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Effectiveness of a regional trauma system in reducing mortality from major trauma: before and after study

Jon Nicholl, Janette Turner

Abstract

Objective: To assess the effect of the development of an experimental trauma centre and regional trauma system on the survival of patients with major trauma.
Design: Controlled before and after study examining outcomes between 1990 and 1993, spanning the introduction of the system in 1991-2.
Setting: Trauma centre in North Staffordshire Royal Infirmary and five associated district general hospitals in the North West Midlands regional trauma system, and two control regions in Lancashire and Humberside.
Subjects: All trauma patients taken by the ambulance services serving the regions or arriving other than by ambulance with injury severity scores >15, whether or not they had vital signs on arrival at hospital.
Main outcome measures: Survival rates standardised for age, severity of injury, and revised trauma score.
Results: In 1990, 33% of major trauma patients in the experimental region were taken to the trauma centre, and by 1993 this had risen to only 39%. Crude death rates changed by the same amount in the control regions (46.5% in 1990-1 to 44.4% in 1992-3) as in the experimental region (44.8% to 41.3%). After standardisation, the estimated change in the probability of dying in the experimental region compared with the control regions was -0.8% per year (95% confidence interval -3.6% to 2.2%); for out of hours care, the change was 1.6% per year (-2.3% to 5.6%), and, for multiply injured patients, the change was -1.6% (-6.1% to 2.6%).
Conclusion: Any reductions in mortality from regionalising major trauma care in shire areas of England would probably be modest compared with reports from the United States.

Introduction

A working party of the Royal College of Surgeons of England found "significant deficiencies in the management of seriously injured patients," most notably that up to 33% of the deaths of 514 patients with major trauma admitted to hospitals' accident and emergency departments could have been avoided.[1] It recommended that accident and emergency services for the care of major trauma patients in Britain should be reorganised so that such patients would be transferred to regional trauma centres conceived along the lines of the American model,[2] which was widely reported as reducing avoidable trauma deaths, particularly for patients with multiple injuries.[3–6] In this model a number of key elements were identified by the American College of Surgeons—such as 24 hour reception in emergency departments by senior staff, all key specialties in the treatment of trauma care on the same site, a high volume of seriously injured patients (about 10-20 a week), and a system to ensure that seriously injured patients would be treated in the trauma centre.[2]

In order to assess whether this concept would transfer cost effectively into the British setting, the Department of Health funded the establishment and evaluation of an experimental regional trauma system in the North West Midlands region based around the North Staffordshire Royal Infirmary. The nascent regional system covered an area of about 6000 km^2 with a catchment population of 1.8 million and was served by five other district general hospitals' accident and emergency departments and three ambulance services (see table 1).

This paper concentrates on the benefits from the system in terms of survival from major trauma. Detailed results on other patient groups, avoidable deaths, outcomes for survivors, and costs will be reported elsewhere.

Methods

Design

We examined changes in outcomes for trauma patients before and after the development of the trauma system. In order to control for secular trends over the four years studied, from January 1990 to December 1993, we compared changes in the experimental

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region with changes in two control regions—Lancashire and Humberside—which were similar to the North West Midlands region at the start of the study, before the development of the trauma system. Both control regions had a single central hospital which, like the North Staffordshire Royal Infirmary, had an accident and emergency department of good practice, with neurosurgery on site, to which patients with head injuries were referred from within the region, but neither had cardiothoracic surgery (see table 1).

We obtained approval for our observational study from the appropriate ethics committees. The design and progress of the study were overseen by an advisory group convened by the Department of Health.

Inclusion criteria

We included all patients who had an injury severity score[7] of >15, indicating major trauma, and who were brought directly to accident and emergency departments in the regions by any means other than ambulance services from outside the regional systems (whether or not they were recorded as dead on arrival).

Outcomes

The development of the trauma system was monitored by measuring changes in the processes of care in the experimental region and control regions. All patients were followed up to assess survival at six months after the trauma. Deaths were assessed from the records of all hospitals in the United Kingdom to which patients were admitted or transferred, and from coroner's lists in the study regions.

Details recorded

We obtained information from ambulance service records, accident and emergency records, inpatient notes and hospital administrative databases, and coroner's records. A full description of all injuries sustained and their codes on the abbreviated injury scale[8] was made from accident and emergency records, inpatient notes, and necropsy reports. The abbreviated injury scale indicates threat to life and ranges from 1 to 6 (non-survivable injury). Injury mechanism was classified as blunt or penetrating. The injury descriptions were coded with the 1990 abbreviated injury scale dictionary.[8] Injury severity scores[7] were calculated by summing the squares of scores on the abbreviated injury scale of the most severe injuries in up to three body regions. Injury severity scores range from 1 to 75 (non-survivable injuries).

Table 1 Summary of services and facilities for trauma care in North West Midland region, provided with experimental regional trauma system, and in two control regions

Characteristics	Experimental region	Control regions	
		Lancashire	Humberside
Approximate area (km^2)	5500	2500	3500
Size of catchment population (millions)	1.8	1.3	0.9
No of ambulance services	3	1	1
No of district general hospitals with accident and emergency departments:	6	5	3
With neurosurgery on site	1	1	1
With cardiothoracic surgery on site	1	1	0
Range of new attendances at accident and emergency (thousands per year)	20-90	30-70	40-80

All injuries from the regions were coded by four researchers, with advice from a fifth (JT) for difficult cases. The injury coders attended several one-day training sessions on coding injuries, organised with the help of the coordinator of the major trauma outcome study, that were designed to ensure, as far as possible, consistency in scoring between the researchers. Agreement between researchers was assessed during the study.

Statistical methods

We compared trends in death rates over the study period in the experimental region and control regions after adjustment for case mix. We made the adjustment by "indirect standardisation," calculating expected numbers of deaths in each year in the three regions and comparing these with observed numbers to calculate standardised mortality ratios.

For the indirect standardisation, we used three different methods: using strata derived from age, injury severity scores, and revised trauma scores (which are based on the Glasgow coma score, respiratory rate, and systolic blood pressure); using the TRISS method[9]; or using the death rates observed within the study for all data combined. Patients with injury severity scores of 75 (of whom 0/129 survived) or revised trauma scores of 0 (1/283 survived) could not contribute to examining differences in survival and were excluded from comparisons of standardised mortality ratios.

For the TRISS method, we calculated expected numbers of deaths using the British norms for blunt injuries from the major trauma outcome study[10] and American rates for the few cases of penetrating injury (British norms were not available). When using the TRISS method, we also had to exclude patients with missing age ($n=5$) or missing revised trauma scores ($n=873/2229$) from comparisons of standardised mortality ratios.

To calculate standardised mortality ratios based on internally derived standard death rates, we used strata defined by three categories of injury severity scores (16-24, 25-40, and 41-74), two age groups (0-64 and ≥ 65), and five categories of revised trauma scores (0-5.79, 5.97-6.82, 6.90-7.55, 7.84, and missing). We estimated differences in trends between regions by fitting equivalent logistic regression models to the proportions of deaths, using injury severity scores, age group (0-44, 45-64, 65-74, or ≥ 75), and revised trauma scores (including a missing data category) as covariates. The same models were also fitted without revised trauma scores, as has been recommended[11] in order to examine the robustness of the estimate obtained by including the "missing" category for revised trauma scores.

Results

Development of the trauma system

The main developments in the trauma system were at the trauma centre. Briefly, these were the appointment of four new consultants to provide 24 hour cover by consultants, 12 nursing staff for accident and emergency, and 12 nursing staff for the intensive care unit; the start of the West Midlands helicopter ambulance service during 1991; and one further consultant and the development of the current

"trauma team" model in 1992. Training in advanced trauma life support,[12] nursing teams for the reception of seriously injured patients, and paramedic training also developed from mid-1991.

Numbers of patients with major trauma

During the four year study the trauma centre was the primary receiving hospital for 416 patients with major trauma, and other hospitals in the experimental region received 727 major trauma patients (table 2). There were 1002 major trauma patients during the study in Lancashire and 501 in Humberside. In this period the total number of major trauma patients seen in the experimental region declined by about 20%, from 319 in 1990 to 251 in 1993. This decline closely reflected the 28% reduction in the number of deaths in road traffic accidents and "serious" injuries recorded in police statistics (Stats19) for the experimental region.

Processes of care

The proportion of major trauma patients in the experimental region who were taken directly to the trauma centre increased from 34% in 1990 to 39% in 1993, from a widening catchment area (table 3).

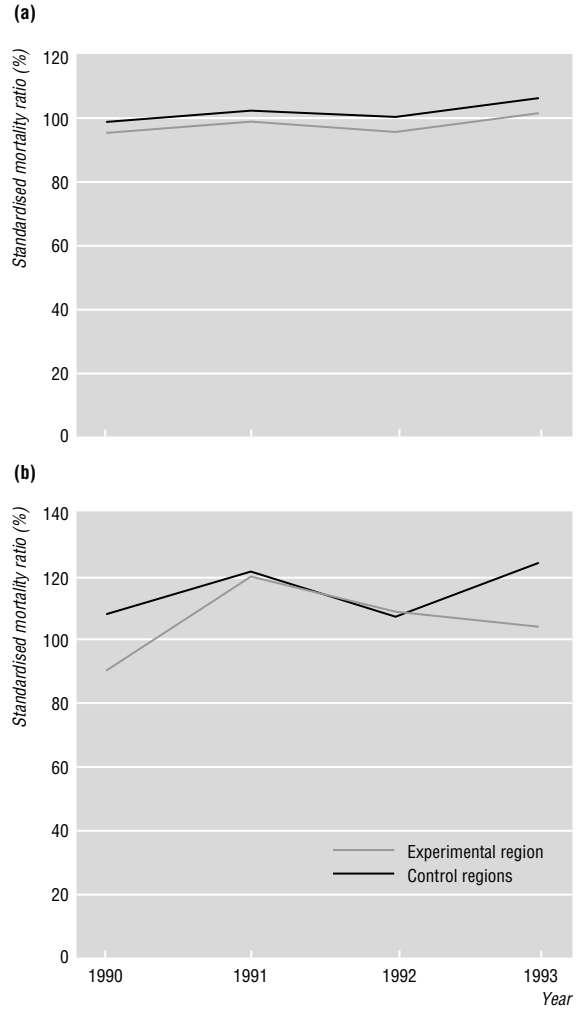

Fig 1 Standardised mortality ratios for all patients with major trauma in North West Midland region, provided with experimental regional trauma system, and in two control regions: (a) calculated by means of internally derived standards, and (b) calculated by means of TRISS with results of the British major trauma outcome study[10] as the standard

Table 2 No of patients with major trauma patients (injury severity score >15) recorded in North West Midland region, provided with experimental regional trauma system, and in two control regions

	Year			
	1990	1991	1992	1993
Experimental region				
Trauma centre (North Staffordshire Royal Infirmary)	108	98	112	98
District general hospitals	211	172	191	153
Total	319	270	303	251
Control regions				
Lancashire	253	269	247	233
Humberside	117	120	157	107
Total	370	389	404	340

Table 3 Percentage of patients with major trauma transported directly to the central hospital in North West Midland region, provided with experimental regional trauma system, and in two control regions, Lancashire and Humberside

	Year			
Types of patient	1990	1991	1992	1993
All major trauma patients				
Experimental region	34	36	37	39
Control regions	42	40	46	43
Patients with multiple injuries				
Experimental region	26	34	40	41
Control regions	44	42	50	45
Patients seen out of hours				
Experimental region	34	36	38	42
Control regions	45	40	49	49
Patients with severe head injuries*				
Experimental region	41	38	31	46
Control regions	37	44	43	35

*Abbreviated injury scale=5.

Table 4 Changes in processes of care for patients with major trauma seen in the trauma centre in North West Midland region, provided with experimental regional trauma system

	Year			
Process	1990	1991	1992	1993
Percentage of patients:				
First attended by consultant in accident and emergency	28	49	71	70
Ever attended by consultant in accident and emergency	36	53	77	79
Admitted to intensive care unit	43	56	55	54
Median (interquartile range) time to operation for patients sent to theatre within 24 hours (hours)	2.9 (1.8-7.5)	3.5 (1.7-6.7)	2.7 (1.3-9.7)	3.3 (2.3-8.9)

However, this change was not significantly different from that in the control regions, except for patients with multiple injuries (those with two or more injuries in different body regions with abbreviated injury scale scores of ≥ 3), the proportion of whom being taken directly to the trauma centre increased from 26% to 41% (χ^2 test for difference in trends $= 6.25$, df $= 1$, $P < 0.02$).

In the trauma centre's accident and emergency department the proportion of major trauma patients attended first by a consultant rose from 28% in 1990 to 70% in 1993 (table 4), whereas this never exceeded 24% in other hospitals in the experimental region or in the control regions. There was also a small increase in the proportion of patients admitted to the intensive care unit, but no change in the length of time from arrival in accident and emergency to an operation for those who had an operation within 24 hours.

Table 5 Numbers (percentages) of deaths of patients with major trauma in North West Midland region, provided with experimental regional trauma system, and in two control regions before the establishment of the Stoke regional trauma centre (1990-1) and after establishment of the centre (1992-3)

	Experimental region		Control regions	
Injury severity score	**Before (1990-1)**	**After (1992-3)**	**Before (1990-1)**	**After (1992-3)**
Patients aged <65 years				
16-24	11/193 (5.7)	11/171 (6.4)	16/229 (7.0)	12/214 (5.6)
25-40	62/151 (41.1)	55/158 (34.8)	78/204 (38.2)	73/205 (35.6)
41-74	27/35 (77.1)	23/30 (76.7)	24/33 (72.7)	23/34 (67.6)
Patients aged ≥65 years				
16-24	8/45 (17.8)	18/51 (35.3)	17/58 (29.3)	30/81 (37.0)
25-40	57/66 (86.4)	49/68 (72.1)	74/87 (85.1)	57/73 (78.1)
41-74	12/12 (100)	10/12 (83.3)	8/9 (88.9)	9/10 (90.0)
Total	177/502 (35.3 (95% CI 31.1 to 39.5))	166/490 (33.9 (95% CI 29.7 to 38.1))	217/620 (35.0 (95% CI 31.2 to 38.8))	204/617 (33.1 (95% CI 29.4 to 36.8))
Excluded cases				
Unknown age or injury severity score	0	0	1/4 (25.0)	2/3 (66.7)
Injury severity score=75	27/27 (100)	14/14 (100)	44/44 (100)	42/42 (100)
Revised trauma score=0	60/60 (100)	49/50 (98.0)	91/91 (100)	82/82 (100)
All cases	264/589 (44.8 (95% CI 40.8 to 48.8))	229/554 (41.3 (95% CI 37.2 to 45.4))	353/759 (46.5 (95% CI 42.0 to 50.0))	330/744 (44.4 (95% CI 40.8 to 48.0))

Deaths from major trauma

During the study, 493 (43%) of the 1143 major trauma patients in the experimental region died, while 683 (45%) of the 1503 patients in the control regions died. There was little evidence of any difference between the experimental region and the control regions in changes in mortality. Between 1990-1 and 1992-3 the crude death rate from major trauma declined from 44.8% to 41.3% in the experimental region and by a similar amount, from 46.5% to 44.4%, in the control regions. There was also no difference when we excluded cases with unknown age or injury severity scores, or with injury severity scores of 75 or revised trauma scores of 0 (table 5).

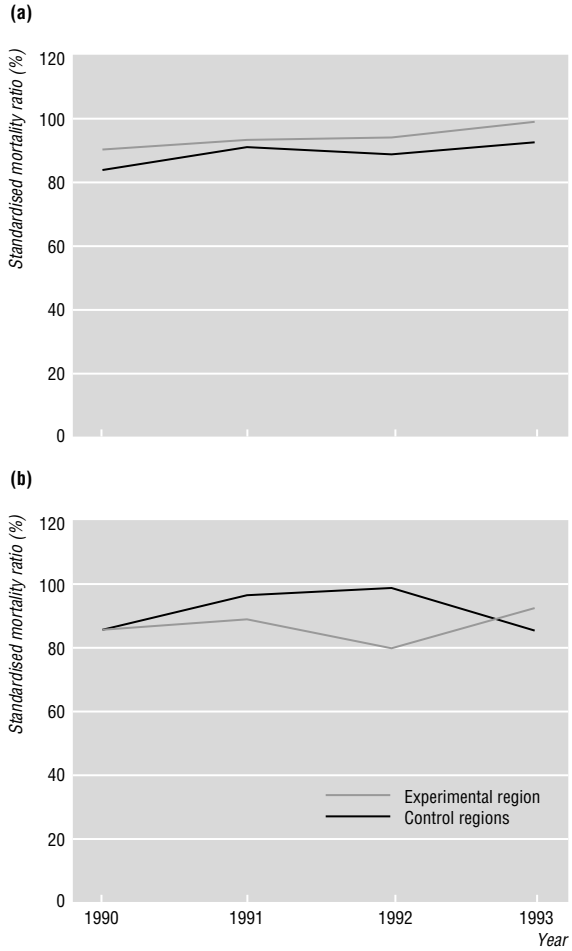

Fig 2 Standardised mortality ratios for patients with major trauma (calculated by means of internally derived standards) in North West Midland region, provided with experimental regional trauma system, and in two control regions: (a) patients seen out of hours, and (b) patients with multiple injuries

Standardised mortality ratios

Standardised mortality ratios—calculated by means of TRISS or internally derived standards based on age, injury severity scores, and the revised trauma scores—showed no evidence of relative improvement in the experimental region during the four year study (fig 1). For patients admitted to accident and emergency departments out of hours (20 00 to 07 59) and for patients with multiple injuries, there was also no evidence that standardised mortality ratios improved in the experimental region relative to the controls (figs 2).

Using a multiple logistic regression model including age, injury severity scores, and revised trauma scores, we estimated that the annual change from 1990 in the probability of dying in the experimental region compared with the control regions was −0.8% (95% confidence interval −3.6% to 2.2%) for all major trauma patients, 1.6% (−2.3% to 5.6%) for patients seen out of hours, and −1.6% (−6.1% to 2.6%) for patients with multiple injuries. Using the model including only age and injury severity scores, we estimated that the relative annual change in the probability of dying in the experimental region for all major trauma patients was −0.2% (−2.9% to 2.7%).

Discussion

In a unique prospective experimental study, carried out by an independent research team, we investigated whether funding a good accident and emergency department in order to provide facilities for a regional trauma centre and encouraging the development of a trauma system could improve survival from major

trauma. The processes of care did change in several ways, but there was no evidence of any significant improvement in the chance of major trauma patients surviving compared with control regions. Several questions are raised by these findings: are they reliable, and if they are, why do they differ from indicative results from the United States, and how generalisable are they?

Reliability

A randomised study was not possible, of course, but it is widely accepted that a controlled before and after study such as we have undertaken is the next best approach.

The control areas in this study were selected because they were similar in size and characteristics to the experimental area at the start of the period of evaluation and could therefore be expected to be subject to the same influences. This means that, at the outset, each control region also included a central hospital with a large, high quality accident and emergency department. However, we have not compared the outcomes of patients treated in these hospitals but trends in the outcomes of all major trauma occurring in the regions they help serve. These comparisons of regional trends were made more reliable by ensuring that there were as few pre-existing differences as possible.

The question of whether the "before" and "after" phases clearly represent periods before and after the development of a central trauma system is less clear. At the start of the study period, in January 1990, some efforts had already been made at the North Staffordshire Royal Infirmary to involve the surrounding hospitals in an integrated approach to managing major trauma in the region. Equally, at the end of the study in December 1993, developments were still taking place. Nevertheless, substantial investment and change did not take place until mid-1991, when staffing and resources in the accident and emergency department and intensive care unit were increased, and these developments were completed during 1992. Thus the study does clearly span a period of rapid change in the resources available for the care of patients with serious injuries.

With regard to the accuracy of our data, in 1993 the internal audit at the North Staffordshire Royal Infirmary recorded 123 major trauma patients being taken directly to the hospital, but we identified only 98. This difference arose principally because of differences in assigning scores on the abbreviated injury scale and differences in inclusion criteria. For example, we included only those patients brought in directly by the three ambulance services included in the study, or indirectly from the satellite hospitals in the experimental region. The methods we used for scoring patients' injuries produced better agreement between the researchers who coded injuries than has previously been reported in Britain[13] (agreement on injury severity scores 41% *v* 28%,[13] disagreement on injury severity scores >15 17.5% *v* 19-24%[13]) and were applied consistently by the same researchers over the four years of the study in order to minimise bias in the comparisons.

The power of our study to detect a relative decline of four deaths per 100 major trauma patients admitted with vital signs to the trauma centre per year was only 50%, and this raises the question of how much reliance can be put on the finding of no significant effect. The results, however, are consistent with the facts that there has been no relative decline in the case fatality rate among casualties from road traffic accidents in the experimental region compared with the control regions[14]; there were only small changes in the processes of care; and the small effect detected was not specific to or different in those groups in which it would have been expected to be greatest—patients seen out of hours, and multiply injured patients.

Generalisability

These results are in sharp contrast to reports from the United States, where it has been reported that major trauma patients can receive better care in regions with trauma systems than in regions without[15] and that avoidable deaths can be substantially reduced after the introduction of trauma centres.[3–6 16–18] However, most of the earlier studies examined avoidable death rates in uncontrolled case series or used historical controls. When before and after comparisons were made there were usually no controls to take account of changes in external factors. With a few exceptions, no attempt has been made to blind assessors of avoidable deaths to the hospital (or region, or period) in which the patients were treated. These deficiencies in early studies have been well documented.[19] More recent before and after studies, which have attempted to overcome these problems, have shown mixed results. Evaluation of the Los Angeles trauma system, based on 1424 major trauma patients (injury severity scores >15), did not find a significant improvement in survival,[20] and a study including 8221 patients with injury severity scores >15 in Oregon found an improvement of only marginal significance.[21]

However, it is generally accepted that such systems can reduce mortality. We suggest that there are two broad groups of reasons why we could find no evidence of effectiveness in our study. Firstly, the trauma system in the North West Midlands region did not develop into a comprehensive regionalised system. Thus, for example, by the end of our study, the objective of "getting the right patient to the right hospital at the right time"[22] had not been achieved. Secondly, trauma epidemiology is so different in kind and volume in Britain compared with the United States that there is no reason to expect that American solutions should translate directly to Britain. For example, penetrating injuries cause less than 5% of major trauma in Britain[10] but typically cause over 20% of cases in the United States,[16] and in the whole of the North West Midlands region there were only six major trauma patients taken to hospitals each week.

The benefits from developing regional trauma systems in shire areas of England are probably modest, therefore, compared with reports from the United States. However, we evaluated only one model of regional trauma care, in only one setting, and that system was not fully developed. Thus, greater benefits might be found with trauma systems in other environments, such as metropolitan conurbations, or if greater integration in the whole process of trauma care could be achieved. Nevertheless, our results cast some doubt on the benefits of adopting a national policy of regionalising trauma care along the lines of the American model.

Contributing authors: Brian Williams, John Brazier (study design); Sylvia Bickley, Patricia Myers, Neil Beeby, Marita Lunn (data collection); Simon Dixon (health economics).

Key messages

- In an experimental regional trauma system in the North West Midlands region the trauma centre was provided with 24 hour cover by consultants in accident and emergency and additional resources for intensive care
- We assessed the effect of the regional trauma system on the survival of patients with major trauma
- There was little evidence of the development of an integrated trauma system, and the proportion of patients taken directly to the trauma centre increased only for those with multiple injuries
- There was no reliable or consistent evidence that these developments improved patients' chance of survival from major trauma in the region
- Possible benefits from regionalising trauma care in shire areas of England are probably modest compared with claims from the United States

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Effect of a strict HLA matching policy on distribution of cadaveric kidney transplants to Indo-Asian and white European recipients: regional study

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The matching of donor and recipient for HLA type is an important factor in determining the survival of kidney grafts.[1] Our unit participates in national and regional organ sharing schemes and allocates locally donated kidneys according to HLA matching. Consequently only 2% of our transplants have had two mismatches for HLA-DR. This policy could put patients whose HLA types differ from those in the donor population at a disadvantage.[2]

In this study we measured the rates of end stage renal failure, kidney donation from cadavers, and kidney transplantation in the white European and Indo-Asian populations of Coventry and Warwickshire.

Patients, methods, and results

Data on the adult population in Coventry and Warwickshire were obtained from the 1991 national census. Patient records from 1988 to 1995 inclusive were examined to determine the patient's place of residence. The ethnic group of patients was identified by surname and by the ethnic group declared at the time of registration at the hospital. We included only Indo-Asian and white European patients in the study. The definition of beneficial HLA matching was that used by the United Kingdom Transplant Support Service Authority. Statistical analysis was by the χ^2 test and Student's t-test as appropriate.