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ORIGINAL ARTICLE

CONTENTS

Cost-effectiveness of dialysis and kidney transplantation to treat end-stage renal disease in Ukraine

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ABSTRACT

Aim: To determine the economic feasibility of using kidney transplantation compared to hemodialysis in end-stage renal disease in the long term in countries with a low and medium level of economic development using the example of Ukraine.

Materials and Methods: The cost effectiveness analysis method was used. Conducted Markov modeling and comparison of the consequences of kidney transplantation and hemodialysis in terms of treatment costs and the number of added years of life for a cohort of 1,675 patients were carried out. The incremental cost-effectiveness ratio is defined.

Results: Based on the results of modeling, it was determined that among 1,675 patients with end-stage kidney disease in Ukraine, 1,248 (74.5%) will remain alive after 10 years of treatment when kidney transplantation technology is used. The highest costs will be in the first year ($25,864), and in subsequent years - about $5,769. With the use of hemodialysis technology, only 728 patients (43.5%) will be alive after 10 years, the cost of treating one patient per year is $11,351. The use of kidney transplantation adds 3191 years of quality life for 1675 patients compared with hemodialysis (1.9 years per patient).

Conclusions: Kidney transplantation is an economically feasible technology for Ukraine, as the incremental cost-effectiveness ratio is $4694, which is 1.04 times higher than Ukraine's GDP per capita. The results of the study allow us to recommend that decision-makers in countries with a low and medium level of economic development give priority in financing to renal transplantation.

KEY WORDS: prevalence, kidney disease, Markov modeling, transplantation, hemodialysis, Ukraine

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INTRODUCTION

Significant attention and growing interest in most countries to the economic side of the health care system, characteristic of the last decades, is explained by the fact that health is becoming an increasingly valuable factor. The costs of maintaining the health care system are increasing. This trend persists in almost every country in the world and requires a thorough search for new solutions to curb the growth of costs. That is why it is urgent to implement an economic assessment of the feasibility of introducing new technologies in the medical field and the effectiveness of the existing approaches [1].

Treatment of end-stage renal disease is one of the areas that require such an assessment. Chronic kidney disease is a global socio-economic problem, as 5-10% of the world's population has signs of this disease [2, 3]. The number of terminally ill patients increases to 7% every year. They require treatment with renal replacement therapy (RRT). According to experts' forecasts, every 10 years the number of patients who will need treatment with RRT methods will double [4,5].

In 2020, there were 11,940 citizens with end-stage kidney disease in Ukraine (284.4 per 1 million population), of which 1,803 people were treated with renal replacement therapy for the first time. Hemodialysis technology was used for 1675 patients (93%), renal transplantation was performed in 128 patients (7%). 10,250 patients (244.1 per 1 million population) received various types of renal replacement therapy [6]. 8,791 patients were treated with various types of dialysis, which is 209.4 per 1 million population. In 2020, 1,675 people started dialysis treatment for the first time. The number of patients who underwent kidney transplantation is 1,459 (34.8 per 1 million population), of which 128 patients underwent transplantation in 2021 [7]. Among patients treated with hemodialysis, a high mortality rate is noted, because 11.1% of the total number of people treated by this method die annually, and in the case of transplantation, the mortality rate is 1.4% [7].

The main method of treatment for such patients is renal transplantation [8-11], while in Ukraine, hemodialysis is used for renal replacement therapy in more than 90% of cases [7, 12, 13]. That is why it is relevant for Ukraine to carry out a comparative economic evaluation of the treatment of end-stage renal disease by the method of hemodialysis and kidney transplantation.

AIM

The purpose of this study was to determine the economic feasibility of using renal transplantation technology compared to hemodialysis in end-stage renal disease in the long term in countries with a low and medium level of economic development, using Ukraine as an example.

MATERIALS AND METHODS

The cost effectiveness analysis (CEA) method was used to determine the economic feasibility of priority use of a certain technology. Markov modeling of the results of the use of two medical technologies for renal replacement therapy was carried out: hemodialysis (the first technology) and kidney transplantation (the second technology). This method is optimal for economic forecasting of the long-term impact of renal replacement therapy technologies on treatment outcomes, taking into account the quality and life expectancy of patients.

In the Markov model, a hypothetical cohort of patients who are in the initial state before the study and transition to different states during the cycle according to certain probabilities is studied [14, 15]. A patient can be in only one of the states, so the number of patients who are distributed by state is determined in each subsequent cycle. Costs for both options were estimated in monetary units.

Comparisons of the relative improvement in population health due to the use of new technology were assessed using the Quality Adjusted Life Years (QALY) indicator. The number of QALYs and treatment costs were calculated during each Markov cycle for the specified condition and the technologies studied.

A technology in which one unit of incremental health improvement (in our case - one QALY) can be achieved at an acceptable incremental cost of one technology to the comparison alternative (the second technology) is considered economically feasible (formula 1).

ICER = (C2-C1) / (QALY2-QALY1) (1)

where: ICER – incremental cost-effectiveness ratio;

C1 – costs for the "first" technology in monetary units;

C2 – costs for the "second" technology in monetary units;

QALY1 - the number of years of quality life when using the "first" technology;

QALY2 - the number of years of quality life when using the "second" technology.

The research program included the following stages:

1. Development of the Markov model (definition of Markov states and variants of the transition between them).
2. Search for scientific and statistical data to calculate the matrix of transition probabilities between Markov states.
3. Calculation of the number of QALYs and the cost of renal replacement therapy by hemodialysis ("first" technology)
4. Calculation of the number of QALYs and the cost of renal replacement therapy by kidney transplantation ("second" technology).
5. Determining the ICER and deciding on the recommendations.

During the simulation of both technologies, we assumed that they are used for all patients with an established diagnosis of end-stage renal disease who require RRT for the first time in the current year.

When modeling the use of the "first" RRT technology (hemodialysis), the following Markov states were defined: 1. a patient who receives hemodialysis sessions and has no complications; 2. a patient who has complications due to hemodialysis that require treatment; 3. death.

Taking into account statistical data, we determined the probabilities of transitions between states (Table 1).

The indicators of the quality of life during the stay in different states of this model (taken into account when calculating the number of QALYs) were taken as follows: hemodialysis without complications – 0.61; hemodialysis with complications - 0.55; death is 0.

When creating the second model (kidney transplantation), we defined the following Markov states: 1. a patient with a transplanted kidney without complications (receives immunosuppressive therapy, supportive treatment, laboratory diagnostics, consultations); 2. a patient who underwent a kidney transplant and complications arose - rejection of the transplant (such patient is transferred to hemodialysis); 3. death.

Taking into account statistical data, we determined the probabilities of transitions between states (Table 2).

The indicators of the quality of life during the stay in various states were taken as follows: a patient with a transplanted kidney - 0.72, a patient with transplant rejection (on hemodialysis) - 0.59; death is 0.

The time horizon of the simulation was 10 years. The duration of the Markov cycle is 1 year. The discounting of life expectancy and the amount of expenses was taken into account in the amount of 3% per year.

Table 1. Probability matrix of transitions between Markov states during hemodialysis

From state/to state	1. hemodialysis without complications	2. hemodialysis with complications	3. Death
1. Hemodialysis without complications	0.81	0.11	0.08
2. Hemodialysis with complications	0.05	0.87	0.08
3. Death	0.00	0.00	1.00

Table 2. Probability matrix of transitions between Markov states during kidney transplantation

From state/to state	1. A patient with a kidney transplant	2. Transplant rejection	3. Death
1. Kidney transplant patient (first year after surgery)*	0.716	0.27	0.014
1. A patient with a kidney transplant (following years after surgery)	0.976	0.01	0.014
2. Transplant rejection	0	0.92	0.08
3. Death	0	0	1

*the first year after the operation, the graft rejection rate reaches 27%, in subsequent years - 1%.

Table 3. Aggregate costs of RRT by hemodialysis per year per patient

No. z/p	Name of expenses	Costs, USD
1	Hemodialysis procedure	8859
2	Laboratory tests	246
3	Medication correction of complications	769
4	Diagnosis and treatment of viral hepatitis	369
5	Indirect costs of the patient (transportation)	1108
	Together	11351

Table 4. Costs of RRT by kidney transplantation

Name	Costs, USD
Expenses during the first year	*28564*
Transplantation operation	21513
Immunosuppressive therapy	5128
Correction of complications	897
Laboratory diagnostics	385
Observations, consultations	641
Expenses during the second and subsequent years	*5769*
Immunosuppressive therapy	4359
Correction of complications	769
Laboratory diagnostics	385
Observations, consultations	256

RESULTS

Hemodialysis replacement therapy is life-long and is carried out in a medical facility three times a week (144-150 times a year). This technology requires additional costs (prevention and treatment of complications, transport) and significantly reduces the quality and length of life. The amount of expenses per patient during the year during hemodialysis treatment is 11,351 USD (Table 3).

The cost of a kidney transplant includes: expenses for management and examination of the donor and recipient; costs of the operation, including all con-

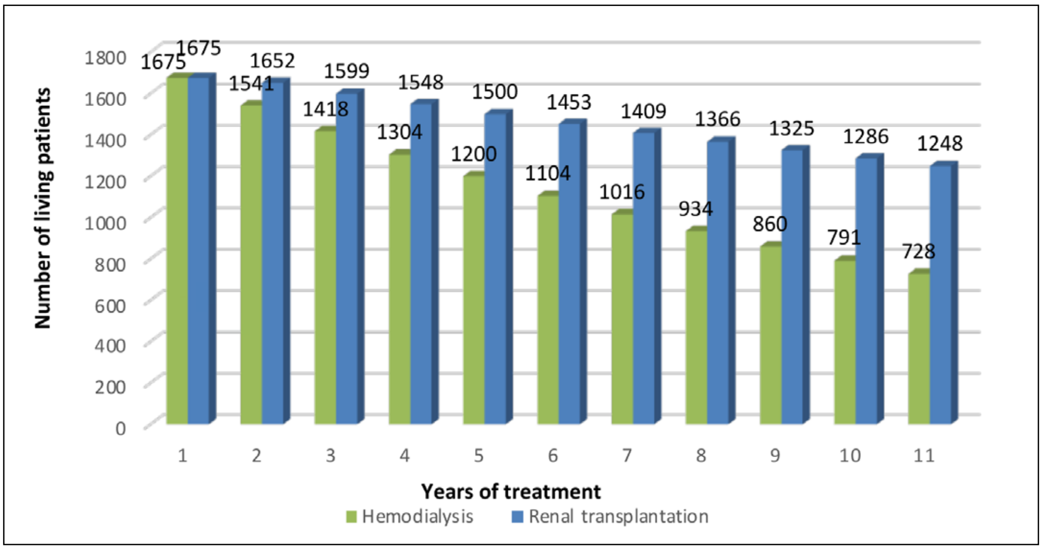

Fig. 1. Forecast of the dynamics of the number of patients who receive RRT by hemodialysis and kidney transplantation during 10 years of treatment.

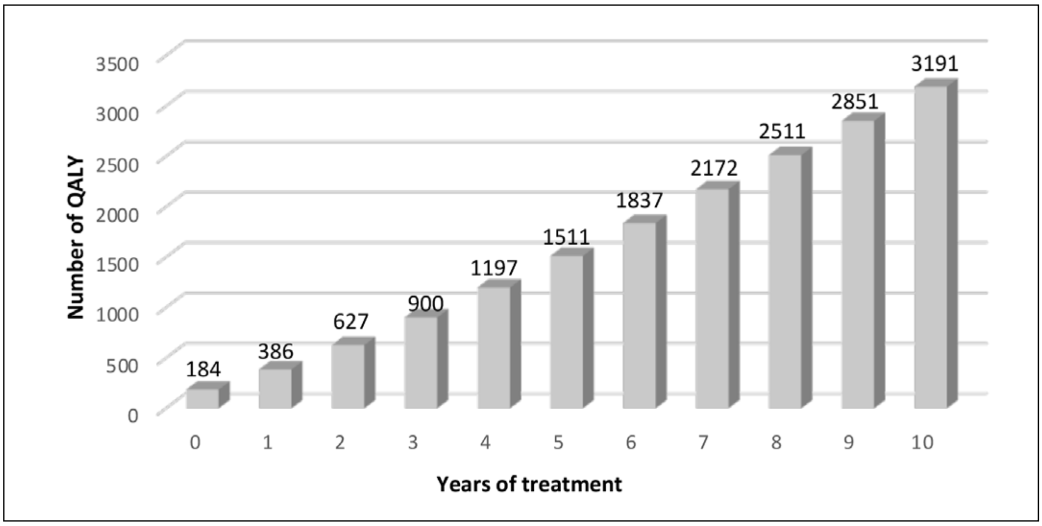

Fig. 2. The number of additional QALYs per 1,675 people obtained as a result of the use of RRT by the method of renal transplantation compared to hemodialysis, with discounting, years (forecast).

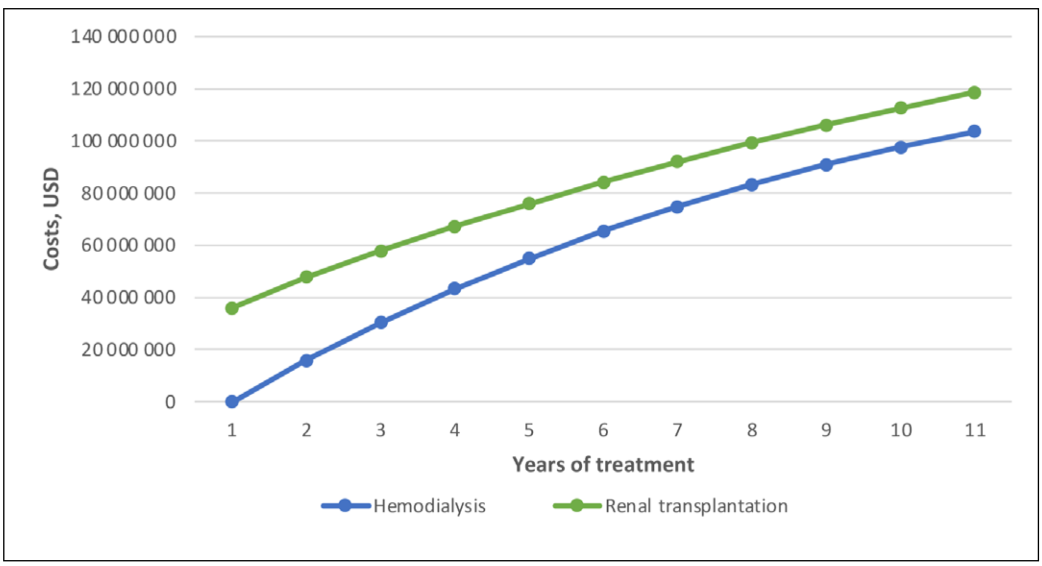

Fig. 3. Dynamics of cumulative costs for conducting RRT by methods of kidney transplantation and hemodialysis (with discounting, for 1675 people, forecast).

sumables; costs for preservation and transportation of the organ; costs for immunosuppressive therapy in the hospital are added; management of the patient in a medical institution after surgery, including costs for laboratory diagnostics, correction of complications, observation, consultations. We calculated the costs of transplantation, immunosuppressive therapy, treatment of complications, laboratory diagnostics, as well as the probability of transplant rejection in the period after discharge from the hospital (Table 4).

The highest costs when using a transplant will be in the first year ($25,864). In subsequent years, the annual cost will be about $5,769. Funds are spent mainly on life-long immunosuppressive therapy to prevent transplant rejection.

According to the results of Markov modeling in the case of renal replacement therapy by transplantation, it was determined that 1,248 (74.5%) of 1,675 patients will continue treatment at the end of the 10-year period. When using hemodialysis, due to the significant frequency of complications and the high mortality rate, only 728 patients (43.5% of the initial number) will continue treatment after 10 years (Fig. 1).

During 10 years of RRT by hemodialysis, the mortality rate per 1000 will be 565 people (56.5‰). In the case of transplantation, the mortality per 1000 people in 10 years is 255 people (25.5‰).

As for the calculation of the quality-adjusted life-year (QALY), it was found that using kidney transplantation, the number of QALYs for 1,675 patients during the 10-year treatment period would be 9,958 years (5,945 per 1,000 people). When performing RRT by the hemodialysis method, the number of QALYs will be 6,767 for 1,675 people or 4,040 per 1,000 people. The use of kidney transplantation adds 3,191 QALYs for 1,675 patients compared with hemodialysis (1.9 years per patient) (Fig. 2).

The total cumulative costs for conducting RRT by the method of renal transplantation, taking into account the cost of transplantation for 1675 people for 10 years, will be $118,738,529 ($70889 for one case). The amount of cumulative costs for hemodialysis for 10 years for the same number of patients, taking into account discounting, will amount to $103,758,684 ($61,945 per person) (Fig. 3).

We determine the cost of one QALY when using kidney transplantation compared to hemodialysis technology using the formula given earlier:

ICER = (118,738,529– 103,758,684) / (9958 - 6767) = 4694 USD

DISCUSSION

We conducted an analysis of a significant number of publications on the identification of priority technologies from the point of view of economic feasibility, which relate to strategies for the treatment of kidney diseases in different countries [2, 3, 10, 16, 17]. Under the optimistic scenario of an unlimited supply of kidneys and no waiting time for transplantation, renal transplantation for middle-aged and older adults provides a significant relative increase in life expectancy of at least 3.5 years compared to being on dialysis. Transplantation for young adults also achieves the greatest increase in life expectancy compared to those who remain on dialysis [18].

Studies have shown that kidney transplantation provides the greatest benefit and is the most effective method of renal replacement therapy compared to other methods [5, 9, 11, 19-21]. It is good value for money and sometimes provides cost savings. In contrast, dialysis is expensive, costing more than $20 billion annually in the United States, and demand for renal replacement therapy is increasing worldwide. Therefore, maximizing kidney transplantation is a priority in cost-effectiveness systems and clinical programs in most countries. Given current waiting times for transplants, the additional benefits of transplants over dialysis only become apparent after 4–5 years. Transplant increases life expectancy by 3–15 years compared to maintenance dialysis, with the increase depending on recipient and donor age[18].

Each state has special socio-economic conditions, so we determined the economic feasibility of renal transplantation compared to hemodialysis for Ukraine, which belongs to countries with a low and medium level of economic development. The size of the gross domestic product (GDP) in Ukraine in 2022 was 4,534 USD per capita [22]. According to the simulation results, the indicator of the cost of one QALY (ICER) is 1.04 times higher than GDP per capita. WHO recommends that the technology be considered economically feasible if the cost of one QALY is 1-3 GDP per capita [23]. Therefore, carrying out replacement therapy through renal transplantation in Ukraine is an economically feasible technology.

There are a number of limitations in the conducted research. Our estimates of increased survival do not take into account the possible presence of comorbidities. In the course of the simulation, we assume an ideal scenario regarding the availability of donor kidneys and the possibility of transplantation for all patients with end-stage renal disease. Treatment costs may differ from those calculated due to changes in the cost of drugs, examinations, and hospital expenses. But when conducting a sensitivity analysis, in the case of a doubling of transplant costs, the cost of one QALY will not exceed three GDP per capita in Ukraine. Therefore, transplantation will remain an economically feasible technology.

CONCLUSIONS

It was studied using Markov modeling that in Ukraine the use of kidney transplantation compared to hemodialysis gives the opportunity to save the life of 310 people out of 1000 who need RRT. Renal transplantation is an economically feasible technology for Ukraine, as the cost of one QALY of life is 4,694 USD, which is 1.04 times the size of Ukraine's GDP per capita. We hope that the results of our study will be useful to those who make decisions about the financing of medical technologies in countries with a low and medium level of economic development. Although transplantation is a valuable medical procedure and its cost exceeds the cost of hemodialysis, its use prolongs people's lives and makes them of higher quality. Therefore, it is advisable to give priority in financing to renal transplantation.

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CONFLICT OF INTEREST
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