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Cost-effectiveness Analysis of End-stage Renal Disease Treatments

THESIA I. GARNER, PHD* AND RACHEL DARDIS, PHD†

The cost-effectiveness of various end-stage renal disease (ESRD) treatments was compared using two different cost measures. The first measure, gross social costs, excluded output gains due to treatment, whereas the second measure, net social costs, included output gains from both market and nonmarket activities. The cost-effectiveness criterion was the cost-per-life year gained or the implicit value of a year of life. The lower the cost-per-life year gained, the more cost-effective the treatment was. Four ERSD treatments were evaluated over 20 years. Home dialysis and transplantation were more cost-effective than in-center dialysis, regardless of whether gross or net social costs were used. However, lower values were obtained in the case of net social costs reflecting a provision for output gains due to treatment. The use of net social costs also resulted in greater variations in costs-per-life year gained by age. Changes in survival probabilities affected the results for transplant patients and dialysis patients differently. Key words: cost-effectiveness analysis; end-stage renal disease treatments; gross social costs; net social costs; implicit life year values. (Med Care 1987; 25:25–34)

During the last 10 to 15 years there has been an increasing interest in the application of cost-effectiveness and cost-benefit analyses to the medical field. The main reasons for this interest are the rapidly increasing expenditures for medical care and a realization that we live in a world of scarce resources. Total national health expenditures rose from $74.7 billion in 1970 to $322.4 billion in 1982.[1] According to Birnbaum, total resources consumed by catastrophic illness accounted for more than 20% of national health care expenditures in the late 1970s.[2]

With the passage of Public Law 92–603 (the Social Security Amendments of 1972), end-stage renal disease (ESRD) patients became the first, and thus far only, victims of catastrophic illness whose treatment costs primarily are provided for by the federal government. As a result, ESRD expenditures are large relative to the number of ESRD patients,[3] and these patients are competing with many other individuals with chronic or catastrophic medical conditions for limited health care resources. As the competition becomes more acute, rationing by design or by default might again be necessary, as was

* From the Bureau of Labor Statistics, U.S. Department of Labor, Washington, D.C.

† From the Department of Textiles and Consumer Economics, University of Maryland, College Park, Maryland.

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Address correspondence to: Dr. Dardis, Department of Textiles and Consumer Economics, University of Maryland, College Park, MD 20742.

the case before the legislation.[4] Thus, program evaluation is important to assess the costs, benefits, and outcomes of ESRD treatments.

Since the late 1960s, various studies have been conducted to assess the costs, benefits, and outcomes of ESRD treatments. Two studies[5,6] used cost-benefit analyses in which benefits were measured by the projected earnings of patients dialyzing or with functioning transplants. Neither of these studies made provision for nonmarket activities, in particular the services of home-makers; thus, benefits were undervalued. Buxton and West[5] estimated the implicit social value of maintaining a patient on home or in-center dialysis by subtracting the present value of future earnings from costs and dividing this value by the number of discounted life-years gained from treatment.

Several other studies[7-11] used cost-effectiveness analysis in which the implicit value of a life-year was obtained by comparing the costs of treatment to the number of life-years gained from treatment. Life-years were discounted in some instances and undiscounted in others. In addition, the output gains of patients undergoing treatment were excluded.

The purpose of this study was to compare the cost-effectiveness of various ESRD treatments using two cost measures. The first measure, gross social costs, excludes output gains due to treatment, whereas the second measure, net social costs, includes output gains from both market and nonmarket activities. Separate analyses were conducted for different age/sex groups in order to assess the impact of differences in survival rates and output gains on the cost-effectiveness of the various treatments.

Methods

Cost-Effectiveness Models

A gross social costs model and a net social costs model were used to evaluate the cost-effectiveness of different ESRD treatments. The costs of treatments were measured in dollars, and the benefits were measured by the number of life-years gained from each treatment, times the value of a life-year, plus the output gains due to treatment in the case of net social costs. Costs and benefits were based on the experience of a group of patients receiving a particular treatment. The cost-effectiveness criterion was the implicit value of a life-year, i.e., the dollar value of a life-year which, when multiplied by the number of life-years gained, would yield program benefits equal to program costs. The implicit life-year value is equivalent to the cost per life-year gained. The lower the implicit life-year value (or cost per life-year gained) the more cost-effective the treatment is.

Gross Social Costs Model

The gross social costs of any treatment mode are the opportunity cost of resources used to provide the program, i.e., the value of production foregone for other goods and services. All future costs are discounted in order to convert them to the same period of time. This procedure recognizes that money may be put to productive use over time so that a dollar received in the future is worth less than a dollar received today.[12] The present value of gross social costs for an individual aged 'a' ($PVGSC_a$) is given below.

$$(1.) \qquad PVGSC_a = \sum_{j=a}^{n} \frac{P_a^j T_j}{(1+i)^{j-a+1}}$$

where

- a = midpoint of the age group to which an individual belongs when treatment begins,
- j = time period under consideration ($j = a, a + 1, \ldots, n$),
- P_a^j = probability that an individual aged 'a' will survive year 'j',
- T_j = treatment costs for an individual at age 'j', and
- i = discount rate.

Treatment costs are the costs associated with a particular treatment mode, including costs of labor, materials, and capital. Disability costs are not included in gross social costs because such payments are transfer payments, i.e., payments from one group to another.

The cost per life-year gained is obtained by equating the gross social costs of treatment to the number of life-years gained times the value of a life-year. The present value of life-years gained for an individual aged 'a' (PVL_a) is given below.

$$(2.)\qquad PVL_a = \sum_{j=a}^{n} \frac{P_a^j V_a}{(1+i)^{j-a+1}} = V_a \sum_{j=a}^{n} \frac{P_a^j}{(1+i)^{j-a+1}}$$

where V_a is the implicit value of a life-year or cost per life-year gained and the other terms are as defined earlier.

The above formula indicates that the same dollar value is attached to a life-year over time. However, future life-years are discounted. This does not mean that future life-years are worth less than current life-years. Rather, as Weinstein and Stason note, "The reasons for discounting life-years is precisely that they are being valued relative to dollars, and since a dollar in the future is discounted relative to a present dollar, so must a life year in the future be discounted relative to a present dollar."[13]

Net Social Costs Model

This model focuses on the resource costs to society of health care programs as opposed to the costs incurred by the health care providers. The value of additional output generated by health care recipients is deducted from the gross social costs of health care programs to yield the net social costs of such programs. Output values are measured by the actual or imputed earnings of patients.

Actual earnings are used for persons working in the labor force, whereas inputed earnings are used for homemakers because their services are not valued in the marketplace. The present value of net social costs for an individual age 'a' ($PVNSC_a$) is given below.

$$(3.)\qquad PVNSC_a = \sum_{j=a}^{n} \frac{P_a^j(T_j)}{(1+i)^{j-a+1}} - \sum_{j=a}^{n} \frac{P_a^j W_j Y_j}{(1+i)^{j-a+1}}$$

where

W_j = probability that an individual will be working at age 'j',

Y_j = earnings of an individual at age 'j', and the other terms are as defined earlier.

The cost per life-year gained is obtained by equating the net social costs of treatment to the number of life-years gained times the value of a life year in the manner previously described.

Application of Cost-Effectiveness Models

The four main treatment modes for ESRD are home dialysis, in-center dialysis, living-related donor (LRD) transplant, and cadaveric donor (CAD) transplant. Although there are two primary types of dialysis, hemodialysis and peritoneal dialysis, the results for dialysis are based primarily on data for hemodialysis because of the unavailability of data for peritoneal dialysis at the time of the study. Each treatment mode was evaluated over 5-, 10-, 15-, and 20-year periods using discount rates of 5% and 10% to convert future outcomes to the present. The 10% rate was prescribed by the Office of Management and Budget[14] for federal projects; the 5% rate was used to determine how sensitive the results were to a particular discount rate. The first year of treatment was 1981, and all costs and earnings were expressed in constant 1981 dollars.

Data were obtained for males and females in six different age groups due to variations in survival rates, work patterns, and earnings

by age. The age groups were as follows: 0–10, 11–20, 21–30, 31–40, 41–50, and 50–64. The mid-point of each age group was used as the starting age for individuals undergoing each of the four treatment modes. The analysis made provision for changes over time for dialysis and transplant patients from the onset of treatment until the end of the 20-year period or death occurred. It was assumed that dialysis patients would continue with the same treatment mode (home or in-center) for the duration of the treatment. In the case of transplant patients, provision was made for graft failure, a second transplant, and dialysis. Third and subsequent transplants were not modeled, because only a small percentage of transplant patients receive more than two transplants.[15] It was assumed that all patients in a specified age/sex group began treatment at the same time. Survival and transplant rejection probabilities and treatment costs for each age/sex group were incorporated in the estimation of life-year values. Data for all patients were included in the analysis irrespective of whether they suvived 5, 10, 15, or 20 years. Thus the implicit life-year values were the average cost per life-year gained for the group.

Data Used in the Analysis

Major data used in the analysis pertained to the following three categories: a) survival and graft retention rates, b) ESRD treatment costs, and c) value of additional output generated by ESRD patients. Information concerning each category including data sources is given in Table 1. More detailed information is available from the authors upon request.

Results

There was little difference in the costs per life-year gained when discount rates of 5% and 10% were used. Accordingly only the results for a 10% discount rate are reported here. Variations in values based on low estimates of survival probabilities and earnings are first discussed. The impact of changes in survival probabilities and earnings on costs per life-year gained are then discussed.

Cost Per Life-Year Gained: Low Estimates

Costs per life-year gained for males are given in Table 2. These values were obtained from specific values for each group using the age distribution of patients in each treatment mode as weights. Costs range from approximately $17,000 to $37,000 depending on the measure used (gross or net social costs) and treatment mode. There is a decline in costs when provision is made for output gains, i.e., net social costs are used in place of gross social costs. In both instances the most cost-effective treatment modes are LRD transplants followed by home dialysis, CAD transplants, and in-center dialysis (10, 15, 20 years of treatment).

Costs per life-year gained for females are given in Table 3. There is little difference between values for males and females when gross social costs are used due to the fact that treatment costs were the same for both sexes. Those differences that occur reflect differences in the age distributions of males and females in each treatment mode. However, costs per life-year gained are higher for females than for males in the case of net social costs reflecting differences in labor force participation and earnings. In general, the results for females are similar to those for males with respect to measure used and treatment mode.

Variations in Costs by Years of Treatment: Low Estimates

The data in Tables 2 and 3 also show the impact of the number of years of treatment on costs per life-year gained. There is little difference in the case of dialysis, because most of the costs are incurred on a continuous basis for the duration of the treatment. In contrast, surgery costs are one-time costs so that the costs of surgery decline over time,

TABLE 1. Data Used in the Analysis

Category	Source
Low survival and graft retention rates[a]	K. Krakauer, National Institute of Allergy and Information Diseases, National Institute of Health
High survival rates[b]	Low survival rates
ESRD treatment costs	
Costs excluding drug costs[c]	Eggers, PW, Health Care Financing Administration, US Department of Health and Human Services.
Drug costs	U.S. Department of Health and Human Services (1982)[17]
Value of additional output generated by ESRD patients	
Probability of working or home-making[d]	Evans and Hart, The National Kidney Dialysis and Kidney Transplant Study
Earnings in labor force	
High estimate[e]	U.S. Bureau of the Census[18]
Low estimate	75% of high estimate
Earnings of female homemakers	Brody[19] Walker and Gauger[20]

[a] Data for persons who have begun dialysis or received a transplant in 1977–1978. Age-specific rates were available for 4–4.5 years. These rates were used to generate rates for dialysis patients for the remaining 16 years using Preston's formula; $S = e^{-kt}$ where S = cumulative probability of survival, k = annual mortality rate, and t = time.[16] In the case of transplant patients, data from 9 months to 4.5 years were used because death and rejection rates were higher for the first 9 months after the transplant operation.

[b] Designed to reflect improvements in patient and graft survival rates.[8] Mortality rates were halved for dialysis and LRD transplants. LRD transplant mortality rates were used for CAD transplants.

[c] Costs were based on per capita Medicare reimbursements for patients treated in 1979. Costs in the first year were based on dialysis/transplant costs of patients undergoing treatment for the first time in 1979. Costs in the later years were based on dialysis/transplant costs of patients undergoing treatment prior to 1979. All costs were updated using the appropriate component of the Consumer Price Index.

[d] Data were available for treatment mode, age, and sex and for individuals working in the labor force or in the home.

[e] Annual mean earnings of year-round civilians workers in 1981.

[f] Based on the market-cost approach in which the market wage rates for various household activities are applied to time spent on such activities.

TABLE 2. Cost per Life-Year Gained for Males[a]

Measure	Years	Treatment Mode: Home Dialysis	In-center Dialysis	LRD Transplant	CAD Transplant
Gross social costs	5	$24,890	$31,090	$27,079	$36,640
	10	25,120	31,489	23,282	32,167
	15	25,168	31,569	22,532	31,332
	20	25,182	31,591	22,379	31,155
Net social costs	5	18,674	27,429	21,038	30,110
	10	19,210	28,065	17,397	26,033
	15	19,285	28,173	16,674	25,370
	20	19,302	28,203	16,540	25,286

[a] Low estimates.

TABLE 3. Cost per Life-Year Gained for Females[a]

Measure	Years	Treatment Mode			
		Home Dialysis	In-center Dialysis	LRD Transplant	CAD Transplant
Gross social costs	5	$24,882	$31,076	$27,093	$36,552
	10	25,108	31,472	23,319	32,130
	15	25,155	31,551	22,579	31,308
	20	25,169	31,572	22,431	31,137
Net social costs	5	22,036	28,886	23,541	32,995
	10	22,380	29,412	19,744	28,674
	15	22,459	29,516	19,024	27,935
	20	22,481	29,543	18,870	27,787

[a] Low estimates.

resulting in a reduction in values for transplant patients. The data also indicate that the time period of 20 years was sufficient to capture most of the gains from surgery.

Variations in Costs by Age and Sex: Low Estimates

Costs variations after 20 years of treatment were also examined. There are negligible variations in costs by age for dialysis patients when gross social costs are used. This reflects the fact that the same treatment costs were used for all age/sex groups. Although survival probabilities vary by age, this does not affect the resulting life-year values, because a decrease in the number of life-years saved by dialysis is also accompanied by a decrease in total program treatment costs. In contrast, greater variations exist for transplant patients due to differences in survival and graft retention rates by age. Individuals with transplants in the 21–30 age group have costs ranging from 82% to 94% of costs for individuals in the other age groups.

The impact of age increases when net social costs are used because there are additional differences in work probabilities and earnings by age. The lowest costs are otained for the 21–30 and 31–40 age groups; costs for individuals in these age groups range from 59% to 87% of costs for individuals in the two younger and two older age groups.

The rankings of the various treatment modes for the four younger age groups are similar to those obtained earlier. However, CAD transplant patients in the two older age groups have higher costs per life-year gained than in-center dialysis patients in six out of eight instances. Costs for in-center dialysis and CAD transplants are also very close for males in the 50–64 age group in the case of net social costs. These results indicate that the age distribution of ESRD patients should be taken into consideration in evaluating the cost-effectiveness of various treatment modes.

Changes in Assumptions: 20 Years

The previous results were based on low estimates of survival probabilities and earnings. They are compared to those obtained using high estimates of survival probabilities and earnings in Table 4. In the case of dialysis patients, there is little difference in high and low estimates. Again this is expected because higher survival probabilities are offset by higher total program treatment costs. The fact that many dialysis patients do not work also means that variations in earnings have only a limited impact on average life-year values.

In contrast, changes in survival probabilities and earnings have a considerable impact on costs per life year gained for transplant patients. The reduction of the percentage in costs ranges from 24% to 48% for males and from 24% to 37% for females when high estimates replace low estimates. In both in-

TABLE 4. Variations in Costs per Life-Year Gained[a]

Sex/Measure	Estimate[b]	Home Dialysis	In-center Dialysis	LRD Transplant	CAD Transplant
		Treatment Mode			
Males					
Gross Social Costs	Low	$25,182	$31,591	$22,379	$31,155
	High	25,384	31,994	16,962	22,572
Net Social Costs	Low	19,302	28,203	16,540	25,286
	High	18,009	27,800	8,673	14,201
Females					
Gross Social Costs	Low	25,169	31,572	22,431	31,137
	High	25,377	31,984	16,992	22,589
Net Social Costs	Low	22,481	29,543	18,870	27,787
	High	21,988	29,482	11,974	17,851

[a] Twenty years.
[b] Low estimate has lower survival probabilities and earnings than high estimate.

stances the greatest percentage reduction is obtained when net social costs are used.

The results in Table 4 also provide some indication of the sensitivity of the results to assumptions concerning survival rates and earnings and the use of gross or net social costs. In the case of LRD transplants, the cost per life-year gained declines from approximately $22,000 to $17,000 for males when high estimates replace low estimates and from $17,000 to $9,000 when the productivity of the individual is taken into account. Similar reductions are obtained for the other three transplant categories. The decline in costs for dialysis patients is due primarily to the use of net social costs in place of gross social costs.

Comparison with Results of Other Studies

The results of this study (low and high estimates) and four other U.S. studies[7–9,11] are compared in Table 5. Values are based on gross social costs, pertain to all individuals undergoing treatment, and have been converted to 1981 dollars using the CPI for all items. In all five studies, home dialysis is more cost-effective than in-center dialysis

TABLE 5. Comparison of Costs per Life-Year Gained[a]

Study	Discount Rate	Years	Home Dialysis	In-center Dialysis	LRD Transplant	CAD Transplant
			Treatment Mode			
GAO, 1977[7]	—	Second	$17,767	$35,535	—	—
Stange and Sumner, 1978[8]	5–7%	10	28,456	44,142		24,900–28,815
Roberts and Associates, 1980[9]	—	Life	21,212	39,630	12,319	23,839
Maxwell and Grass DHHS, 1982[11]	—	Annual	16,706	18,600–23,250	—	—
Garner and Dardis, 1985						
Low[b]	10%	20	25,177	31,582	22,400	31,148
High[c]	10%	20	25,381	31,989	16,974	22,578

[a] Gross Social Costs, 1981 dollars.
[b] Low estimates of survival probabilities and earnings.
[c] High estimates of survival probabilities and earnings.

though the magnitude of the difference varies.

The results of this study (low estimates) are similar to those reported by Stange and Sumner[8] and Roberts and his associates[9] with respect to the rankings of the various treatment modes. The most cost-effective treatment mode is an LRD transplant followed by home dialysis, and in-center dialysis is the most cost-ineffective treatment mode. The lower values obtained by Roberts and his associates in the case of transplants reflect the absence of discounting, an omission that is important because the benefits from surgery accrue over the life of the individual.

Discussion

The results of this study indicate that the use of net social costs in the evaluation of health care programs is both feasible and desirable. Provision for output gains due to treatment will result in a more accurate assessment of the net costs to society of health care programs and will focus attention on the outcome of such programs—the increase in the number of healthy, productive life-years. The greater the rehabilitation of the patient with respect to work activities, the smaller the net costs to society are.

The cost-effectiveness of the four treatment modes was evaluated by comparing the cost per life-year gained for each mode. The divergence in cost-effectiveness of the four treatment modes, regardless of whether gross or net social costs were used, was in keeping with the results of other studies. In the case of low survival probabilities and earnings, LRD transplants and home dialysis were the two most cost-effective treatment modes. In the case of high survival probabilities and earnings, CAD transplants replaced home dialysis as the second most cost-effective treatment mode (20 years). Thus assumptions concerning survival rates for transplant patients will affect the cost-effectiveness of transplantation. In contrast, costs for dialysis patients were unaffected by improvements in survival rates, because the increase in the number of life-years was accompanied by increased treatment costs.

In-center dialysis was the most cost-ineffective treatment mode in nearly all instances. It is also the dominant treatment mode accounting for 75% of all ESRD treatments in 1983.[21] This dominance suggests that certain constraints exist that preclude the use of the most cost-effective treatments for all patients. The greatest constraints exist undoubtedly with respect to transplantation. Fifty percent of the dialysis population is over the age of 55, and transplantation may not be a viable option for many of these patients. In addition, those individuals who do qualify for transplantation are dependent on the availability of organs. In 1983, there were 7,137 people awaiting transplants compared to 6,123 who received transplants.[21] In view of these circumstances, it is not surprising that only 7% of ESRD patients received transplants in 1983.

Home dialysis appears to suffer from fewer supply constraints than transplantation, although medical complications, lack of a partner, and inadequate home facilities may eliminate home dialysis as an option for many individuals. The number of patients undergoing home dialysis increased from 7,661 in 1980 to 13,645 in 1983.[21] The greatest increase has occurred in the number of patients using continuous ambulatory peritoneal dialysis (CAPD). In 1980, 2,334 home patients dialyzed with CAPD compared to 8,532 in 1983. Over one half of all home dialysis patients used CAPD in 1983 compared to less than one third in 1980. Although adequate costs and survival probability data are not currently available, CAPD is being promoted as a less expensive treatment option than hemodialysis. In addition, increased patient flexibility is expected from the use of this treatment. Thus, the results for home dialysis may be even more favorable than those reported here.

In spite of the growth of home dialysis, the proportion of patients receiving this

treatment only increased from 13% in 1980 to 17% in 1983. This is due to the increase in the total number of patients receiving ESRD treatments. These data indicate that, although recent policy changes with respect to the ESRD program have been successful in encouraging the use of home dialysis in place of in-center dialysis, much greater efforts will be required in the future if home dialysis is to become the dominant treatment mode. Existing financial incentives may still encourage individuals to use in-center as opposed to home dialysis. The emergence of CAPD as a viable home dialysis option may play a major role here.

The results for different age groups indicated that the greatest variations in costs per life-year gained were obtained for transplant patients. The lowest values were obtained for individuals between the ages of 21 and 40, whereas higher values were obtained for younger and older individuals. In the case of dialysis patients, there was little difference between age groups based on gross social costs. However, variations did occur when net social costs were used with the 21 to 40 age groups having the lowest costs.

The primary limitations of this study are data-related. Although our results were based on the most complete data available, they may not adequately reflect the true social costs of the different ESRD treatments. Thus, Medicare charge data do not include the total resource costs to society of the different treatment modes. For example, the social opportunity costs of home dialysis aides and for the physical plant or floor space needed for home treatment were not included in home dialysis Medicare charges. The value of patient travel time and transportation costs were also excluded due to lack of data. Inclusion of these components would be expected to increase treatment costs, especially for in-center dialysis. In addition, the fact that Medicare reimbursements are based on charges rather than on resource costs may result in an overestimate of treatment costs if providers are less efficient in their production of services or include excess profits in their charges.[22]

Treatment mode selection is also important. Thus, patients are not randomly assigned to different treatment modes but rather are selectively placed on treatments that clinicians believe best meet patients' medical and sociomedical needs. Selection factors are expected to affect patient outcomes, including employment and rehabilitation, and treatment costs.[23] Our analysis did not control for differences in productivity gains or treatment costs due to selection factors. Future analyses may produce different results if selection factors for the various treatment modes change. For example, if less healthy in-center dialysis patients were assigned to home dialysis, one might expect a decrease in the overall labor force participation in home dialysis patients and a consequent increase in cost per life-year gained. In spite of such reservations, the methodology used in this study provides useful information to the policy maker concerning the cost-effectiveness of the various treatment modes.

Finally, the methodology presented in this study could be applied to the evaluation of other health care programs. This type of evaluation is important in view of resource constraints that preclude the provisions of the best available medical technology for all Americans. Cost-effectiveness analysis, based on the concept of net social costs, incorporates the returns to society as well as to the individual from health care programs.

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