PAPERS AND ORIGINALS

A flexible model for planning facilities for patients with end-stage renal failure

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Summary and conclusions

Resource needs for patients with renal failure change as policies vary and survival improves. Thus a model was developed to estimate the facilities (number of beds) needed for such patients in the North-west Region; national resource needs could be obtained by multiplying the regional needs by eleven. The model predicted an unforeseen demand for hospital and satellite unit facilities and for unit back-up beds.

The increasing survival of transplants is an important determinant of resource needs, and the model readily indicates the impact of changes in this factor.

Introduction

The rapid developments in the treatment of patients with renal failure pose complex planning problems. The success of dialysis and transplantation has brought in its wake an increasing demand for these facilities, and because of a shortage of funds not all patients can be accepted for treatment. Staff working in this branch of the Health Service have been forced to decide how to allocate resources. Most observers have concentrated their thinking on the short-term consequences of these developments, but equally, if not more, important are the long-term steady-state implications—that is, when provision matches the proportion of the demand that is to be met. For example, if enough donated kidneys and transplant teams were available to perform kidney transplantation on all suitable patients what eventual effect would this have on the demand for kidney machines?

The figures contained in the recent publication¹ of the Office of Health Economics relate to countries at different stages in their transition towards this steady state. A report of the European Dialysis and Transplant Association showed that in 1977 an average of 19 new patients per million population were treated throughout Europe; the “stock” of patients either being treated by dialysis or possessing a functioning transplant averaged 74 patients per million. The treatment rates, however, varied widely between nations. The figures for Britain were 16 and 18 respectively, which were under half those for the leading countries—namely, Denmark, Israel, and Switzerland. These three countries were able to treat some 40 new patients per million population in 1977—this incidence is the one currently assumed. Britain is not expected to provide this level of cover until the next century. Although these statistics ignore the problems peculiar to each country, they show the continuing relative decline in Britain’s provision of renal services as compared with many close neighbours.

Reasons for a reappraisal

Using operational research techniques, workers at the London Hospital developed a model to assist in deciding on the appropriate level of facilities for patients with renal failure.^{2 3} We believe that such an approach is essential, and that it offers the opportunity of planning for efficient use of NHS resources. Several reasons exist for a reappraisal some years after that first commendably analytical effort over and above the need to produce estimates of the long-term implications of current policies. Since that study survival of patients receiving dialysis or with transplants has steadily improved. In the case of patients with transplants this is explained by the increasing number of cadaver kidneys made available, the better understanding of donor and recipient matching, and continually improving surgical and medical techniques. The theory and practice of dialysis are better understood, and the integration of dialysis and transplantation into a single treatment continues. Additionally, doctors are recognising how best to use the alternative patterns of treatment available for individual patients. For example, a new facility, the “minimal-care unit,” has been proposed. This would be a facility between those of home and hospital, at which relatively little help would be provided, and might be appropriate for many patients. We incorporated this increased knowledge in a planning model, which is more detailed and reflects current performance figures better than that recently produced by the planning team of the DHSS.⁴

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FIG 1—Schematic representation of system of treatment for renal failure.

Background data and model

Figure 1 shows the basic flow of patients related to treatment for renal failure; movements from one state to another are represented by arrows. The probabilities of moving from one state (say, the first month of recovery after transplantation) to another (say, rejection) during a one-month interval were ascertained and incorporated into a mathematical model of the process.

The survival characteristics that were used for patients dialysing at home and in hospital were those produced by the European Dialysis and Transplant Association,⁹ and we assumed that figures for minimal-care units would lie halfway between these two. Data pertaining to graft survival were based on 199 first transplantations performed at Manchester Royal Infirmary between 1973 and 1978.

The average duration of stay after transplantation including re-admissions during the first 90 days for these patients was 36.5 days. Altogether, 63% of patients will exit from the "successful transplantation" stage and need long-term dialysis after graft failure. For each patient who receives a transplant, 0.2 are assumed to reject within the first three months and 0.71 to survive this period and pass into the successful transplantation stage.

There are three categories of patients. *Type A* patients are those who are suitable for either home or minimal-care dialysis. After three months of training in the unit and a further period to adjust to minimal-care or home treatment they await transplantation. This waiting period averages 12 months, during which time 0.75 are assumed to be receiving home dialysis and 0.25 to be dialysing in minimal-care units. It is further assumed that patients who reject a transplant and require subsequent dialysis are divided in the same proportion. For each patient being trained initially in the unit one bed is provided. The model assumes that each minimal-care bed station will accommodate two patients. Each patient receiving either home or minimal-care dialysis will require, on average, two weeks per year in a "back-up bed." *Type B* patients are those considered to be unsuitable candidates for either home or minimal-care dialysis; they number about one-half of type A patients. After three months' stabilisation they receive dialysis for 12 months then enter the same transplantation process as type A patients. Those who reject the transplant return to long-term hospital dialysis. The same monthly mortality is assumed for dialysis before and after transplantation, given survival beyond the first month after failure. Two patients per bed are assumed. There is no unit back-up for these patients. *Type C* patients are those who require treatment but are not candidates for transplantation in a given year either because no graft is available or because they comprise the 10% who are assumed to be unsuitable for transplantation. Altogether, 65% are considered to be suitable for home or minimal-care dialysis (in a ratio of 3:1), and back-up beds are required for both groups. The remaining 35% receive long-term hospital dialysis straight away.

Data covering 10 years are available from the European Dialysis and Transplant Association. The mean life expectancies calculated from these truncated data are 92 months for patients dialysing at home, 82 months for those dialysing in minimal-care units, and 71 for those dialysing in hospital units. That these figures are lower-bound estimates is attested to by the fact that 55% of those receiving home dialysis are still alive after 10 years' treatment. (Interestingly, this grossly unrealistic figure of 92 months contrasts with that of 60 months used in the DHSS model.) Figure 2 shows the survival curve based on 9063 patients dialysing at home throughout Europe. Making

FIG 2—Survival curve for patients receiving home dialysis, based on 9063 patients.⁵

assumptions about the likely survival characteristics, and incorporating natural death rates, enables a more realistic figure for life expectancy to be determined—namely, 132 months. The estimates of resource needs so far exceed current provision that any improvement will undoubtedly take a long time to occur. During this period the survival data will cover a longer period, so that the estimates can be progressively updated.

The life expectancy of patients returned to dialysis after graft failure was taken to be equal to that stated above, given survival beyond the first month after failure. Altogether, 0.9 are assumed to survive that first month. Each month a total of 67.1 will eventually be receiving home dialysis (table I). These figures can be readily converted into total resource needs (table II). For example, the three people receiving minimal-care dialysis will require one and a half beds, given that two people share one facility. These figures are based on a single shift working six days a week for hospital and minimal-care units. Some units will probably operate on a two-shift basis and, wherever this can be achieved, the requirement for hospital places will be reduced accordingly. It should be remembered, however, that there are considerable logistical difficulties in keeping dialysis units operating

TABLE I—Numbers of patients who will eventually be receiving each form of treatment. (The model assumes that one new patient begins treatment each month)

	Type of patient		
	A	B	C
Successful transplantation	..	..	..
Home dialysis:	49	41	
Long term	58.1		65.9
Waiting pool	9		
Minimal-care dialysis:			
Long term	17		19.6
Waiting pool	3		
Hospital dialysis:			
Long term		51.5	37.2
Before transplantation		13	
Training in unit	3		1.95
Total No of patients	139.1	105.5	124.65

TABLE II—Total resource needs, given that one new patient begins treatment each month

	Type of patient		
	A	B	C
Home dialysis machine	67.1		65.9
Minimal-care dialysis	8.5 1.5		9.8
Hospital dialysis		25.75 6.5	18.6
Unit back-up	3.35		3.3
Unit training	3		1.95
Transplantation unit	1.18	1	
Total No of bed places	17.53	33.25	33.65

on a two-shift basis six days a week. Furthermore, the success in reducing hepatitis in renal dialysis units is held to be partly attributable to containing the work load at a level that permits standards to be maintained. This entails, inter alia, building into the unit programme sufficient flexibility to allow patients to attend out of sequence occasionally. Such considerations might suggest that too great a reliance should not be placed on a two-shift, six-day-week, full-capacity approach to hospital dialysis units.

The model also incorporates an average waiting time before transplantation of 12 months, which is the period obtaining at Manchester Royal Infirmary. Continuing refinements in matching techniques are likely to result in an increasing reluctance to transplant "moderate" or "poor" matches into well patients, and this one-year figure is a desirable goal.

Regional predictions

By combining the figures in table II with the estimated prevalence of type A, B, and C patients in a region, the overall resource needs for that region may be obtained. Thus, for example, the North-western Regional Health Authority, with a population of about 4.5 million, may be expected to generate 180 new patients annually. We estimate that 86 (48%) of these will be type A, 43 (24%) type B, and 50 (28%) type C. Such a mix would utilise the planned capacity to perform 120 transplant operations per year, which is considered to be realistic given the current availability of cadaver kidneys. The composite requirements, given these regional demands, are: 12 transplant unit beds, 194 hospital dialysis beds, 113 minimal-care dialysis beds, 30 unit training beds, and 38 unit back-up beds. The national figures, based on the same set of assumptions, may be obtained simply by multiplying these figures by eleven. These regional figures represent a total of 387 occupied bed places. In addition to 760 home dialysis machines, 496 patients will be carrying a successful transplant, and the total number of people receiving treatment in this steady state is 1905, or 433 patients per million population. The degree of reasonableness claimed for the figures used in the model may perhaps be gauged by comparing this derived plateau value with that forecast in 1977 for Britain by the European Dialysis and Transplant Association, which was 425 patients per million population. If half of the beds for hospital and minimal-care dialysis are run on a two-shift day, then one-quarter fewer are required for long-term dialysis.

Figure 3 shows the effect of having different numbers of patients eligible for transplantation among 15 new patients treated each month. This suggests that each new transplantation performed is "worth" about 1.75 home dialysis machines and 0.9 bed places. The bed resource needs are fairly insensitive to changes in the ratio of type A patients to all patients eligible for transplantation (types A+B). A ratio of 0.33 is assumed; changes from this ratio attenuate the effect on bed resources by a factor of five. For example, if the ratio is changed by 10%, bed resources will only change 2%.

Importance of the model

We undertook this study to provide a basis for discussion of future developments in the North-west Region. The flexibility referred to in the title relates to the ability to examine the implications of changes in parameters stemming from changes in regional policy or medical practice. Increased survival of transplants is, clearly, an important determinant of future resource needs. The model has already been used in the North-

FIG 3—Requirements for treating 15 new patients per month, assuming that one-third of those eligible for transplantation are type B patients—that is, they receive dialysis in the unit.

west to explore the impact of likely changes in this key factor on the total resource needs in the region, and the figures obtained are now incorporated into long-term planning deliberations. The model's most important prediction is probably the unforeseen demand for hospital and satellite unit facilities and for unit back-up beds, which have traditionally been grossly underprovided for, with the consequent danger of blocking scarce resources for the other categories of patients.

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ONE HUNDRED YEARS AGO According to a recent notice in the *Reichs-Anzeiger*, Duke Charles Theodore of Bavaria is admitted as a fully qualified medical practitioner, the condition of undergoing the *Staats-Examen* having in the case of His Highness been dispensed with. In 1872, on the occasion of the jubilee celebration at the Munich University, the honorary title of Doctor of Medicine was conferred upon him. Both before and since that time, Duke Charles has devoted himself with ardour to medical studies, and has been a pupil of the most eminent surgeons. His specialty is the treatment and cure of ophthalmic diseases, in which he has testified his skill by successful operations in presence of the highest scientific authorities. The prince is now in his fortieth year, and actively pursues his profession at the Castle of Tegerusee. Sometimes he is roused up in the night just as an ordinary practitioner, and rides miles across country, conveying relief to the suffering. By the official notification referred to, His Highness's professional status becomes in all respects the same as that of any practitioner. It may be added that, where necessary, the prince pays for his patients' physic, and also sees them supplied with strengthening wines and nourishing food at his own cost. Duke Charles is the author of several papers of considerable merit on histological subjects in German scientific periodicals. (*British Medical Journal*, 1880.)