Transplantation

The first successful human corneal transplant was around 1900 by Zirm, corneal xenografting having been tried as early as 1837 but without notable success. From the early 1950s, Calne envisaged kidney transplantation as practicable therapy; and surgical, immunological, and immunosuppressive advances made it so by the mid-1980s. By 1970, Barnard had pioneered heart transplantation; and liver transplantation was also under way. Xenografting from transgenic pigs is the challenge of the next decade, together with improvements in unrelated donor bone marrow transplantation.

By 1990, transplantation had achieved one-year graft survival rates of 80% or more for most solid organs, and has done so through surgical innovation, advances in immunosuppression, beneficial matching of kidney donor to recipient, better preservation solutions, and by studying center variation in donor rates as well as in transplant outcome. Epidemiological studies monitor malignancies secondary to immunosuppression. Quality of life as well as length of life (see Life Expectancy) is improved by transplantation.

Statistical science has underpinned most of this progress. Well-conducted randomized controlled trials (see Clinical Trials, Overview) of new immunosuppression therapies and preservation fluids have been published [23]; there has been occasional but critical early stopping of trials, because of overimmunosuppression, on the basis of surrogate endpoints of rejection episodes and major infections [14]. Proposals for the design and analysis of randomized trials with recurrent events [3] have had application in kidney transplantation. Two small trials in bone marrow transplantation were used to illustrate a new statistical measure to aid in the interpretation of published trials [1].

Beneficial matching [7, 10]; that is, the rules by which cadaveric donor kidneys have been exchanged in the UK, had a statistical basis and has persisted for 10 years up to 1997 when extended, also on statistical grounds, to favorable matching. Similar work on matching and matchability (see below) has been done independently by Mickey and colleagues [12, 22]. Validation studies have featured, whether in independent data sets (matching effects in distinct epochs of follow-up [9, 26, 28]) or by meta-analysis (DR mismatching in corneal transplantation [17]). Matchability score, dependent upon human leukocyte antigen (HLA) phenotype and exchange rules, for patients on the kidney transplant waiting list was introduced by Gilks [6, 8, 10] to summarize a patient’s chance of getting a well-matched donor kidney in two or five years, and hence to aid individual decision-making on whether to accept or reject an offered kidney.

Special studies such as Corneal Transplant Follow-up Study (CTFS) and International Marrow Unrelated Search and Transplant (I MUST) Study have been set up to establish the core data that national registries (see Disease Registers) should seek to collect because they determine either waiting times [18], tissue allocation or prognosis [19] or quality of outcome, for which visual acuity is a natural measure [27]. In the I MUST Study, minimization, as in randomized trials, was adapted to select prospectively a control cohort of twice as many HLA-identical sibling transplants to correspond to the unrelated donor transplants in terms of marginal frequency for age group, diagnosis, risk, and transplant center. A second aspect of the design of the I MUST Study is noteworthy: in unrelated bone marrow donor searches, the patients for whom the search procedure finds an unrelated HLA-identical donor are effectively selected by “genetic randomization”. A time-dependent covariate indicator (or several to account fully for non-proportionality of hazards (see Proportional Hazards) post transplant) can be switched on at that time and, by following all patients for whom an unrelated donor search was initiated, the effect of unrelated HLA-identical bone marrow transplantation against alternative management can be estimated in an unbiased manner. Effective randomization makes the proposed analysis even more powerful than the use of a time-dependent indicator to switch patients from “awaiting cardiac transplantation” to “recipient status” [21], leading to appropriate analyses of the cost-effectiveness of heart transplantation (see Health Economics).

Cardiothoracic transplantation has posed other important statistical problems, including analysis of repeated biopsies after cardiac transplantation [25], informative censoring of quality-of-life measurements [4], and individualization of cyclosporine dose by monitoring the variability of cyclosporine blood levels and also the patient’s kidney and liver function [2]. Kalman filter techniques [20], applied to weight-adjusted reciprocal creatinine for detection of
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kidney rejection episodes, were pioneering but did not
become routine, perhaps because they were devel-
oped before cyclosporine. Sharples [11, 24] used a
Gibbs sampling approach (see Markov Chain
Monte Carlo) to modeling the longer-term risk of
developing coronary occlusive disease after heart
transplantation and thereby showed that there were
particularly high transition intensities from mild to
severe disease and from severe disease to death; thus,
one mild disease developed, a patient’s deteriora-
tion was rapid and research should focus on reducing
progression from mild to severe disease.

Renal graft failure rates have been published in
the UK on a center-anonymized basis since the early
1970s. Center variation has reduced considerably in
the post-cyclosporine era [5] and further analysis by
the confidence ranking methods developed by Gold-
stein & Spiegelhalter [13] would allow comparison
of centers over calendar time, with or without adjust-
ment for case mix, but taking account of center
covariates such as whether a department of transplant
immunology or transfusion medicine was responsible
for tissue typing and cross-matching. In renal trans-
plantation where centers’ policies, let alone practice,
on acceptance of older or asystolic donors, adherence
to favorable matching, and retransplantation of older
or diabetic or highly sensitized recipients may differ
greatly, there is merit in no adjustment for case mix
on the basis that the case mix is effectively center-
determined.

Donor statistics are as important in transplantation
as understanding the determinants of graft out-
come. Confidential audit of all deaths in intensive
care units in England and Wales in 1989–1990 [15,
16] showed that the second reason, after relatives’
refusal, for missed suitable organs differed for the
different organs—e.g. failure to ask in the case of kidneys
but nonprocurement of offered suitable livers. The
confidential audit also showed that even if all poten-
tial kidney donors in intensive care units became
actual donors the need for cadaveric kidneys would
not be met. Since then, the problem of nonprocure-
ment of donor livers has been solved by designation
of new centers but the shortage of donor kidneys has
been exacerbated by the successful introduction of
rear seat-belt legislation which saves lives.

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Availability of transplantable organs from brain stem


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