and the combination of a tricyclic drug with small doses of thyroxine or triiodothyronine; the latter treatment is said to be more effective in women than in men.

The use of prefrontal leucotomy in the treatment of severe cases of resistant depression is still a controversial subject. Certainly with the new stereotaxic operations personality change is a less frequent complication of the operation. However, there is a reluctance to embark on an irreversible procedure in what is always a potentially reversible disorder. In weighing the prognosis against the possible disadvantages of the operation it is advisable to obtain the opinion of someone with considerable experience of it.

Contemporary Themes

Cost-benefit Analysis of Long-term Haemodialysis for Chronic Renal Failure

M. J. BUXTON, R. R. WEST

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Summary

A cost-benefit analysis of long-term maintenance haemodialysis indicates that there is a large gulf between the cost of the service and "economic" benefit. The difference may be considered to represent one estimate of the price society is prepared to pay to maintain life. Using "best estimates" from available data we found the implicit social value of maintaining a patient on haemodialysis to be approximately £4720 per annum in hospital or £2600 at home. The analysis would suggest that society must look carefully at alternative uses for health expenditure before extending indiscriminately to large sections of the population these treatment programmes or others similarly expensive.

Introduction

There are 46 units in the United Kingdom for the treatment of acute renal failure by long-term maintenance dialysis. This method of therapy has been expanded steadily in the past 10 years, and there are now about 580 patients being dialysed in hospital units and about 830 dialysing themselves at home.[1] A similar expansion of dialysis units has occurred in Western Europe, the U.S.A., and Australia. However, the number of patients taken on to the programme each year still falls short of the number considered suitable for long-term dialysis. Estimates of the incidence range between 23 and 39 new patients per year per million population under the age of 55-60.[2-4] Though in the past it has been indicated that shortage of trained staff rather than direct economic constraints has held back provision of this form of medical care in the United Kingdom,[5] maintenance dialysis does in fact have a high and continuous cost, and, even if staff shortages can be overcome, analysis is required to examine whether the benefits from such therapies justify the use of the scarce resources involved.

In 1967 Kerr reported to the Royal Society of Medicine the very high cost of providing long-term maintenance dialysis to all potential candidates under the age of 55 in the U.K.[6] In the United States Klarman, Francis, and Rosenthal made a cost-effectiveness comparison of hospital dialysis, home dialysis, and renal transplantation in terms of life years gained.[7] Their approach was extended to a cost-benefit analysis by LeSourd, Fogel, and Johnston in a report prepared for the U.S. Department of Health, Education, and Welfare.[8]

Our paper adopts a similar approach, though it introduces an alternative means of expressing the results and incorporates several important differences regarding the data. Firstly, recent statistics from the European Dialysis and Transplant Association (E.D.T.A.)[1] are used as the basis for the estimates of relevant costs and benefits, supplemented by more detailed data from recent expenditures in Cardiff and Glamorgan. Secondly, adjustment is made for the fact that patients must first survive a period on hospital dialysis while training for home dialysis and waiting for installation of machinery and necessary home modifications.[9] Omission of this led earlier studies to exaggerate the advantages of home dialysis over hospital dialysis by comparing the survival rates of patients on home dialysis with those on hospital dialysis. Thirdly, account is taken of the cost effects of the dependence of home dialysis patients on fully equipped hospital units and of costs incurred privately on nursing and special diets.

2. Patient Survival on Long-term Dialysis

The data for patient survival used in this analysis are those reported by the E.D.T.A. for the period ending 31 December 1972.[1] That survival has not improved as rapidly as many have hoped may be explained in part by expansion of the programme, so that each year there have been new, inexperienced units taking on initial and not typical cohorts of patients. However, this situation is likely to be repeated if the programme is further expanded. The six-year survival of patients on hospital dialysis was reported by E.D.T.A. as 50%. This is detailed in column 3 of table I. Our "best estimate" of long-term survival is based on an extrapolation of the E.D.T.A. survival data for years 1 to 6 inclusive fitted to a negative exponential function ($s = 1 - e^{-kt}$, where s is survival, t is time, and k is a constant; the correlation coefficient relating this function to the observed survival is

Centre for Studies in Social Policy, 62 Doughty Street, London WC1N 2LS
M. J. BUXTON, B.A., Research Fellow

Department of Social and Occupational Medicine, Welsh National School of Medicine, Cardiff CF4 4XN
R. R. WEST, M.A., PH.D., Lecturer

$r = -0.99$), further reduced by the gradually increasing mortality of a normal population cohort with the same initial age structure as the E.D.T.A. population (table I, column 2). An upper limit for the long-term survival may be defined whereby patients experience only the mortality of the normal population cohort after the sixth year and a lower limit whereby all patients die shortly after the documented six-year period. Though these limits are extreme they are useful in testing the sensitivity of the findings to variations in the assumed value of such parameters.

Survival of patients on long-term dialysis at home is generally better than that of hospital patients. The E.D.T.A. figure for the years 1970-2 was 68·4% survival at six years. Clearly this advantage over hospital survival is partly due to selection of cases suitable for home dialysis being much the same as a selection of cases with better prognosis. However, it is also in part due to the fact that the high initial mortality has already occurred in hospital units. Only after patients have become established on dialysis, after they have survived the initial critical days, are they trained for and transferred to home dialysis. The duration of hospital dialysis before transfer to home dialysis for 949 cases in the U.K. is presented in the E.D.T.A. 1972 report, from which it would appear that a mean duration of hospital dialysis before home transfer is about six months. Thus in table I, column 7, the six-year survival of patients on home dialysis (63·4%) is composed of the first half year on hospital dialysis (91·0% survival) plus five and a half years on home dialysis. The "best estimate" of long-term survival is an extrapolation onwards based on the negative exponential curve fitted to the E.D.T.A. survival data for the first to sixth years inclusive ($r = -0.99$). As with the hospital dialysis population different extrapolations of survival could be employed within the comparable extreme upper and lower limits.

3. Cost of Hospital Dialysis

The estimates of costs presented here are based on recent expenditures in Cardiff and Glamorgan, adjusted where necessary to 1972 prices by the application of an appropriate price index. In the case of hospital dialysis the capital costs associated with the declining cohort receiving treatment have been converted into an equivalent annual cost, on the reasonable assumption that in fact new patients would be brought into the unit to maintain the desired level of capital-utilization. The cost of "temporary" buildings for the 10-bed unit is £115 000, and in the absence of evidence to the contrary a useful life of 20 years is assumed. The dialysis equipment for the same unit costs £32 500, but only a 10-year life is expected. If these capital sums are depreciated over the suggested periods and an interest rate of 10% assumed, the annual equivalent capital cost per unit is £18 800.* The direct running costs of the unit are £116 000. If a 10-bed (or 30-patient) unit treating chronic renal failure patients without associated home dialysis or renal transplantation (if aiming to be full and refusing further admissions for 10% or less of the time) maintains 24 patients on average, the combined "annual capital" and direct running cost per year per patient is approximately £5600.

*Equivalent annual cost $= K\frac{i(1+i)^n}{(1+i)^n - 1}$

where K = capital cost
n = useful life of capital in years
and i = rate of interest.

4. Cost of Home Dialysis

Portions of the capital cost of establishing patients on home dialysis were paid by two different authorities. While the hospital management committee (H.M.C.) covered the cost of dialysis equipment and its installation, necessary building modifications to the patients' homes were undertaken by the county council. The latter vary considerably in cost, but the most common recent practice has been to install mobile caravan units at a cost of about £1300. This figure has been used in the estimation of the cost of the home dialysis programme, since the "cheaper" alterations were likely to have been subsidized by patients' families by the provision of existing rooms for the equipment, and therefore they would probably have true costs as high as for the caravan units. There is little evidence about the likely useful life of these units. For simplicity it is assumed that they can last up to the 20-year time horizon but are patient-specific—that is to say, they are not transferred to a new patient on the death of the first user. The cost of these units is therefore considered as occurring at the beginning of the 20-year time period, provision being made for that number who are expected to survive the first six months of hospital dialysis. The H.M.C. estimated the cost of dialysis equipment as £2500 per machine. This is treated like the hospital capital cost as non-patient-specific, and an equivalent annual cost of £410 per patient results. The direct running costs incurred by the H.M.C. were estimated as £2700 per patient for 1972.

Patients receiving dialysis at home are dependent on fully equipped specialist hospital units not only during the initia, stages of establishment on dialysis and training in self-dialysisl but also in event of complications. We have estimated that in Cardiff home dialysis patients received approximately 5% of their dialyses in hospital during 1971-3.[9] Thus in the assessment of the cost of maintaing patients on home dialysis a portion (£280 per patient per annum) of the hospital unit cost must be incorporated. Hence the cost directly attributable to the health service for a home dialysis patient totals £3390 per annum plus an initial cost of £1300.

5. Indirect Cost of Long-term Maintenance Dialysis

In addition to the costs directly incurred by dialysis units on equipment and on salaries of doctors, nurses, and technicians, there are those extra costs incurred in the long-term maintenance of renal-failure patients by other hospital departments and other sectors of the health and social services.[6] Such extra costs are particularly difficult to itemize accurately, especially as much expensive research is being undertaken in many hospitals with dialysis units to study and, it is hoped, to alleviate diseases associated with chronic renal failure—as, for example, bone densitometry for the monitoring of calcium loss.[10]

Secondly, the grave problem of hepatitis infection is of considerable economic significance. In 1972 all but six of the 568 European dialysis units reported hepatitis among staff, and mortality among reported cases was 2·4%. The deaths of highly trained medical or technical staff and sickness absence of up to nine months constitute a serious loss of resources.[11] This loss and the discouragement of recruitment because of the hepatitis hazard together increase the real cost of maintaining the dialysis programme.

There are also costs incurred privately by the patient's family in providing some degree of nursing care and in purchasing special diets, though part of such expenditure may be passed on to the health and social services budget. Such expenditure is likely to be greater for patients on home dialysis, thus further narrowing the true difference between home cost and hospital cost. We have no reliable data on which to base an estimate of these indirect costs in our calculations, but their existence must increase the total costs of long-term maintenance dialysis, and allowance should be made accordingly when conclusions are drawn.

6. Cost-benefit Analysis

The estimation of the costs of long-term therapy is easiest if

there is concurrence of treatment costs and life-years saved. This is the case in estimating the cost of long-term maintenance haemodialysis in a hospital unit, as described in section 3 of this paper, where the cost per life-year is constant and approximately £5600. Home-dialysis patients impose a more complex pattern of costs reflecting the patient specificity of some of the capital cost and the cost of the first six months spent in a hospital unit. Thus the relationship between treatment costs and life-years saved is not so simple. However, a comparable *average* annual cost for home dialysis is approximately £3800.†

In narrow economic terms the benefit to society can be expressed as the present value (PV) of the wages earned by the surviving patients discounted at an appropriate rate. These "economic" benefits are particularly sensitive to the rates of rehabilitation. The E.D.T.A. reported 77% of hospital dialysis patients "able to work" after two years on dialysis, and 90% "able to work" after one year of home dialysis. However, provisional analysis of more recent data from the Cardiff unit (for the E.D.T.A. 1973 report), in which the "able to work" classification was further subdivided into (i) "and working full-time," (ii) "and working part-time," and (iii) "but not working," suggests that fewer than 50% of hospital dialysis patients work full time and that about 65% of home dialysis patients work full time. The rehabilitation rates we have used are based on the Cardiff estimates but include the appropriate full-time equivalents' rates for those likely to be able to work part time. This gives rehabilitation rates for hospital dialysis of 30% at the end of year 1, 52% at end of year 2, and 60% at end of year 3 and subsequent years. For home dialysis the rates are 45%, 65%, and 75% respectively. To allow for this increase in economic benefit with the duration of haemodialysis therapy, the PV of benefit should be compared with PV of cost. To the numbers able to work (table I, columns 5 and 9) we applied average annual wages (1972) of £1908 for men and £1066 for women in the proportions of the E.D.T.A. registry population. From these we calculated the annual present value of economic benefit, using a discount rate of 10% but allowing for an average annual increase in productivity of 3% (table I, columns 6 and 10).

The total present value of "economic" benefit of maintaining on hospital dialysis a cohort of initially 1000 patients is thus estimated at £3 626 000 for hospital dialysis and £6 315 000 for home dialysis (the latter figure reflecting the higher rehabilitation rates of home-dialysis patients mainly owing to the selection criteria for home-dialysis training). This PV of benefit is compared with the discounted costs of maintaining the survivors of an initial cohort of 1000 patients for 20 years (shown in table I, columns 4 and 8), which total £23 083 000 for hospital dialysis and £19 991 000 for home dialysis (allowing for the first half year being spent in hospital).

It is clear that with such assumptions regarding rehabilitation the economic benefit is far smaller than the annual costs of maintenance dialysis in hospital or at home. This difference may be reduced to some extent by allowance for unpaid "economic services" of the housewife at home (particularly in the case of home dialysis), but essentially the difference represents the minimum social value of patients' life-years saved implicit in the continuance, or more pertinently the expansion, of such dialysis programmes. The implicit social value (ISV) of maintaining a patient on hospital dialysis is thus £4720 and for home dialysis £2600,§ on the basic assumptions outlined previously concerning costs and "economic" benefit.

† $\frac{\text{Total present value of costs}}{\text{Discounted sum of life-years saved.}}$
This implies that society's present valuation of a life-year saved in the future declines as that future year becomes more distant.

§Implicit social value (ISV) = $\frac{\text{total present value of costs} - \text{total present value of benefits}}{\text{discounted sum of life-years saved}}$

Discussion

While the values of the parameters we have used represent in each case the "best estimate" from available data, there is no doubt that some of these values (for instance, survival or rehabilitation rates) may prove inaccurate when evidence from a greater number of cases becomes available, and other values (discount rate or average earnings) may prove inappropriate in future economic environments. We have therefore tested the sensitivity of our findings (in terms of a cost:benefit ratio (total PV costs:total PV "economic" benefit) and of the ISV) to gross changes in the values of the major variables. In each of these sensitivity tests, the results of which are presented in table II, the value of one variable was altered to an extreme value (high or low) while the other variables remained unchanged, as summarized below.

A Basic "best estimate" assumptions.
B Low survival rate: all patients die after documented six-year period.
C High survival rate: mortality rate of normal cohort after six-year period.

TABLE I—*Survival, Costs, and Benefits of Initial 1000-Patient Cohort on Long-term Haemodialysis, over 20-Year Period*

Year	Normal Cohort	Hospital Dialysis				Home Dialysis			
		Survivors	Discounted Cost £000	Fully Rehabilitated	Discounted "Economic" Benefit £000	Survivors	Discounted Cost £000	Fully Rehabilitated	Discounted "Economic" Benefit £000
1	2	3	4	5	6	7	8	9	10
0	1000	1000	—	—	—	1000	1183	—	—
(½)						910	2548	—	—
1	997	833	4665	250	185	865	1360	389	288
2	992	715	3578	375	430	802	2319	521	627
3	987	640	2845	384	488	753	1968	565	700
4	981	587	2346	352	444	710	1685	533	622
5	976	530	1943	318	378	671	1446	503	583
6	969	500	1624	300	325	634	1240	476	515
7	961	413	1310	248	270	588	1055	441	452
8	954	364	1014	218	215	547	893	410	392
9	947	320	812	192	177	509	755	382	340
10	940	282	650	169	144	474	640	356	295
11	931	248	521	149	120	440	539	330	258
12	922	217	414	130	98	409	455	307	223
13	911	191	330	115	81	379	384	284	194
14	900	167	263	100	66	351	324	263	167
15	890	146	207	88	54	325	273	243	145
16	876	128	168	77	44	300	230	225	125
17	861	111	134	67	36	276	192	207	107
18	845	97	106	58	28	254	162	191	93
19	828	84	84	50	24	234	135	176	81
20	811	73	67	44	19	215	111	161	68
		Total PV	23 083*		3626*		19 991*		6315*

Note: *These totals may differ from the sum of the components owing to rounding.

TABLE II—*Results of Sensitivity Tests*

Test Reference	Survival Rate	Discount Factor	Costs	Rehabilitation Rate	Average Earnings	Hospital		Home	
						Cost:Benefit	ISV	Cost:Benefit	ISV
A	N	N	N	N	N	6·4:1	£4720	3·2:1	£2600
B	Low	N	N	N	N	7·4:1	£4840	4·0:1	£2990
C	High	N	N	N	N	5·8:1	£4630	3·0:1	£2490
D	N	High	N	N	N	7·0:1	£4970	3·5:1	£2850
E	N	Low	N	N	N	5·8:1	£4520	2·8:1	£2360
F	N	N	High	N	N	12·7:1	£10320	6·3:1	£6410
G	N	N	Low	N	N	3·2:1	£1920	1·6:1	£700
H	N	N	N	Low	N	11·0:1	£5090	7·4:1	£3290
J	N	N	N	High	N	4·9:1	£4460	2·7:1	£2390
K	N	N	N	N	Low	12·7:1	£5160	6·3:1	£3210
M	N	N	N	N	High	3·2:1	£3840	1·6:1	£1400

Note: N = normal value, viz. "best" estimate detailed in text.

D High discount factor: 14%.
E Low discount factor: 6%.
F High costs: twice those detailed in text (sections 3, 4, 5).
G Low costs: one-half those detailed in text.
H Low rehabilitation rate:
hospital: year 1—20%; year 2—25%; year 3 and subsequent years—35%.
home: year 1—25%; year 2—35%; year 3 and subsequent years—45%.
J High rehabilitation rate:
hospital: year 1—50%; year 2—60%; year 3 and subsequent years—77%.
home: year 1—50%; year 2—70%; year 3 and subsequent years—90%.
K Low average earnings: one-half those detailed in text (section 6).
M High average earnings: twice those detailed in text.

The results indicate, not surprisingly, that the cost figures are the most crucial, but even halving costs (test G) would leave an ISV of £1920 for hospital dialysis and £700 for home dialysis. Such a reduction in cost would, in the current situation of rising constant-price costs of hospital manpower, imply substantial, and unforeseen, cost-reducing technological developments in dialysis therapy. Indeed hospital dialysis as a long-term therapy does not quite "break even," in terms of costs and "economic" benefit as measured here, even when the most favourable values for all variables are used together (C:B = 1:1; ISV = £20), though in this case home dialysis shows a "healthy" economic return (C:B = 1:1·8; ISV = −£1480). However, these implicit social values would be increased if account were taken of unmeasured indirect costs.

We would also stress that in comparing home and hospital survival rates there is likely to be a bias in favour of home dialysis that results from the selection of lower risk cases at the longer established centres for home dialysis training. Moreover, home dialysis may not be considered as a mode of long-term therapy on its own: it must be part of an integrated programme of treatment by dialysis at hospital and at home and often also by renal transplantation.[9] On the other hand, it would seem intuitively reasonable to expect society to value more highly the "non-economic" benefits of home dialysis as such patients are better reintegrated into family and community life than those on hospital dialysis. We have not included transplantation in this cost-benefit analysis, but by comparison with long-term dialysis it appears to offer patients greater individual independence and possibly better prospects of rehabilitation at the expense of poorer chances of survival. However, with the appropriate data the method of analysis used here could give a comparable cost-benefit ratio and ISV for transplantation, or indeed for any well-documented health-care programme.

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