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Economic burden and cost-utility analysis of three renal replacement therapies in ESRD patients from Yunnan Province, China

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Abstract

Purpose To compare the economic burden and cost-utility analysis of the renal replacement therapies, including hemodialysis (HD), peritoneal dialysis (PD), and allograft kidney transplantation (KT) among end-stage renal disease (ESRD) patients from Yunnan Province, China.

Methods Multistage stratified random sampling method was used to select presentative sample of 298 patients from four hospitals in Yunnan Province. The two-step model was applied to calculate a direct economic burden; the human capital approach was used to analyze the indirect economic burden. SF-36 scale was applied to assess the quality of life, while the improving score of quality of life was used to evaluate the cost-utility score.

Results A total of 298 patients were analyzed, including 108 HD patients, 91 PD patients and 99 KT patients. The mean unit economic expenses of HD, PD, and KT were $11,783.6 ± 402.63, $11,059.8 ± 709.51, and $21,151.1 ± 11,419.57, respectively. Based on the cost-utility analysis, the cost of improving one unit of quality of life in KT, PD, and HD was $599.86, $1373.89 and $2021.20, respectively; a significant difference was observed between the KT group and the HD or PD group ($P < 0.05$).

Conclusions The economic burden of ESRD in Yunnan was substantial. The cost-utility was the best in the renal transplantation group. Kidney transplantation is still recommended as the first approach for patients with ESRD, followed by PD.

Keywords End-stage renal disease · Renal replacement therapy · Economic burden · Yunnan province

Abbreviations

ESRD	End-stage renal disease
HD	Hemodialysis
PD	Peritoneal dialysis
KD	Kidney transplantation
QOL	Quality of life

Introduction

End-stage renal disease (ESRD), also known as kidney failure is the last stage of chronic kidney disease (CKD) and emerging global public health problem [1]. According to the statistics, the annual growth rate of ESRD in the Asia–Pacific regions is 4.2–17.3% [2, 3]. In China, the prevalence of CKD is 10.8%, among which 3 million patients suffer from ESRD [4]. The most effective treatment for ESRD is renal replacement therapy (RRT), which includes hemodialysis (HD), peritoneal dialysis (PD), and allograft kidney transplantation (KT) [5, 6]. Survey performed in 20 Latin American countries revealed that HD is the main treatment of choice for patients with ESRD (up to 413 ESRD patients selected HD in per million people), followed by PD (135 ESRD patients selected PD in per million people) and KT (19 ESRD patients selected KT in per million people) [7]. In China, only 20% of patients with ESRD have received RRT; and these patients are largely concentrated in large and medium-sized cities. According to the Chinese National Renal Data System database, 520,748 patients obtained HD, whereas 86,559 patients obtained PD, in 2017. The growth rate was more than 11% per year [8].

The medical costs related to ESRD present a significant burden for the family, health system and society in general [9, 10]. In the USA, patients suffering from ESRD patients (which account for 1% of the total patients)used up to 6.7%

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of the total medical insurance, while in Japan, patients(which account for 0.18% of the total patients) occupied 4.1% of the national health expenditures. Even though less than 0.1% of the Canadians suffer from ESRD, their direct medical cost was $1.3 billion, while their total economic burden reached $1.9 billion. In Australia, the incidence of catastrophic health payments of ESRD was 71%, while 51% of affected families have faced medical impoverishment [11].

Yunnan is located in a mountainous area of southwest China. This region is characterized by complex topography and a diverse climate. In 2017, the region had a population of 46.0 million people spread over 129 counties [12]. Yunnan is also known as one of the poorest provinces in China. Due to the uneven economic development and labor costs, the economic burden of RRT in different regions fluctuates. There are only a few studies, mainly single-center reports on the economic burden and cost-utility analysis of ESRD in Yunnan Province. The aim of this study was to compare the economic burden and cost-utility analysis of the three RRTs in Yunnan Province to provide patients and health policies with relevant information.

Materials and methods

Study area and population, design, subjects and sampling techniques

A cross-sectional survey was conducted from January to August 2018. A multistage stratified random sampling method was used to extract a sample of patients from Yunnan Province. The study was divided into three main steps: (1) which was done according to the standard of per capita Gross Domestic Product (GDP), 129 counties were classified into economically advantaged and economically disadvantaged counties. Kunming was selected as the economically advantaged county; and Pure as the economically disadvantaged county, (2) was to qualify the RRT at four hospitals in these two counties, (3) a total of 100 HD patients and 100 PD patients were selected by simple random sampling. Since the First Affiliated Hospital of Kunming Medical University is specialized in preforming KT, all of KT patients were selected from this hospital. The total number of patients with ESRD was 300.

Data collection and measurement

Questionnaire

A self-designed questionnaire included questions related to age, gender, nationality, marital status, educational level, economic conditions, the initial kidney disease and presence of a disability. Information on ESRD costs included costs for hospitalization, outpatient service, expenses for medicine, costs of accommodation and transportation during the visits, costs of nursing homes, and expenses of work absence. The expenses were adjusted to 2018 values and then converted to US dollars using the official conversion rate in 2018, ¥6.66 for each $1.00.

Laboratory results

The laboratory results included the blood urea nitrogen (Bun), serum creatinine (Cre), hemoglobin (Hb), serum albumin (ALB), blood calcium and blood phosphorus levels.

Inclusion and exclusion criteria

The patient inclusion criteria were the following: glomerular filtration rate (GFR) < 15 ml/min (1.73 m^2), which was defined as the CKD5, namely for ESRD; the renal replacement therapies (HD, PD and KT) in patients with ESRD that did not change over a period of three months; patients with certain communication skills, conscious, able to understand and cooperate; aged 18 years and older.

The exclusion criteria were dottiness, traumatic brain injuries, with malignant tumors, recent major surgery, the induction period of dialysis patients and those with a personality disorder.

Ehical approval

The research was conducted in accordance with the Declaration of Helsinki, and the Ethics Committee of Kunming Medical University approved the protocol. All participants read and signed informed consent.

Costing analysis

The economic burden of an illness is the ceiling amount that can be saved if a disease is avoided. It included direct and indirect expenses [13], with the former measuring the costs used for the prevention and treatment of an illness that includes direct medical costs and direct non-medical costs. The direct medical costs included outpatient service, hospital care, and self-purchase of pharmaceutical products; the direct non-medical costs included accommodation and transportation expenses during visits and the costs of caregivers. The direct costs were calculated by multiplying the days lost by the average gross earning per day in 2018, while the indirect costs were measured as the expenses of productivity lost due to the incidence rate. The present research applied two-step model method to calculate direct costs as well as applied a human capital model for indirect costs. Income data was taken from the reported annual per capita net income of Yunnan [12].

Quality of life

Quality of life (QOL) is the health-related quality of life (HR-QOL), which can be defined as an individual's usual or expected physical, emotional well-being or social experience, and can beaffected by a medical condition and the treatment [14]. The 36-Item short-form health survey (SF-36), which is a general QOL scale developed by American Medical Outcomes Research Institute in 1990, was used to measure the ESRD patients' QOL. It covers a wide variety of 36 generic projects and relies on objective and/or subjective assessments, which were divided into eight domains, such as physical functioning (PF), role physical (RP), bodily pain (BP), general health (GH),vitality (VT), social function (SF), role emotional (RE), mental health (MH). The SF-36 scale meets scientific standards of good validity and reliability [15].

Statistical analysis

Epidata 3.1 software was used to establish the database. Chi-square tests and exact probability methods were used for categorical variables. A non-parametric test was used for level data analysis. Pearson correlation analysis and Spearman correlation analysis were used for two variables. All statistical significance decisions were based on two-tailed *P* values. A *p*-value < 0.05 was considered statistically significant. Besides, all statistical analyses were conducted using the Statistics Package for the Social Sciences software release 17.0 (SPSS, Chicago, IL, USA).

Results

General characteristics of the patients

A total of 300 patients aged 18 years or older were selected from 4 hospitals. Among them, 298 patients signed the informed consent, including 108 HD patients, 91 PD patients, and 99 KT patients. The HD patients underwent conventional HD, four hours per session, three times weekly. Dialyzer was disposable and was never reused. The PD patients received continuous ambulatory peritoneal dialysis (CAPD: 2 L of dextrose-based 1.5–2.5% dialysis solution (Dianeal, Baxter, Guangzhou, China)), by four exchanges daily. The KT recipients received intravenous injection of 20 mg basiliximab (IL-2RA) on postoperative day 0 and day 4. In addition, immunosuppressive therapy containing Mycophenolate mofetil (MMF was administered at a dose of 1500 mg orally daily) in combination with tacrolimus (at a dose of 0.03–0.05 mg/kg every 12 h), and corticosteroids were applied in all cases. The dosage of MMF and tacrolimus were adjusted based on blood concentrations. The general characteristics of the patients are presented in Table 1.

In total, there were 190 males and 108 females; the ratio of males and females was 1.76, while the ratio of males and females in HD, PD, and KT were 1.4:1, 1.33:1, 3.13:1, respectively. The KT group was the youngest group (mean (SD) age was 36.4 (9.3) years), followed by HD group (mean (SD) age was 49.4 (14.8) years) and PD group. The KT group had the highest education level and the most prolonged treatment duration ($P < 0.01$). For patient who received allografts transplantation, 72 cases (73.5%) received living donor-related transplantation, while 26 cases (26.5%) received cadaveric transplantation.

The direct cost of RRTs in Yunnan Province

Estimates of different expense components of the RRTs are listed in Table 2. The mean unit direct cost, direct medical costs and direct non-medical costs of KT were the highest among the three groups ($P < 0.01$) followed by HD group, which had higher direct costs and higher direct medical costs compared to PD group ($P < 0.01$). Direct medical costs comprised the largest component of total direct costs, accounting for over 95%.

Table 1 Demographic characteristics of the study population

Characteristics	HD	PD	KT
Age (years), mean (SD)	49.4 (14.8)	51.5 (12.2)*	36.4 (9.3)**
< 60 years (%)	84 (77.8)	66 (72.5)*	98 (99)**
≥ 60 years (%)	24 (22.2)	25 (27.5)*	1 (1)**
Gender			
Male (%)	63 (58.3)	52 (57.1)	75 (75.8)**
Female (%)	45 (41.7)	39 (42.9)	24 (24.2)
Treatment times (month), mean (SD)	24.2 (20.3)	20.1 (13.1)*	29.9 (31.8)**
Level of education (year), mean (SD)	10.8 (4.8)	4.9 (4.3)**	12.7 (3.6)**
Total	108 (36.2)	91 (30.5)	99 (33.3)

**$P < 0.01$, *$P < 0.05$

Quality of life in three RRT groups

Table 3 shows the scores of eight dimensions among the three RRT groups in Yunnan Province. The SF-36, MCS, and PHS scores showed significant differences among groups ($P < 0.05$). At the same time, almost all domains of the KT group resulted as superior to that of patients on dialysis.

Economic burden and cost-utility analysis in three RRT groups

Table 4 shows the economic burden and cost-utility analysis of different RRT used among patients in Yunnan Province. Among the three RRT, both of the total economic expenses and direct costs of KT were the highest ($21,151.1 ± 11,419.57 and $20,575.6 ± 11,499.14); however, the indirect costs of KT were the lowest ($575.5 ± 93.54). Based on the cost-utility analysis, the cost of improving one unit of QOL was $599.86 in the KT group, $1373.89 in the PD group and $2021.20 in the HD group; a significant difference was observed between the KT groups and the HD or PD group.

Discussion

Differences in age and gender among ESDR patient undergoing RRTs

In the present study, 83% of patients who underwent RRT (including 99% of patients who received KT patients) were

Table 2 The mean unit direct cost of RRT (in US$) in Yunnan Province

Mean unit costs	HD	PD	KT
Direct medical costs	10,814.4 ± 483.13	9783.5 ± 963.25**	20,169.0 ± 11,588.64**
Direct non-medical costs	222.1 ± 309.58	220.4 ± 290.78*	406.65 ± 83.52**
Transportation	61.9 ± 95.98	30.0 ± 27.08**	129.6 ± 243.59**
Accommodation	43.7 ± 12.54	25.8 ± 4.42**	146.1 ± 62.17**
Nutrition	116.5 ± 70.92	164.7 ± 134.09**	123.5 ± 40.69**
Total direct costs	11,036.5 ± 409.29	10,003.9 ± 636.41*	20,575.6 ± 11,499.14**

**$P < 0.01$, *$P < 0.05$

Table 3 The dimensions scores of QOL between three RRT groups ($X ± S$)

	HD	PD	KT
Physical functioning	69.86 ± 26.07	64.18 ± 17.10**	93.33 ± 11.02**
Role-physical	17.59 ± 33.88	35.16 ± 26.35**	67.42 ± 42.02**
Bodily pain	69.93 ± 29.95	69.01 ± 17.58	92.32 ± 14.56**
General health	35.14 ± 20.93	27.64 ± 14.97**	66.31 ± 18.25**
Emotional well-being	64.26 ± 19.23	59.87 ± 14.00**	80.12 ± 17.14**
Role-emotional	25.31 ± 38.63	46.89 ± 29.81**	73.06 ± 41.70**
Social functioning	63.66 ± 25.49	75.27 ± 20.58**	82.83 ± 22.27**
Vitality	42.45 ± 23.31	51.92 ± 14.27**	76.06 ± 17.34**
Mental comprehensive score	34.11 ± 23.05	49.20 ± 14.25**	73.75 ± 23.29**
Physical comprehensive score	60.70 ± 18.40	55.33 ± 10.62**	84.10 ± 9.76**
SF-36	50.83 ± 17.73	53.05 ± 9.70**	80.26 ± 12.23**

*$P < 0.05$, **$P < 0.01$

Table 4 Economic costs and cost-utility analysis of RRT (in US$) in Yunnan Province

	HD	PD	KT
Direct costs	11,036.5 ± 409.29	10,003.9 ± 636.41*	20,575.6 ± 11,499.14**
Indirect costs	747.1 ± 373.06	1055.9 ± 783.34*	575.5 ± 93.54**
Total costs	11,783.6 ± 402.63	11,059.8 ± 709.51*	21,151.1 ± 11,419.57**
Increase value of QOL	5.83	8.05	35.26
Cost-utility ratio	2021.20	1373.89	599.86

*$P < 0.05$, **$P < 0.01$

all bellow 60 years old. The disproportion was multifactorial. In China, ESRD patients tend to be younger than 60 years old [16]. Besides, the risks of surgery and immunosuppressive treatment need to be fully discussed, requiring patients with good physical quality to withstand surgery. Moreover, access to KT was limited to patients who could afford to pay for treatment expenses.

Our data suggested that the proportion of males receiving RRT was higher compared to females. Specifically, up to 75.8% of the patients receiving KT were males, which is consistent with previous studies [16]. Besides, the proportion of men suffering from ESRD was higher compared to female patients. In China, relatives are primary donors for kidney transplantation. In addition, considering that in China, men are still considered as the family's economic backbone, relatives are more eager to donate the kidney to males. Nowadays, health care and education between men and women are unequal in many places in the world [17]. The theme of 2018 World Kidney Day was "Focus on the kidney, caring about women's health", emphasizing women's health, especially kidney health [18]. It advocated equality in accepting organ donation regardless of gender.

Economic burden and cost-utility analysis of different RRTs

There is no cure for ESRD. Yet, many people livelong lives while on treatment, which can be expensive. In this study, the mean economic burden unit of HD, PD and TF was $\$11{,}783.6 \pm 402.63$, $\$11{,}059.8 \pm 709.51$, $\$21{,}151.1 \pm 11{,}419.57$ respectively. Nevertheless, according to the data from the Yunnan Provincial Department of human resources and social security [19], the average social wage in Yunnan province was \$9543.8/year. Therefore, the economic burden of patients with ESRD was much higher than per capita wage, which is to say that a middle-income family of three in Yunnan Province would be "medically impoverishment" if solely responsible for the cost of RRT.

The main economic expenses of the KT group included the cost of surgery operation and induction therapy in the transplantation year. In addition, the postoperative immunosuppressive therapy was also included the direct medical expenses. These results showed that the mean unit of direct medical expenses, direct non-medical expenses and total economic expenses of KT were higher compared to other RRTs. The reasons might be the following: first, the costs of surgery operation and immunosuppressive therapy of KT are higher than the costs of dialysis [20]. Second, due to the severe shortage of transplanted organs, it usually takes a long time to find a suitable donor kidney. Third, the First Affiliated Hospital of Kunming Medical University is a unique hospital specialized in KT, therefore, patients were required to move to Kunming to complete the operation. Besides, to get regular check-ups and monitor the blood concentration of immunosuppressive after the operation, the KT patients were required to move between the 1st Affiliated Hospital of KMU and their home.

On the other hand, HD patients underwent HD in the HD centers near their home, while PD received home-based treatment. Therefore, the costs of transportation and accommodation were the highest in the KT group. Nevertheless, our findings indicated the highest QOL in the KT group, followed by PD and HD.

QOL is a significant predictor of clinical outcomes for ESRD patients; poor QOL predicts death and hospitalization [21]. We found that dialysis had a significant influence on ESRD patients' QOL, such as post-dialysis fatigue, quality of sleep, depression, pruritus, ostalgia, muscle weakness, and restless legs. Although the economic burden of KT was the highest, it led to the optimal QOL and cost-utility. This study suggests kidney transplant more than dialysis as it results in a better quality of life and higher life expectancy. The smaller is the cost-utility ratio, the higher is the cost-utility. The KT group received the highest cost-utility. Moreover, the KT group included younger and, most probably healthier patients. So, the costs to improve QOL were well expected to be less, which is consistent with previous researches [22–24].

Furthermore, the mean unit medical expenses of HD patients were higher than that of PD patients, which is consistent with other studies [20]. The reasons may be related to the labor and equipment costs of HD, which were significantly higher than PD. The erythropoietin, iron agents, and levocarnitine were more frequently used in HD patients. Moreover, HD patients needed to go back and forth between the hospital and home frequently, which increased transportation costs.

Approximately 70% of ESRD patients were suitable for both HD and PD. In Hong Kong, more than 80% of dialysis patients chose PD. Yet, PD patients account for only 10% of all dialysis patients in Mainland China. Many studies have suggested that PD, particularly continuous ambulatory peritoneal dialysis, is an effective RRT for patients with ESRD. Based on economic suitability, PD requires lowercost; has good cost-utility, higher early survival rate, better protection of residual renal function and causes few cardiovascular complications. Patients with PD benefit from home-based treatment and they have a superior social function. 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 areas like Yunnan [25, 26].

Suggestions

It is of paramount importance to implement a comprehensive program of prevention and treatment of ESRD. Effective interventions must be applied to manage and treat patients with CKD. Besides, it is necessary to popularize and apply the knowledge of CKD and pre-dialysis. For example, we can suggest that patients take a low protein and low salt diet, and control their blood pressure and blood glucose regularly.

The policy to solve the medical impoverishment of ESRD should start from the selection of therapy and the management mode. Doctors need to balance the economic burden and the benefit of cost-utility. Over recent years, advocating "Integration treatment of RRT" and "Multidisciplinary Team models". Because the three types of RRT play a different role in different periods of ESRD, they are not antagonistic.

Yunnan is a region located in a mountainous area with complex topography. It is one of the poorest provinces in China. It is not convenient for patients to travel between the hospital and home frequently, especially in a rural region. To obtain higher comprehensive benefits, it is suggested to give policy priority to KT following by PD.

Limitations

This study has a few limitations. Firstly, this study includes patient data from only four hospitals. Secondly, the recorded amounts for direct non-medical and indirect costs were based on patients and their family members' recollection and might be subject to recall bias. Thirdly, the type of health insurance lacked in our research, as well as it may be an important factor in influencing the economic burden of ESRD.

Conclusions

Our data indicates a large number of the economic burden that is spent on the treatment of ESRD in Yunnan Province. On the one hand, it suggested strengthening the education and treatment for patients with CKD. On another hand, it recommended KT and PD as treatment of choice for patients with ESRD. To establish a network of Hierarchical medical system, improving patient's QOL and reducing the economic burden.

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Author Contributions QL conceived the ideal, designed of the study and worked on the manuscript. HW conducted field study and drafted the original manuscript. YC conducted field study and investigation. JZ and WC collected the data. ZZ provided critical comments of the manuscript. All authors approved the final version of the manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that there are no conflicts of interest.

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