and adjusted for demographic location and features of the studies found a CKD utility score of 0.8, and 0.69 for dialysis (13), close to the scores we used. Additionally, our sensitivity analysis included much lower values for both health status, such as those found in USA studies using time-trade-off methods: between 0.69 and 0.67 for the CKD stages, and 0.63 and 0.54 for the dialysis patients(14,15).

From the institutional information provided by the RHP, we estimated an annual cost of hemodialysis treatment per patient of $13,458.79. We found two studies that reported cost for hemodialysis in Peru. The first one from 2006 estimated an annual cost of $7,128 in a Hospital of the Ministry of Health(16), and the second one from 2005 found the cost to be $7,536 for a hospital in EsSalud(17). Assuming an average yearly inflation of 2.5% for the period, the cost would be around $10 thousand. A smaller cost of dialysis is associated with higher ICER, however, to obtain an ICER equal to zero, this cost should be 9.8 thousand. Thus, even if those past estimations still hold, the intervention is preferred over the usual care.

In 2008 there were several Latin American countries with CKD detection programs, such as Brazil, Argentina, Colombia, and Bolivia, among others(8). However, in our literature review, we could not find any economic evaluations related to them. There is a lack of information assessing the economic impact of prevention strategies in the Region. The ISPOR 6th Latin America Conference in Sao Paulo expressed the necessity to produce more evidence of the economic impact of these strategies with the final aim to better allocate resources(18). Considering that one of the most important factors for the long-term sustainability of prevention programs is the perception of benefits among decision-makers, we hope our findings could provide with some referential information for other ongoing strategies, with the final aim to highlight the (clinical and economic) importance of prevention among CKD patients.

Several calls have been made for strategies that aim to reduce the incidence of patients needing RRT in the Region, because of the historic economic disparities that directly affect the coverage of treatment(9,19). The RPH created a prevention strategy that relies on a multidisciplinary team capable to provide effective management of the CKD and associated comorbidities and defining a structured follow-up for patients. Moreover, it promotes coordination between primary and specialized care providers to face the CKD as a public health problem. All of these features are aligned with recommendations for effective secondary care(18,20).

Limitations

The estimations of annual cost per-patient using a weighted average has two sources of uncertainty. First, the distribution among CKD stages that would influence the final cost due to important differences in the costs between CKD stages. Our stages distribution are consistent with those reported by national level, and even to those obtained with large sample sizes(1,21,22). We do not believe a major change in the composition should be expected. Second, the cost itself. We used an institutional tariff to prevent for this variation. Moreover, we include a 15% up-and-down variation for the costs in the PSA to assess robustness.

The follow-up period in the epidemiologic study, whose results are inputs in this analysis are probably too short to observe significant variations in the mortality rates. It is expected that an increase in the lifespan of adhered patients would lead to higher treatment costs and therefore make the RHP more expensive than the results we presented and change the ICER per QALY that we obtained. Given that the RHP is cost-saving compared to the usual care it is not likely that the results would shift in favor of the usual care, but certainly would present a different scenario.

Conclusions

The RHP is a feasible and cost-saving strategy to prevent progression to dialysis in a low- and middle-income country such as Peru. Our results should be used to inform decision-making processes regarding implementation of preventive interventions against CKD.

Declarations

Ethics approval and consent to participate

Not applicable. This is a secondary data analysis that uses the results from a previous epidemiologic study on the effectiveness of the Renal Health Program, and from those, model the disease progression for two scenarios: intervention and usual care. The intervention and data collected obtained approval from the Hospital E. Rebagliati IRB.

Consent of publication

Not applicable

Availability of data and materials

This is a modeling analysis with all parameters needed to replicate the results presented in the manuscript: Methods section for the disease models, and Results for the unitary costs and utility scores. Hence, no repositories where generated for this study.

Competing Interests

ES is an independent consultant hired via a third party by the funding organization to conduct this analysis. JBZ is a Nephrology employed in the Renal Health Unit of the Hospital E. Rebagliati and lead the creation and implementation of the Renal Health Program. YHR and VS work in the funding organization.

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Authors' Contribution

ES, JBZ, YHR, and VS conceptualization of study. ES quantitative analysis and manuscript writing. JBZ, YHR and VS important contributions to improve manuscript. All authors read and approved the final manuscript.

References

1. Loza-Munarriz C, Ramos-Muñoz W [Situation Analysis of the Chronic Kidney Disease in Peru] [Internet]. Dirección General de Epidemiología. Ministerio de Salud - MISA; 2016. Available from: http://www.dge.gob.pe/portal/index.php?option=com_content&view=article&id=598&Itemid=353.
2. Francis ER, Kuo C-C, Bernabe-Ortiz A, Nessel L, Gilman RH, Checkley W, et al. Burden of chronic kidney disease in resource-limited settings from Peru: a population-based study. BMC Nephrol. 2015 Jul;24:16:114.
3. Dirección General de Epidemiología - DGE. Carga de Enfermedad en el Perú. Estimación de los años de vida saludables perdidos [Internet]. Lima: Ministerio de Salud - MINSA; 2014. Available from: http://www.dge.gob.pe/portal/docs/tools/Cargaenfermedad2012.pdf.
4. Mushi L, Marschall P, Fleßa S. The cost of dialysis in low and middle-income countries: a systematic review. BMC Health Serv Res [Internet]. 2015 Nov 12 [cited 2020 Feb 25];15. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4642658/.
5. doi/10.5935/0101-2800.20150081

Herrera-Añazco P, Benites-Zapata VA, León-Yurivilca I, Huarcaya-Cotaquispe R, Silveira-Chau M. Chronic kidney disease in Peru: a challenge for a country with an emerging economy. Jornal Brasileiro de Nefrologia [Internet]. 2015 [cited 2018 Nov 18];37(4). Available from: http://www.gnresearch.org/doi/10.5935/0101-2800.20150081.

6. Bravo-Zúñiga J, Gálvez-Inga J, Carrillo-Onofre P, Chávez-Gómez R, Castro-Monteverde P. Early detection of chronic renal disease: coordinated work between primary and specialized care in an ambulatory renal network of Peru. J Bras Nefrol. 2019;07(2):176–84. 41(.
7. Saldarriaga E, Bravo-Zúñiga J, Hurtado-Roca Y, Alva I, Suárez V. Renal Health Program: Cost-Effectiveness Analysis of a Secondary Prevention Strategy to delay progression to dialysis and overall mortality among CKD patients in Lima, Peru. Value in Health. 2019 May;22:S382–3.
8. Cusumano AM, Bedat MCG. Chronic Kidney Disease in Latin America: Time to Improve Screening and Detection. CJASN. 2008 Mar 1;3(2):594–600.
9. Rosa-Diez G, Gonzalez-Bedat M, Pecoits-Filho R, Marinovich S, Fernandez S, Lugon J, et al. Renal replacement therapy in Latin American end-stage renal disease. Clin Kidney J. 2014 Aug;7(4):431–6.
10. Levey AS, de Jong PE, Coresh J, El Nahas M, Astor BC, Matsushita K, et al. The definition, classification, and prognosis of chronic kidney disease: a KDIGO Controversies Conference report. Kidney Int. 2011 Jul;80(1):17–28.
11. Cieza Zevallos J, Jeanette BH, Zegarra Montes L, Ortiz Soriano V, León Rabanal C. Supervivencia en terapias de reemplazo renal dentro de un concepto integral de oferta de servicios públicos en el Perú, periodo 2008 y 2012. Acta Médica Peruana. 2013 Oct;30(4):80–5.
12. 10.1111/nep.13203
Go D-S, Kim S-H, Park J, Ryu D-R, Lee H-J, Jo M-W. Cost-utility Analysis of the National Health Screening Program for Chronic Kidney Disease in Korea. Nephrology [Internet]. 2017 Dec 5 [cited 2018 Nov 21]; Available from: https://onlinelibrary.wiley.com/doi/abs/10.1111/nep.13203.
13. Wyld M, Morton RL, Hayen A, Howard K, Webster AC. A Systematic Review and Meta-Analysis of Utility-Based Quality of Life in Chronic Kidney Disease Treatments. PLoS Med [Internet]. 2012 Sep 11;9(9). Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3439392/.
14. Irina Gorodetskaya S, Zenios CE, McCulloch A, Bostrom C-Y, Hsu AB, Bindman, et al. Health-related quality of life and estimates of utility in chronic kidney disease. Kidney Int. 2005;68:2801–8.
15. Lee CP, Chertow GM, Zenios SA. An Empiric Estimate of the Value of Life: Updating the Renal Dialysis Cost-Effectiveness Standard. Value in Health. 2009 Jan 1;12(1):80–7.
16. Hurtado A. End stage renal failure and risk factors in Peru [Internet]. Ministry of Health; 2006. Available from: ftp://ftp2.minsa.gob.pe/donwload/esn/dnt/srenal/InsRenalPeru.pdf.
17. Loza-Concha R, Quispe A. Costo-utilidad del transplante renal frente a la hemodiálisis en el tratamiento de la insuficiencia renal crónica terminal en un hospital peruano. Revista Peruana de Medicina Experimental y Salud Pública. 2011;28(3):432–9.
18. Gilardino RE, González-Pier E, Brabata C. End-Stage Renal Disease Models in the Americas: Optimizing Resources to Achieve Better Health Outcomes. Value in Health Regional Issues. Dec. 2018;1:17:115–8.
19. RodriGuez-Iturbe B, Bellorin-Font E. End-stage renal disease prevention strategies in Latin America. Kidney Int. 2005 Sep;68(1):30–6.
20. Wouters OJ, O'Donoghue DJ, Ritchie J, Kanavos PG, Narva AS. Early chronic kidney disease: diagnosis, management and models of care. Nat Rev Nephrol. 2015 Aug;11(8):491–502.
21. Hill NR, Fatoba ST, Oke JL, Hirst JA, O'Callaghan CA, Lasserson DS, et al. Global Prevalence of Chronic Kidney Disease – A Systematic Review and Meta-Analysis. PLOS ONE. 2016 Jul;6(7):e0158765. 11(.
22. O'Callaghan CA, Shine B, Lasserson DS. Chronic kidney disease: a large-scale population-based study of the effects of introducing the CKD-EPI formula for eGFR reporting. BMJ Open. 2011 Jan 1;1(2):e000308.

Tables

Table 1
Treatment cost for each stage and alternative

	Stage 1		**Stage 2**		**Stage 3a**		**Stage 3b**		**Stage 4**	
	Diabetic patient	Non-diabetic patient	Diabetic patient	Non-diabetic patient	Diabetic patient	Non-diabetic patient	Diabetic patient	Non-diabetic patient	Diabetic patient	Non-diabetic patient
Cohort distribution										
Proportion of diabetes within stage (% (n))	51% (1,833)	49% (1,781)	42% (2,109)	58% (2,890)	29% (2,407)	71% (6,026)	24% (536)	76% (1,671)	22% (245)	78% (856)
Proportion of stages within cohort (%)	18%		25%		41%		11%		5%	
Treatment cost for the Renal Health Program										
Outpatient visits (USD)	314.67	314.67	314.67	314.67	339.52	339.52	439.45	369.76	1,017.76	839.58
Laboratory tests (USD)	37.70	34.00	37.70	34.00	69.30	61.91	269.91	197.21	343.70	296.67
Drugs (USD)	47.27	42.91	47.27	42.91	47.27	42.91	117.79	83.94	334.70	280.12
Hospital overhead (USD)	20.00	20.00	20.00	20.00	20.00	20.00	39.97	39.97	39.97	39.97
Total (USD)	419.64	411.58	419.64	411.58	476.12	464.36	867.12	690.85	1,736.12	1,456.30
Annual Cost per patient for each stage (USD)	415.67		414.97		467.70		733.67		1,518.58	
Annual Cost per patient (USD)	531.18									
Treatment cost Standard of care (SoC)										
Outpatient visits	49.0		49.0		49.0		98.0		98.0	
Laboratory test	92.2		92.2		92.2		92.2		92.2	
Total	141.2		141.2		141.2		190.2		190.2	

	Stage 1	Stage 2	Stage 3a	Stage 3b	Stage 4
Annual Cost per patient (USD)	45.18				

Table 2
Study parameters

	Value	Sensitivity values
Survival projection		
Dialysis (Probability C2D)		
Treatment effect (Hazard Ratio)	0.42	0.21–0.71
Lambda	0.008	
Gamma	0.938	
Mortality (Probability C2Dth)		
Treatment effect (Hazard Ratio)	1	0.88–1.13
Lambda	0.043	
Gamma	1.143	
Mortality among dialysis patients (Probability D2Dth)	5%	
Annual costs (USD)		
RHP cost of treatment	531.20	451.51–610.91
Standard of care cost of treatment	45.19	38.48–51.82
Dialysis treatment	13,458.79	11,439.70–15,477.58
RHP Initial investment (unique)	30,411.52	
RHP annual operational costs	4,994.55	
Utility scores		
CKD event-free	0.84	0.76–0.92
First time dialysis	0.65	0.59–0.72
General		
Discount rate costs and outcomes	3%	0% – 5%
Exchange rate (PEN per USD)	3.3	
Projection length (cycles)	30	
Cycle length (years)	1	

RHP: Renal Health Program; CKD: Chronic Kidney Disease; USD: United States Dollars; PEN: Peruvian Soles

Table 3
Cost-Effectiveness Analysis Results

	Renal Health Program	Standard of care	Difference
Costs (USD, per person)	9,356.67	10,139.70	-782.73
YL (per person)	9.50	9.14	0.36
QALY (per person)	8.18	8.15	0.04
ICER /YL (USD)	-2,173		
ICER /QALY (USD)	-21,660		

QALY: Quality-Adjusted Life Year; ICER: Incremental Cost-Effectiveness Ratio; YL: Years of Life; USD: United States Dollars.

Figures

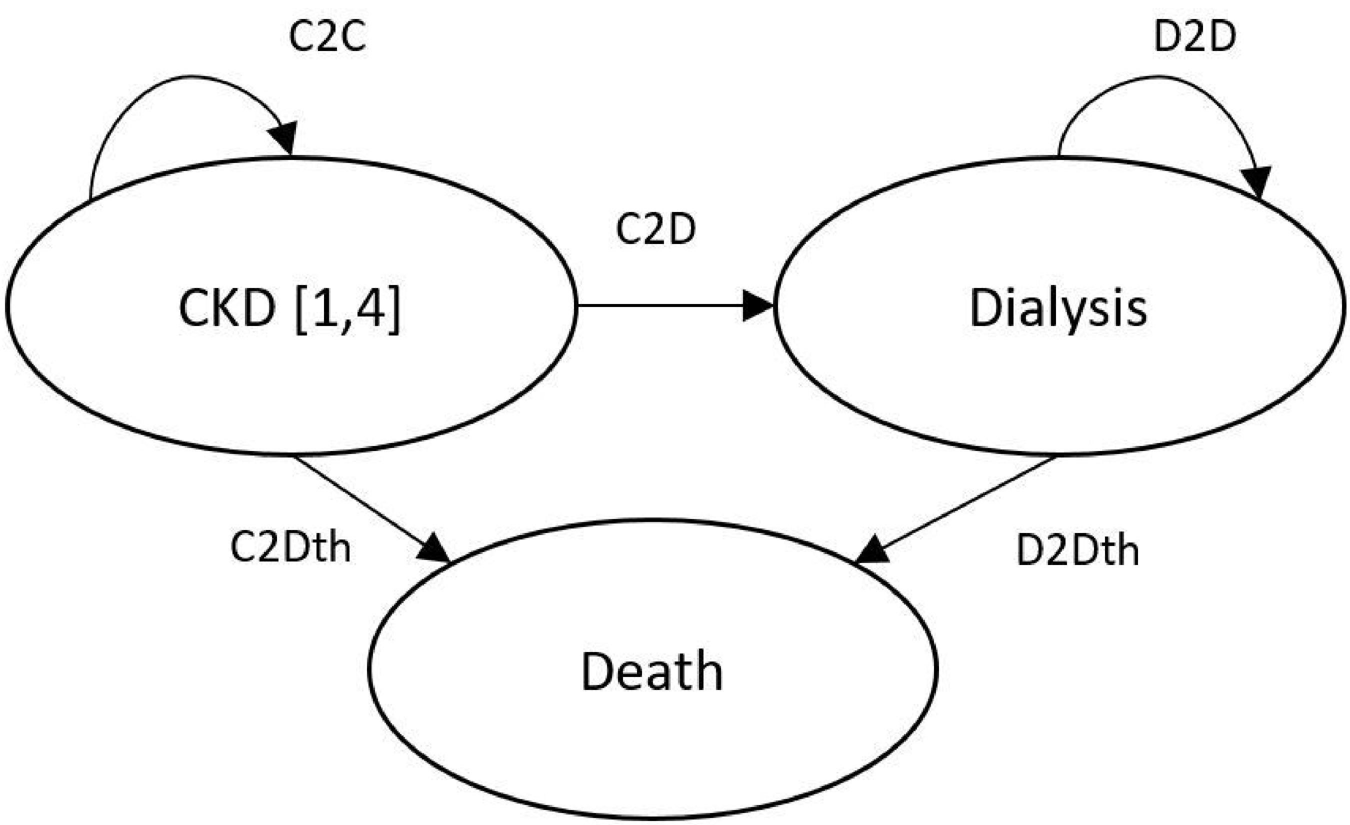

Figure 1

Markov Model and transition probabilities codes CKD: Chronic Kidney disease. Includes stages 1 to 4 of the disease

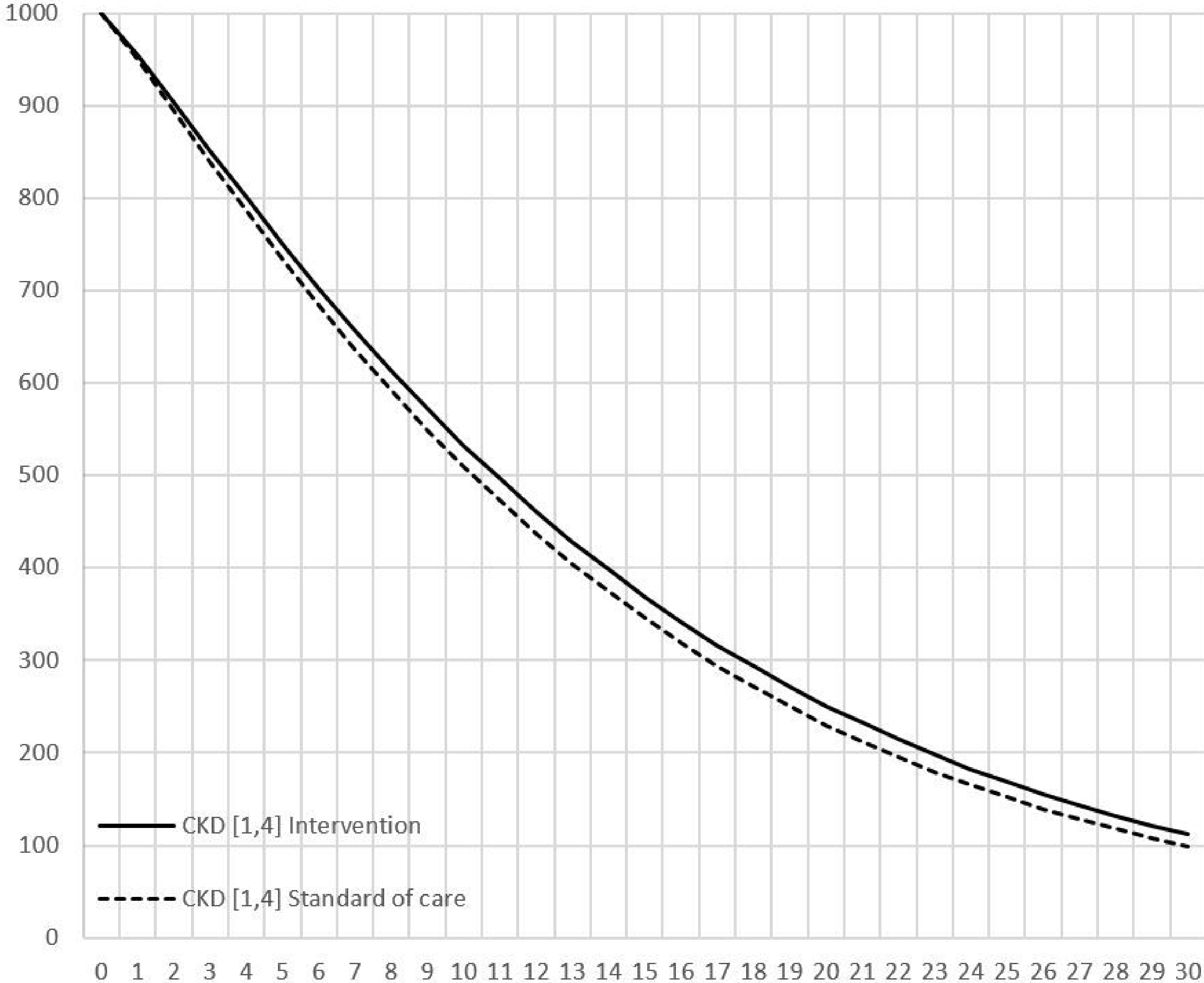

Figure 2

Event-free survival by alternative CKD: Chronic Kidney disease. Includes stages 1 to 4 of the disease

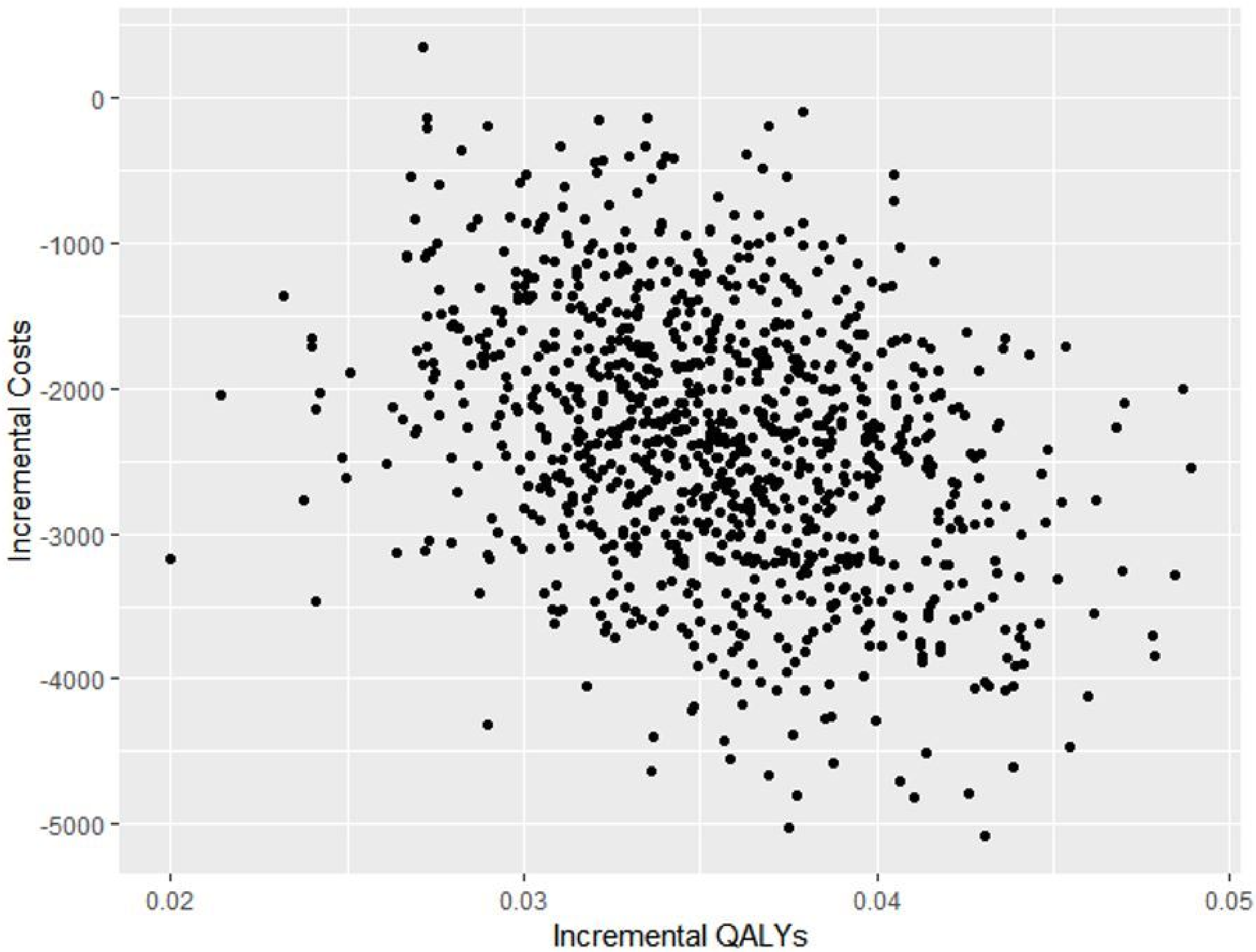

Figure 3

Probabilistic Sensitivity Analysis. The x-axis expresses the incremental Quality Adjusted Life-Years (QALYs) comparing the Renal Health Program (RHP) to Standard of Care, while the y-axis represents the incremental costs of the same comparison.