A computer model for predicting the demand for end-stage renal failure (ESRF) treatment, contract setting and monitoring

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Abstract

Background. The high cost of end-stage renal failure (ESRF) treatment, and the anticipated need for expansion of the service at a time of limited resources for health care expenditure, means that careful planning of such an expansion is necessary. This needs to inform the setting and monitoring of contracts between commissioning organizations and providers of treatment. A spreadsheet based computer model is described which fulfils both of these needs.

Methods. A computer programme was written to run on a commonly available spreadsheet in order to predict the demand for ESRF treatment, set contracts, and monitor in year performance.

Results. The model described has facilitated contracting for ESRF services. Purchasers have used it to examine various planning scenarios, while the provider unit has used it to support a business case for further development. Using this model, the predictions for the Sheffield resident population are that the total number of patients on the ESRF treatment programme will increase from a mid-year average of 204 patients in the year 1994-95 to 266 patients in the year 1999-2000, while costs increase over the same time period from £2.37 million to £2.78 million.

Conclusions. A computer spreadsheet based model described is a useful tool for predicting demand, and setting and monitoring contracts, for treatment for ESRF. Problems with the model and potential further developments are discussed.

Key words: computer model; contracting; end-stage renal failure; prediction

Introduction

Treatment for end-stage renal failure (ESRF) is the archetypal high-cost, low-volume service. The treatments available are very effective, delaying otherwise inevitable death by many years. In many regions in Britain responsibility for purchasing these services was devolved to Health Authority Districts in April 1993. There has historically been an underprovision of services for ESRF in Britain [1,2] compared to other developed economies [3], and with regard to the epidemiology of chronic renal failure [4]. There is therefore pressure to increase provision for ESRF treatment, which is constrained because finances are limited. Following the establishment of the division between purchasers (Health Authorities, responsible for the commissioning of all necessary health services for a given population) and providers of treatment (Renal Units operating within NHS Hospital Trusts) in the United Kingdom some particular problems associated with commissioning these services have become apparent.

Firstly, once a patient is taken onto a treatment programme, a commitment has been made to continue that treatment for the rest of that patient’s life. This leads to a continual upward pressure on numbers and hence costs, until a steady state is reached when the numbers of patients being treated has increased so that the number dying is equal to the number of new patients.

Secondly, because of the near universal mortality in untreated patients, commissioning authorities are under substantial public and professional pressure continually to increase funding.

Thirdly, commissioning organizations generally started from a low level of knowledge of the nature of the service.

Fourthly, there is no obvious unit of activity on which to base contracts. Multiple visits for regular hospital haemodialysis could not sensibly be treated either as outpatient episodes, or day-case finished consultant episodes.

Because of the historical underprovision, and the fact that doing nothing would lead inevitably to an uncontrolled and unplanned expansion of the service and hence costs, it was imperative to find a way to predict the demand for services, plan, and convert this into contracts.

A number of computer models have been described...
Computer model for predicting the demand for ESRF treatment

**END STAGE RENAL FAILURE**

**Fig. 1.** Possible patient states and flows between states. In addition, patients may move between peritoneal dialysis and home haemodialysis, though this is unusual.

which predict the level of demand for ESRF treatment [5–7]. Bolger and Davies [8] described a simulation model which provided accurate projections of the numbers of people requiring treatment by different methods, as well as enabling projections under different planning scenarios. However it was not used for setting or monitoring contracts.

The computer model described here was designed to:

- predict demand for ESRF treatment;
- combine this with costs, in order to set contracts and provide total cost estimates for present and future years;
- monitor workload in year so as to predict end of year variation from contracted numbers and adjust planning parameters as necessary;
- enable various ‘what if?’ planning scenarios to be examined;
- be simple to use.

**Methods**

The model is written as a spreadsheet to run on Microsoft Excel ©.

The ESRF population is treated as consisting of four ‘pools’: those treated by haemodialysis at home, and in hospital, those on peritoneal dialysis, and transplanted patients. A patient starting ESRF treatment will start on one or other form of dialysis, but may either get a transplant, or change dialysis modality, or die. Patients with functioning transplants may have to resume dialysis if the graft fails, or they themselves may die. This is illustrated in Figure 1. (It is possible for a patient with ESRF to receive a transplant without first being on dialysis, but the number that do is so small as to be irrelevant for planning purposes.)

Starting with the known numbers of patients being treated by each modality, the model predicts the annual change by calculating the additions and losses from each pool. These changes are calculated on the basis of parameters which were either determined after negotiation with the providers, or

Table 1. Excerpt from spreadsheet showing how the predicted changes are derived from the planning parameters, in order to predict the numbers on the programme in the relevant year (Sheffield data)

<table>
<thead>
<tr>
<th>FORECAST: Input Data</th>
<th>YEAR 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resident population ('000s)</td>
<td>530</td>
</tr>
<tr>
<td>Mid year average no. of patients in previous year</td>
<td>Total haemo</td>
</tr>
<tr>
<td>Overall acceptance per 1,000,000 popn</td>
<td>60</td>
</tr>
<tr>
<td>Proportion (%) to Haemo or CAPD</td>
<td>40</td>
</tr>
<tr>
<td>Acceptance rate per 1,000,000 popn</td>
<td>24</td>
</tr>
<tr>
<td>New transplants</td>
<td>11</td>
</tr>
<tr>
<td>% transplant failures in current year</td>
<td>75</td>
</tr>
<tr>
<td>% transplant failures in subsequent years</td>
<td>10</td>
</tr>
<tr>
<td>Treatment mortality of transplant failures (%)</td>
<td>3</td>
</tr>
<tr>
<td>% dying per annum</td>
<td>14.72</td>
</tr>
<tr>
<td>Transfer in %: Hm to PD, PD to Hm</td>
<td>4.05</td>
</tr>
<tr>
<td>Forecast for:</td>
<td>Total haemo</td>
</tr>
<tr>
<td>Mid year average no. of patients in previous year</td>
<td>Total</td>
</tr>
<tr>
<td>New patients</td>
<td>+13</td>
</tr>
<tr>
<td>New transplants</td>
<td>-11</td>
</tr>
<tr>
<td>Transplant failures</td>
<td>+3</td>
</tr>
<tr>
<td>Deaths</td>
<td>-13</td>
</tr>
<tr>
<td>Transfers - HD to CAPD</td>
<td>-4</td>
</tr>
<tr>
<td>Transfers - CAPD to HD</td>
<td>+6</td>
</tr>
<tr>
<td>Mid year average no. of patients in forecast year</td>
<td>Total</td>
</tr>
<tr>
<td>Change</td>
<td>-6</td>
</tr>
</tbody>
</table>
Fig. 2. Projected numbers of haemodialysis (home and hospital combined), CAPD and transplanted patients, together with the total on treatment, over the next 5 years using the current planning assumptions for Sheffield.

Fig. 3. Projected costs of haemodialysis (home and hospital combined), CAPD and transplantation, together with the total costs, over the next 5 years using the current planning assumptions for Sheffield.

estimated from observations of patient flows in previous years. The following were determined in agreement with the provider unit:

- the take on-rate of new patients per million population;
- the proportion starting on haemodialysis and peritoneal dialysis.

The following were derived from observations:

- the number of transplants per year;
- the transfer rates between treatment modalities;
- the modality specific mortality rates;
- the transplant failure rate for the first and subsequent years.

Because of an agreed policy to encourage peritoneal dialysis and satellite haemodialysis provision, the number of home haemodialysis patients is assumed to remain constant. This
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Fig. 4. Projected total numbers on treatment over the next 12 years if the take-on rate is increased from 60 per million population to 80, while 40% of new patients start on haemodialysis (and 60% on CAPD), and the transplant rate of 15 per annum is maintained.

Fig. 5. Projected numbers on haemodialysis and CAPD over the next 12 years if the ratio of patients started on haemodialysis and peritoneal dialysis is 60% HD/40% CAPD instead of 40% HD/60% CAPD.

means that the model does not predict that any new patient starts on home haemodialysis unless a home haemodialysis patient receives a transplant, transfers to another modality, or dies. These assumptions could be altered to reflect local policies elsewhere.

Agreement was reached with the local provider unit that contracts should be expressed in terms of the mid-year average number of patients on each modality (as the cost of different treatments varies). The model was therefore designed to predict, on the basis of the mid-year average numbers in any one year, the mid-year average for the next year.

Table 1 shows how the predicted changes are derived from the planning parameters and added to the previous year’s figures in order to predict the numbers on the programme in the relevant year.

By inserting the agreed costs for treatment the overall costs are calculated. It is on this basis that the contract is
determined. Because of their expense, erythropoietin and cyclosporin are added separately, again on the basis of agreed costs and proportions of the relevant patients receiving the drugs. The predicted numbers of patients in the forthcoming year are then used to predict the following year's activity, with the same or different planning parameters. There is theoretically no limit to the extent of forward projection, but clearly the accuracy of the predictions is progressively reduced.

The 'steady state' situation, in which the number of patients is constant, as the number of new patients is equal to deaths, can also be predicted.

In year, performance is monitored by comparing actual numbers treated with the predictions. This enables prediction of the end of year variance from contracted numbers and recalculation of the planning parameters.

Results

Contracts have been set for six districts in North Trent for 2 years using the model. This has resulted in an improved relationship between purchasers and provider. It has been used by the Department of Public Health to predict demand, and hence costs to the Authority, in the medium term. It has been used by the Renal Unit to predict the overall capacity requirements, and has informed a business case for development.

Figure 2 shows the projected numbers, and Figure 3 the projected costs of treatment, of Sheffield resident patients on each modality for the next 6 years, using our current planning assumptions.

Figures 4–6 show the effects, on projected numbers over the next 12 years, of altering planning parameters from a hypothetical 'standard' assumption of: overall take-on rate of 60 per million per annum, 40% of new patients starting on haemodialysis (and 60% on CAPD), and a transplant rate of 15 per annum. In each case the parameters are held constant for the period in question. Figure 4 shows the effect on total numbers treated of increasing the acceptance rate onto the programme from 60 per million population to 80. Figure 5 shows the effect of altering the ratio of patients started on haemodialysis and peritoneal dialysis from 40% HD/60% CAPD to 60% HD/40% CAPD. Figure 6 shows the effect of being able to perform only seven transplants per annum.

Alternatively, the model can be used to look at the cost implications of various planning assumptions. For example:

in comparison with the 'standard' assumptions of 60 per million population take-on rate, 40% of new patients on haemodialysis, and 15 transplants per year, increasing the take-on rate to 80 per million population leads to an additional 32% in costs after 10 years;

the extra costs of starting 60% (as opposed to 40%) of new patients on haemodialysis can be met within an unchanged budget by reducing the take on rate to 55 per million;

if the transplant rate were increased to 30 per year [9], the acceptance rate could go up to 68 per million, without incurring extra costs.

The model is undergoing continuing refinements. In
Discussion

The computer spreadsheet model described here has greatly facilitated planning and contracting for renal services in North Trent and has been used both by purchasers and the provider unit to estimate workload (and costs) in future years.

It has enhanced the understanding of both purchasers and providers of the service being provided, and the constraints determining each others' behaviour. For example it is easier to demonstrate to the providers the exact way in which a higher proportion of new patients on haemodialysis (which is more expensive than peritoneal dialysis), inevitably means that fewer patients can be taken onto the programme overall. Similarly the important difference between flow (take-on rate, incidence) and stock (prevalence), has been more readily understood by purchasers.

There have of course been some problems with the development and use of the model. In particular, because the development of ESRF, and other patient flows, are stochastic processes, there will always be a random element in the numbers of new patients requiring treatment, etc. Hence predictions are unlikely to be exactly right. In so far as this matters for contracting, we have attempted to overcome this by spreading the financial risk to both purchaser and provider.

Operational difficulties also emerged in obtaining the right monitoring data. These have been addressed, and we hope overcome, for the forthcoming year.

The contracting unit chosen has a negative impact on the efficiency index, as currently formulated, as the service does not generate any recognized activity, but does generate substantial costs. This has been accepted by all parties, and provides further reason for wishing to see the efficiency index reformulated [10].

Unlike previously described models, this spreadsheet-based model can combine planning with setting contracts and in year contract monitoring. It is simple to use, and runs on easily available and widely used software. We believe it is a useful tool in the planning and management of services for patients with end-stage renal failure.

References


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