Original Article

The effect of altering eligibility criteria for entry onto a kidney transplant waiting list

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Abstract

Background. This paper concerns the allocation of kidneys from cadaveric donors to patients with end-stage renal disease (ESRD). Currently, the decision as to whether or not a particular patient should go onto the renal transplant waiting list is left to the discretion of the local dialysis centre, and is usually based almost entirely upon consideration of each case on its individual merits. Would this person like to have a renal transplant, is this possible, and would it seem reasonable to give them a chance? It could be argued that such an approach may not make best use of a scarce national resource. In this study we explore the effects of altering the eligibility criteria for transplantation to take explicit and quantitative account of the fact that some patients are more likely to die than others.

Methods. We performed a survey of one unit’s dialysis patients to ascertain the characteristics used in practice to determine who should go onto the transplant waiting list and who should not. We then created a computer model to simulate a cohort of ESRD patients, initially of the same size and characteristics as that in the unit surveyed, receiving renal replacement therapy over a period of 10 years. Using this model, we compared four strategies for defining eligibility for transplantation: (1) all patients eligible; (2) standard and medium risk patients eligible; (3) only standard risk patients eligible; and (4) no regrafts performed (standard and medium risk according to definitions in the Renal Association Standards Document).

Results. Strategies of allowing only standard or standard and medium risk patients onto the waiting list most closely reflected the current decisions made regarding eligibility. The different strategies considered in the models necessarily gave rise to very considerable variation in the size of the waiting list at the end of the 10 year period (range 98–368), which would have important practical implications. The predicted mean time of kidney function varied from 9.8 years for strategy 4 (no regrafts) to 10.8 years for strategy 3 (only standard risk patients eligible). However, the different strategies had very little effect on other parameters, such as numbers of deaths and the size of the dialysis population.

Conclusions. Variation in decision making from centre to centre regarding access to renal transplantation could make up to a 10% (1 year) difference in the expected half-life of renal transplants performed. Information about recipient characteristics is therefore required when making comparisons between outcome in one transplant unit with that in another, or when comparing one immunosuppressive regime with another.

Keywords: comorbidity; modelling; renal failure; renal replacement therapy; simulation

Introduction

This study examines one specific decision made during the process of allocating transplants to patients with end-stage renal disease (ESRD): who should go onto the transplant waiting list? This decision has been left entirely to the discretion of local centres, where the focus of the decision making has usually rested solely on consideration of patient preference for or against transplantation, tempered by variable medical opinion as to whether or not it would be prudent to offer the possibility of transplantation to a particular individual. At present there is great variation in the proportion of patients considered eligible for transplantation in renal units throughout the country, ranging from 20 to 70% of defined ESRD patients [1]. It could be argued that this individualistic approach is not likely to make best use of a scarce national resource, cadaver donor kidneys.

The literature on outcome after transplantation has concentrated almost exclusively on that of patients receiving grafts [2–4], sometimes in comparison with those remaining on the transplant waiting list but not transplanted [5,6].

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In this study we explore the effects of altering the eligibility criteria for transplantation to take explicit and quantitative account of the fact that some groups of patients are more likely to die than others. We consider each patient as a member of a subgroup of the population, defined by age and comorbidity (diabetes). To put it simply, if only the fitter patients were offered transplantation, what would be the effect on transplant survival, and on the population remaining on dialysis?

We have surveyed the characteristics of patients receiving dialysis at a single centre (Addenbrooke’s, Cambridge, UK), some of whom were currently on the transplant waiting list and some of whom were not. We have compared the findings of this survey with those of four different specified strategies that could be used to determine transplant eligibility, and then explored by way of computer simulations how these different strategies would affect outcome, both as regards transplant function and the renal replacement therapy population as a whole.

Methods

Case study: current waiting list entry

In December 1998 there were 266 patients receiving peritoneal or haemodialysis at Addenbrooke’s Hospital, Cambridge. To define empirically the eligibility criteria used for entry onto the waiting list, factors that appear to be taken into account in routine clinical practice were then investigated using forward stepwise logistic regression. Data were collected from the medical records on the following patient characteristics: date of birth, transplant history, presence of diabetes, and waiting list status. Patients were classified as having diabetes if they were receiving treatment with oral hypoglycaemic agents or insulin at the time of data collection. A significance level of 0.10 was the criterion for inclusion of a factor in the next step of the regression model. Nineteen of the 266 sets of patient notes were unavailable.

Simulations to compare eligibility strategies

Model used

A model of the possible renal replacement therapies that a patient could receive each month was constructed, as shown in the flow diagram in Figure 1 (the numbers in the text refer to Figure 1). At the start of the simulation all patients are on dialysis (1). Within the first month, each patient may die on dialysis (2). If they survive (3), the particular eligibility criterion being tested is imposed (4), resulting in either entry onto the transplant waiting list (5) or the patient remaining on dialysis for that month (6). If on the transplant waiting list, the patient may or may not receive a graft, which may be favourably (7) or unfavourably (8) matched. If no donor kidney is available, the patient will remain on dialysis (9). After receiving a graft, the patient may die with their graft functioning (10), may survive with a functioning graft (11), or the graft may fail (12) and they return to dialysis. If the graft has failed, then the patient may either die on dialysis (13) or survive the rest of the month on dialysis (14). At the end of each month a number of incident ESRD patients joins the dialysis population (15). At the start of the second month, each patient will be on dialysis, be alive with a functioning graft, or will have died.

A program to run the simulations was written using the package STATA [7]. The program was set up to loop through the model 120 times to simulate 10 years of renal replacement therapy (RRT) activity for each run. Eighty such runs were undertaken to test each eligibility criterion imposed.

Initial population (1)

The prevalent dialysis population from Addenbrooke’s Hospital, Cambridge, as described above, was used as the initial population in the simulations (1). In addition to the data on age, transplant history and diabetic status, each patient’s matchscore and matchpoint were collected [8]. A patient’s matchscore depends on HLA phenotype and, based on donor phenotypes and allocation rules, reflects the patient’s probability of receiving a favourably matched graft. Matchpoint 1 denotes the top 10% of patients in terms of matchscore (most likely to receive a favourably matched graft) and matchpoint 10 the bottom 10% (least likely to receive a favourably matched graft) (see Appendix 3). Matchscores and matchpoints were only available for patients who were on the transplant waiting list in June 1998. The remaining patients were allocated a matchpoint according to the distribution of matchpoints in a prevalent population of 3850 on a UKTSSA waiting list used previously to carry out other simulations at UKTSSA.

Patients were categorized with respect to their risk of death on dialysis, according to the recent Renal Association Standards Document [9], as follows. (i) Standard risk: non-diabetic and <5.5 years old; (ii) medium risk: non-diabetic and aged 55–64 years; (iii) diabetic and aged 15–54 years; (iv) high risk: non-diabetic and aged ≥65 years, diabetic and ≥55 years, or all HIV-positive patients. There were no HIV positive patients in our dialysis population during the period of this study.

Dialysis survival (2, 3)

Good data on risk of death on dialysis in the UK were not available. To obtain the best estimate we used dialysis survival probabilities from the USA, available from the US Renal Data System (USRDS) [10], and then standardized these to the UK dialysis population [1]. The USRDS data provided the risk of death by age, but both diabetes and non-diabetes and patients were included in this pool of patients. Hence, these probabilities were adjusted to give survival probabilities according to diabetic status derived from a systematic quantitative overview of the literature, which found that the relative risk of death for diabetics, as compared with non-diabetics, was 1.91 [11]. Unfortunately, data on the prevalence of diabetes was not available by age, and nor was information regarding the possibility of the effect of interaction between age and diabetes on outcome. We therefore made the simplest assumptions, namely that the prevalence of diabetes was constant across age groups, and its effect on outcome was not dependent on age. To allow for the fact that absolute death rate on dialysis in the USA is higher than that in the UK, the death rates were standardized to the UK population, multiplying by a factor of 0.62 (across all the age groups, diabetic and non-diabetic). This factor
Fig. 1. Modelling strategic approaches to deciding on eligibility for entering a transplantation waiting list (numbers refer to the text).

was obtained from the fact that the observed annual death rate in the UK for patients under the age of 65 was 9.7% [1] and the expected death rate in the USA for the same age group was 15.7% [10]. The resulting annual probabilities of death on dialysis are given in Appendix 1. When entered into the model, these were adjusted to give monthly probabilities of death. The outcome on dialysis of the whole population, was, of course, dependent on the age distribution and prevalence of diabetes in the local population.

Eligibility criteria (4, 5, 6)

The following eligibility strategies were then compared:

1. all patients eligible to enter the waiting list;
2. only enter standard and medium risk patients;
3. only enter standard risk patients onto the waiting list; and
4. do not enter if patient has had a failed transplant.

We assessed which of these strategies most closely resembled the current, informal strategy employed at Addenbrookes Hospital by using logistic regression to compare those on the actual waiting list with those that would be included on the list if each of the strategies were applied.

Allocation of transplants (7, 8, 9)

Over the last few years, a relatively constant number of kidneys (range 16–28 and mean 22.8 between 1994 and 1998 inclusive) have been allocated to Addenbrooke’s dialysis patients on the Cambridge transplant waiting list. We therefore, as a close approximation, modelled the allocation of two kidneys per month. In reality, kidneys are either allocated by way of an algorithm employed at a national level, or if a locally harvested kidney is transplanted, using a similar locally derived algorithm. It was not possible to model these algorithms due to the absence of data on donor age and tissue type, recipient waiting time, renal unit’s balance of exchange, and patient sensitization. However, data on the result of employing these algorithms are available from simulations run by UKTSSA. We know that if 4000 kidneys are allocated by UKTSSA algorithms, they will be given to patients of the age and matchpoint distribution shown in Appendix 2. Our model, therefore, was set up so that when the kidneys were allocated in our cohort, they would be given in such a way that the pattern of characteristics (age and matchscore) of the recipients would be the same as the pattern of patient characteristics of recipients in the UKTSSA simulations. To achieve this, patients were grouped according to their age and matchscore.
Each available kidney was then allocated one at a time to a group of patients which was selected at random, but according to the known UKTSSA distribution. We also knew the proportion of favourable to unfavourable grafts in each of the age and matching score groups from the UKTSSA simulations, hence the donor kidney was tagged as being a favourable or unfavourable match at this point. If there were no patients alive and eligible to receive a graft in this group of patients, a new group was selected, and again the kidney was tagged as favourably or unfavourably matched. Once a group of patients was successfully identified, the kidney was randomly allocated to an eligible individual within this group.

Outcome of transplant (10, 11, 12)

Appendices 3 and 4 show the probabilities of death following transplantation and of graft failure in 1 year, according to the following patient characteristics: age, diabetic status, favourably or unfavourably transplanted, and first graft or regraft. These data were available from UKTSSA and were adjusted in the simulations to give monthly probabilities. In the simulation set-up there was an equal chance for the probability matrix for survival to be applied first, or the probability matrix for transplant failure to be applied first to a particular patient each month. Data were only available for the first year following transplantation, and to calculate the probability of death in the second and subsequent years we multiplied the probabilities by a factor of 0.46, derived from the fact that patient survival in the first year was 93%, and in the fifth year, 80% [12]. Similarly, the probability of graft survival in the first year was 84%, and 70% in the fifth year. Hence, the first year probabilities of graft survival were multiplied by a factor of 0.22 to derive the probability of graft survival in the second and subsequent years [12].

Outcome following a failed graft (13, 14)

If a patient’s graft failed, the probabilities of death on dialysis (Appendix 1), according to age and diabetic status, were reapplied within that month.

Entry of incident dialysis patients (15)

Four-hundred-and-seventy-six patients have commenced dialysis at Addenbrookes in the last 5 years, 36 of these following a failed graft. In order to simulate the entry of new patients, seven patients were added to the dialysis population at the end of each month of the simulation, and eight every third month, to be included at the start of the next month’s run. Their ages, diabetic status and occurrence of graft failure were allocated at random, according to the distribution of these characteristics in the original prevalent population from Addenbrookes. Matchpoint scores were allocated according to the distribution of scores in 4000 incident patients entering the UKTSSA waiting list. This model did not allow for an inflation in the number of patients entering the waiting list each year.

Impact of living related transplants on the model

In some centres in some countries, a very high proportion of low-risk recipients receive kidney transplants from living donors and are never entered onto the cadaveric transplant waiting list. Such a policy clearly has a substantial effect on the characteristics of the population on the cadaveric transplant waiting list in those centres. This was not the situation in our centre during the period of this study: in common with most UK units at this time, transplants from living donors accounted for between 5 and 9% of the renal transplants performed each year, with the vast majority of recipients placed on the cadaveric transplant waiting list, excepting for the few weeks between completion of donor work-up and the operation itself.

Results

Case study: current waiting list entry

At present, formal criteria are not strictly imposed to decide eligibility for entry to the transplant waiting list. In general, however, the responsible physicians have agreed that it is inappropriate to place patients thought likely to die within 3 years onto the transplant waiting list, which includes many who are old or have diabetes (J. Firth, personal communication). Following the stepwise logistic regression analysis of patient characteristics of those on and off the transplant waiting list, Table 1 gives odds ratios and their 95% confidence intervals for patients, dependent upon their age and whether or not they have diabetes. Relative to 15–54 year olds, the odds of a patient >65 years old being on the waiting list are 0.02 or 50:1 against, but with a wide confidence interval.

Simulations to compare eligibility strategies

Strategies 2 (standard and medium risk patients eligible) or 3 (only standard risk patients eligible) most closely mirrored the present strategy by which people are entered onto the transplant waiting list, having the highest ratios of logistic coefficient to standard error (see Table 2). Strategy 2 was taken as our baseline in order to assess the effects of applying novel eligibility criteria.

Deaths

Over the 10 year period, strategy 2 (standard and medium risk patients eligible) predicted an average of

<table>
<thead>
<tr>
<th>Table 1. Results of stepwise logistic regression analysis of patient characteristics of those on and off the transplant waiting list</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Odds ratio</strong></td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>15–54</td>
</tr>
<tr>
<td>55–64</td>
</tr>
<tr>
<td>65–100</td>
</tr>
<tr>
<td>Diabetes</td>
</tr>
</tbody>
</table>

This means that relative to someone aged 15–54 years, the odds on a patient over 65 years of age being placed on the waiting list are 0.02 (1:50). See text for further explanation.
Table 2. Comparison of the strategies being tested against patients on the current waiting list by logistic regression

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Only low and medium risk patients eligible</th>
<th>Only low risk patients eligible</th>
<th>No regrafts</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2.76 (0.61) = 4.5</td>
<td>1.66 (0.32) = 5.2</td>
<td>-0.65 (0.42) = -1.5</td>
</tr>
</tbody>
</table>

All patients are not on the waiting list, hence comparison of patients on the current waiting list with strategy 1 has not been applied. For each strategy-specific logistic regression, patients were scored 1 if they were entitled to be added to the waiting list by that strategy, and 0 if not. Entitlement was then compared with the current waiting list via logistic regression to parallel Table 1’s use of logistic regression to explore prognostic factors for being listed. Strategies 2 and 3 best conform to local practice, having the highest ratios of logistic coefficient to standard error.

Table 3. Results of the simulations comparing five strategies for defining eligibility for entry onto the waiting list: outcome at 10 years from 80 simulation runs

<table>
<thead>
<tr>
<th>Patients eligible</th>
<th>Strategy 1 All</th>
<th>Strategy 2 Standard and medium risk only</th>
<th>Strategy 3 Standard risk only</th>
<th>Strategy 4 No regrafts</th>
</tr>
</thead>
</table>

Deaths
On dialysis
66.5 (1.0)
67.0 (1.0)
68.7 (1.0)
66.4 (1.0)

With transplant
5.8 (0.5)
5.2 (0.4)
3.5 (0.3)
6.7 (0.5)

Total
72.3
72.2
72.2
73.1

Use of donor kidneys
Favourable grafts
(16.8 (0.3)
16.8 (0.3)
17.1 (0.3)
17.3 (0.3)

(7.2 (0.3)
7.2 (0.3)
6.9 (0.3)
6.8 (0.3)

Number of patients with functioning graft
145.6 (1.0)
148.0 (1.1)
151.1 (1.0)
144.3 (1.1)

Mean time of kidney function (years)
10.0 (0.3)
10.4 (0.3)
10.8 (0.3)
9.8 (0.3)

Graft failures
8.2 (0.4)
8.6 (0.3)
8.9 (0.3)
7.9 (0.3)

Number of regrafts
3.2 (0.2)
3.6 (0.2)
5.4 (0.2)
0 (0)

Dialysis
Number of patients on dialysis
379.5 (1.6)
377.3 (1.6)
372.3 (1.6)
378.1 (1.6)

Number of patients on waiting list
367.7 (4.0)
176.1 (3.5)
98.6 (3.8)
258.4 (1.6)

Note: values, unless otherwise stated, refer to numbers of patients in year 10. Figures in parentheses are standard errors.

72.2 deaths on dialysis, and 5.2 following a transplant (Table 3). The number of deaths across the different strategies were very similar, and none of the strategies reduced mortality as compared with strategy 2. However, the proportion of deaths on dialysis as compared with those on transplantation did vary between the strategies. For example, a smaller proportion of the deaths occurred after transplantation when eligibility was restricted to standard risk patients only (strategy 3).

Use of donor kidneys
The mean kidney function time per patient was 10.4 years when strategy 2 (standard and medium risk patients eligible) was employed. By restricting eligibility to standard risk patients only (strategy 3), the duration of kidney function was increased by an average of 5 months, whereas if eligibility were not restricted (strategy 1), the duration of kidney function would be decreased by an average of 5 months. The duration of kidney function would also be decreased, as compared with strategy 2, in strategy 4 (no regrafts).

The number of patients surviving with a functioning graft, the proportion of favourably to unfavourably matched grafts, the number of graft failures, and the number of regrafts were very similar across the four strategies employed (Table 3).

Dialysis
Table 3 shows the number of patients on dialysis. The number of patients on dialysis after 10 years varied very little across the strategies; from 379.5 patients with strategy 1 (all eligible) to 372.3 patients with strategy 3 (only standard risk transplanted).

The size of the transplant waiting list necessarily varied considerably between the strategies. As would be expected, the largest waiting list (an average of 367.7 patients) formed when strategy 1 (all patients eligible) was employed, and the smallest waiting list (an average of 98.6 patients) when strategy 3 (only standard risk eligible) was used.
Discussion

In this study, we have examined the criteria used at present in a single medium-sized dialysis centre to determine whether or not patients with end-stage renal failure are placed onto the renal transplant waiting list. We then created a computer simulation model to determine how altering the eligibility criteria for entry onto the waiting list would affect the average life-span of each renal transplant, the numbers of patients receiving dialysis, and the mortality of the population with ESRD.

Previous studies have considered some of the issues involved. There has been much interest in the effect of recipient age on the outcome of renal transplantation; some demonstrating that older age is correlated with reduced survival [3], others arguing that it is of little importance [4], and some that the age of recipients is ‘a controversial issue and an ethical dilemma’ [2]. Comparisons have been made between the survival of dialysis patients and transplant recipients: these have generally concluded that those receiving transplants fare better [5,6,13–16], but difficulties remain regarding the matter of controls. It is not possible (or desirable) to allocate transplants randomly; hence the controls are those who remain on dialysis on the transplant waiting list. Given the nature of the discussions that invariably go on whenever a donor kidney becomes available, it is likely that in most centres, those that are ‘better’ candidates (lower risk) are more likely to actually receive grafts than those who remain on the waiting list but are not transplanted. This process introduces bias into comparisons of survival of patients after transplantation with that of patients remaining on dialysis.

A computer-based simulation model has been used to study the effect of explicitly incorporating different equity criteria into the process of allocating transplant kidneys to recipients. Yuan et al. came to the conclusion that such models were a feasible way to test prospectively the impact of any given allocation algorithm, but noted that the final choice of any particular system of allocation would require a value judgement to be made (how great a reduction in HLA-matchscore could be tolerated to improve a score of equity, or vice versa) [17]. Such thinking has been influential in the development of the allocation plan for renal transplantation reported recently by the United Network for Organ Sharing Region 1 Regional Data Committee [18].

The model that we have developed is necessarily a complex one, and the main constraint on the accuracy of its predictions is the quality of the data entered. The ideal situation would be to have information relevant to all important outcomes available for the population under examination. This would comprise mortality statistics for patients on dialysis, stratified for age, the presence of diabetes and the effect of previous transplantation. Data on the probability of transplantation with or without a favourable matchscore would also be required. Regarding transplantation, similar information on mortality would be needed, as would data on graft survival (stratified for age and diabetic status), both for first and subsequent grafts.

These data are not available for our population, nor are all aspects available for renal patients in the UK, hence we have had to draw on information from a wide variety of sources. Whenever possible, we have chosen to use information from large registries, in particular the USRDS, the UKTSSA and the UK Renal Registry.

Data on the probability of death or graft failure following transplantation and the effect of diabetes were available for the UK [12]. With respect to mortality on dialysis, data stratified for age and comorbidity are not available for the UK. However, in a recent systematic quantitative overview of the literature, we found that the relative differences in mortality associated with age and comorbidity were similar across continents [11], and so we used USA data for risk of death on dialysis with age and comorbidity [10], factored appropriately for relevance to the UK population by reference to the mortality rate quoted in the first publication of the UK Renal Registry [1].

Further improvement in the quality of the model could be made if it were possible to define the age and comorbidity of incident patients, those new to the renal replacement therapy programme, rather than using the characteristics of the prevalent group. The necessary information was not available to do this. It is also proper to note that even if data on all of these issues were available for our population, the modelling process would still have its limitations. Other factors that almost certainly have a bearing on the outcome of renal transplantation are not accounted for in our model at all: for instance donor age, variation in immunosuppressive regime, or the presence or absence of other significant comorbidity factors in recipients, e.g. cardiovascular or cerebrovascular disease. These were not included in our modelling algorithm for pragmatic reasons, not because we think them clinically unimportant. The model is also unable to report the actual distribution of allocated kidneys according to the risk of death between the different strategies, i.e. it cannot specify how many patients transplanted under strategy 1 (all patients eligible) would actually come from a high risk group.

Accepting these limitations, the modelling exercise demonstrated that the decisions presently made at this dialysis centre closely mimic those employed in strategy 2, where only patients defined in the Renal Association Standards Document as being at standard or medium risk were eligible for entry onto the transplant waiting list. In comparison with this strategy, what would be the effects of adopting the alternatives? The most obvious implication would necessarily be on the size of the transplant waiting list, which varied over an almost 4-fold range from strategy 3, where only standard risk patients were eligible, to strategy 1, where all could be considered for transplantation. This has significant implications, both organizational and for individual patients. Maintenance of the renal
transplant waiting list is a considerable logistical and financial burden for the providers of care to the population with end-stage renal failure. It is necessary to maintain mechanisms to allow immediate contact with all on the waiting list, who need to be brought into hospital at very short notice should a kidney become available. Furthermore, it is necessary to ensure particularly close medical supervision of all potential recipients, who may need to be suspended (temporarily or permanently) from and/or re-instated onto the waiting list should their clinical condition alter. There is an additional requirement for regular monitoring, of virological and immunological status in particular. To provide this service for a larger population clearly requires greater allocation of resources than it does for a smaller one.

Variation in the size of the waiting list also has an obvious impact on those on that waiting list. The time that any individual could expect to be on the waiting list before receiving the offer of a kidney would vary by the same factor, assuming (as the models do) that the number of kidneys offered remained the same. There has been little written on the subject, but many patients find being on the transplant waiting list a stressful experience, frequently associated with symptoms of depression and anxiety [19]. Any change that increases the length of time that patients spend on the waiting list is likely to exacerbate such problems.

The different strategies had very little effect on total mortality predicted during the 10 years of the simulation (range across the groups from 72.2 to 73.1) or the number of patients on dialysis at the end of the 10 year period (range 372.3 to 379.5). They did, however, predict some variation in the mean time for which each kidney graft could be expected to function. Compared with strategy 2, which most closely mimicked current practice by allowing standard and medium risk patients access to transplantation, the strategy of allowing all patients access (strategy 1) led to a reduction of 0.4 years in mean graft survival (10.0 vs 10.4 years), whereas the strategy of confining transplantation to those at lowest risk (strategy 3) led to an increase of the same amount (10.8 vs 10.4 years). Strategy 4, where regrafts were not permitted, was associated with a reduced mean time of graft function (9.8 years), probably because by denying regrafts it increased the average age and risk of death of those receiving transplants.

What are the implications of the variations in mean graft survival time of the magnitude predicted? They certainly mean that information about recipient characteristics is required when making comparisons between outcome in one transplant unit with that in another, or when comparing one immunosuppressive regime with another, whenever this is not done in the form of a randomized controlled trial. With respect to the implications for the attitudes of transplant physicians when confronted with individual patients with ESRD, different doctors will no doubt interpret the data in different ways and make different value judgements. There is no ‘right answer’ to the question of who should be put on the waiting list to receive

the chance of getting access to a limited resource, a cadaveric kidney transplant, and a statistical model cannot make such judgements under any circumstance. However, our modelling, with all its limitations, would suggest that a policy that restricts transplantation to roughly the fittest 25% of the dialysis population would lead to an increase in mean graft survival of 5 months compared with current practice in a typical transplant centre, where approximately the fittest 50% are considered eligible.

Acknowledgements. We acknowledge statistics prepared by the UK Transplant Support Service Authority for the National Transplant Database, maintained on behalf of the UK transplant community. We thank Elizabeth Jones of the ERA-EDTA Registry for assistance in obtaining data for this project. We acknowledge financial support from Fujisawa, Inc.

Appendix 1. Annual probability of death on dialysis (see Methods)

<table>
<thead>
<tr>
<th>Age</th>
<th>Heart disease</th>
<th>No heart disease</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Non-diabetic</td>
<td>Diabetic</td>
</tr>
<tr>
<td>15–19</td>
<td>0.035</td>
<td>0.066</td>
</tr>
<tr>
<td>20–24</td>
<td>0.047</td>
<td>0.089</td>
</tr>
<tr>
<td>25–29</td>
<td>0.081</td>
<td>0.150</td>
</tr>
<tr>
<td>30–34</td>
<td>0.095</td>
<td>0.175</td>
</tr>
<tr>
<td>35–39</td>
<td>0.098</td>
<td>0.178</td>
</tr>
<tr>
<td>40–44</td>
<td>0.098</td>
<td>0.178</td>
</tr>
<tr>
<td>45–49</td>
<td>0.101</td>
<td>0.185</td>
</tr>
<tr>
<td>50–54</td>
<td>0.112</td>
<td>0.202</td>
</tr>
<tr>
<td>55–59</td>
<td>0.135</td>
<td>0.242</td>
</tr>
<tr>
<td>60–64</td>
<td>0.160</td>
<td>0.283</td>
</tr>
<tr>
<td>65–69</td>
<td>0.191</td>
<td>0.333</td>
</tr>
<tr>
<td>70–74</td>
<td>0.225</td>
<td>0.386</td>
</tr>
<tr>
<td>75–79</td>
<td>0.261</td>
<td>0.439</td>
</tr>
<tr>
<td>≥80</td>
<td>0.293</td>
<td>0.485</td>
</tr>
</tbody>
</table>

Appendix 2. The distribution of kidneys transplanted across age and matchpoint groups that resulted when the allocation of 4000 kidneys was simulated by UKTSSA, using the algorithm presently employed at a national level

<table>
<thead>
<tr>
<th>Matchpoint score</th>
<th>Age &lt; 55 years</th>
<th>Age 55–64 years</th>
<th>Age ≥65 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fav</td>
<td>Unfav</td>
<td>Fav</td>
<td>Unfav</td>
</tr>
<tr>
<td>1</td>
<td>832</td>
<td>55</td>
<td>217</td>
</tr>
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<td>107</td>
<td>7.5</td>
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</tbody>
</table>

Fav, favourable; Unfav, unfavourable.
Source: UKTSSA, 1998
Appendix 3. First year annual probability of death following transplantation

<table>
<thead>
<tr>
<th>Age</th>
<th>Diabetic</th>
<th>Non-diabetic</th>
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<tbody>
<tr>
<td></td>
<td>Fav</td>
<td>Unfav</td>
</tr>
<tr>
<td>15–39</td>
<td>0.051</td>
<td>0.065</td>
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<tr>
<td>40–49</td>
<td>0.106</td>
<td>0.134</td>
</tr>
<tr>
<td>50–59</td>
<td>0.161</td>
<td>0.202</td>
</tr>
<tr>
<td>≥60</td>
<td>0.252</td>
<td>0.311</td>
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</table>

Fav, favourable; Unfav, unfavourable.
Source: UKTSSA, 1998

Appendix 4. Probability of graft failure in 1 year

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<th>Regraft</th>
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</tr>
<tr>
<td></td>
<td>Fav</td>
<td>Unfav</td>
</tr>
<tr>
<td>15–39</td>
<td>0.161</td>
<td>0.203</td>
</tr>
<tr>
<td>40–49</td>
<td>0.147</td>
<td>0.186</td>
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<tr>
<td>50–59</td>
<td>0.138</td>
<td>0.175</td>
</tr>
<tr>
<td>≥60</td>
<td>0.130</td>
<td>0.171</td>
</tr>
</tbody>
</table>

Fav, favourable; Unfav, unfavourable.
Source: UKTSSA, 1998

References

1. UK RENALREG. UK Renal Registry, Bristol, UK, 1998
7. STATA. Stata Corporation, 702 University Drive East, College Station, TX 77840, USA, 1996

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