P. Stastny

MEDICAL GRAND ROUNDS

PARKLAND MEMORIAL HOSPITAL

JANUARY 14, 1971

[Peter Stastny]

KIDNEY TRANSPLANTATION, 1971

"...the transplantation of organs will one day be assimilated into ordinary clinical practice...It will come about for the simple and sufficient reason that people are so constituted that they would rather be alive than dead."

Sir Peter Medawar, 1968.

CASE 1

[redacted] is a 36 year-old [redacted] woman who received a kidney transplant in this hospital 4½ years ago and is now doing very well.

Her illness began at age 19 during her first pregnancy with pre-eclampsia and pyuria. After her third pregnancy at age 29 she developed persistent hypertension and recurrent urinary tract infections. She developed symptoms of uremia in the spring of 1966.

On admission at [redacted] she had a BUN of 100, creatinine 15, Hgb 6.4, IVP showed bilateral small kidneys. The diagnosis was chronic pyelonephritis.

A renal transplant from her fraternal twin brother was performed on [redacted] 1966.

The patient was last seen in outpatient clinic on [redacted], 1970. Serum creatinine was 1.0 mg%, hematocrit 37.3, BP 120/80, urinalysis normal. She is being maintained on Imuran 100 mg and Prednisone 5 mg daily.

CASE 2

[redacted] is a 33 year-old [redacted] man who was in good health until [redacted], 1968 when he developed low back pain and symptoms of uremia. IVP showed polycystic kidneys. He was maintained on conservative management and 3 peritoneal dialysis until [redacted], 1970. In preparation for transplant he was started on hemodialysis and subsequently had bilateral nephrectomy.

On [redacted], 1970 he received a kidney from his sister. 4 days after transplant he developed acute rejection with fever which was controlled by IV steroid administration. One week later he again showed evidence of rejection with swollen and tender kidney, and increase in serum creatinine. He was then given local irradiation to the graft 150 R on five days. This resulted in subsidence of the local symptoms and improvement in renal function.

On [redacted], 1970, his BUN was 24, creatinine 1.4; he was receiving Imuran 100 mg and Prednisone 60 mg daily. One week later he again developed evidence of rejection. Temperature rose to 103, sharp pain over transplant, decreased urine output, elevation of creatinine to 4.0. At this time he also had WBC 3100 and platelets 50,000. He was given IV solu-medrol. A renal biopsy on [redacted] 1970 showed interstitial edema and

chronic inflammation consistent with rejection. His condition stabilized and has subsequently remained fair with a persistent elevation of his serum creatinine to about 4 mg%.

CASE 3

[redacted]. This 45 year-old [redacted] woman was admitted with a diagnosis of chronic glomerulonephritis which was confirmed on examination of her kidneys which were removed in [redacted], 1970. Complement C3 level prior to transplantation was 70 mg%. She received a kidney from her brother on [redacted], 1970. There was low urinary output during the first week and she was given steroids for suspected rejection. On [redacted]/70 the serum creatinine was 1.4 mg%. A few days later, however, she had to be readmitted with generalized weakness, SOB, hypertension and edema. The creatinine had risen to 3.4 mg%. There was 4+ protein, RBC and casts in the urine. These events continued in spite of intravenous steroids and graft irradiation. Needle biopsy of the kidney on [redacted]/70 showed histologic evidence of rapidly progressive glomerulonephritis. The patient became completely anuric and the graft was removed on [redacted]-70. 95% of the glomeruli were involved with subacute glomerulonephritis. Advanced crescent formation was seen. The remaining glomerular tufts were hypercellular and the GBM was thickened.

CASE 4

[redacted]. A 16 year-old [redacted] developed systemic lupus erythematosus in [redacted] 1967. The illness involved her skin mainly until [redacted] of 1969 when she developed pleuritic pain and arthralgia which were controlled with the use of steroids. In [redacted], 1969 the patient developed edema and proteinuria.

She was first admitted in [redacted], 1970 with hypertension and anasarca. Biopsy of her kidney showed florid lupus glomerulonephritis with involvement of almost all of the glomeruli and presence of hematoxylin bodies. After a brief period of dialysis she received a cadaver kidney transplant on [redacted], 1970. On [redacted] she was discharged on Imuran 75 mg, Prednisone 50 mg daily with a BUN of 55 mg% and serum creatinine 2.1 mg%.

In [redacted], 1970 her creatinine clearance diminished and the elevated blood pressure was a problem. A needle biopsy of the transplanted kidney showed findings consistent with rejection rather than recurrence of SLE. She is maintained on Imuran 75 mg, Prednisolone 45 mg, Aldomet 1.0 gm and Lasix 40 mg. Her creatinine remains 2.6-2.8 mg%.

The major obstacles to kidney transplantation are:

(1) REJECTION: and

(2) RECURRENCE OF THE RECIPIENT'S DISEASE IN THE TRANSPLANTED KIDNEY

The Transplantation Immunologist is expected to provide solutions to these problems. The statistics clearly show that the problems have not been solved but enormous progress has been made in two areas:

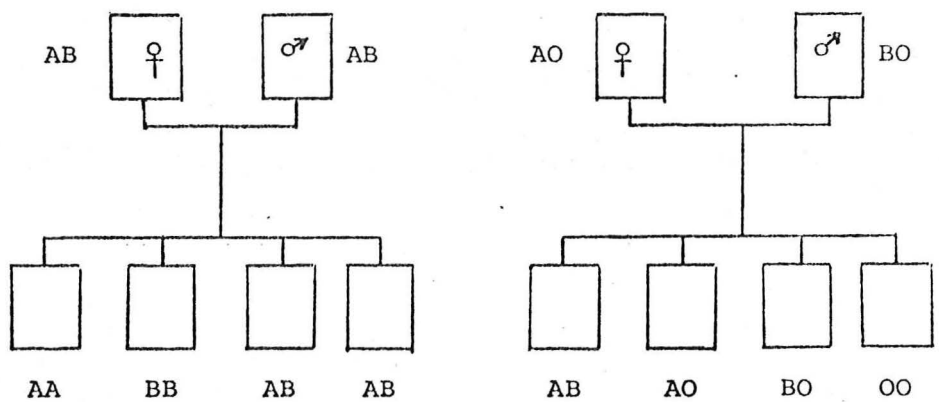
(1) HISTOCOMPATIBILITY TESTING; and

(2) PATHOGENESIS OF RECURRENT GLOMERULAR DISEASE

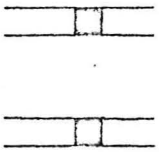
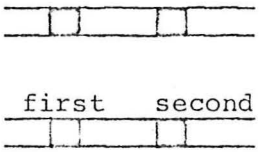
HISTOCOMPATIBILITY TESTING

One major group of histocompatibility antigens appears to govern the fate of all allografts of human cells, tissues and organs. The first discovery of these antigens on human leukocytes was made 10 years ago. However, practically all our knowledge about them has been acquired during the last 4 or 5 years. On the basis of an international agreement this first group of human leukocyte antigens has been called HL-A. If other groups of genetically determined transplantation antigens are discovered they will be designated HL-B, HL-C, HL-D, etc. In addition the ABO system of erythrocyte antigens also plays a major role in human transplantation.

Inheritance of ABO Antigens



GENETIC MODEL

ABO	HL-A
locus	locus
 pair of chromosomes	 first second
one locus	two loci
3 alleles	≥ 10 ≥ 25 alleles
A-B-O	multiple alleles at each locus (mutually exclusive)

ANTIGENS USED FOR DONOR-RECIPIENT MATCHING

ABO Antigens

A, B, O

HL-A Antigens

1st sub-locus:

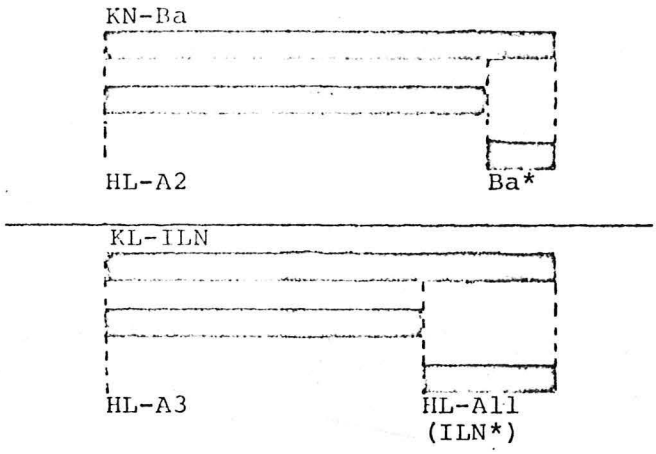
HL-A1, HL-A2, Ba*, HL-A3, HL-A11, HL-A9, HL-A10, Li, X

2nd sub-locus:

HL-A5, R*, HL-A7, HL-A8, HL-A12, HL-A13, AA, BB, FJH, LND, Maki, SL-ET, SL-Mapi, Fe 31/8*, Y

Note: X = unknown antigen of the first sub-locus
Y = unknown antigen of the second sub-locus

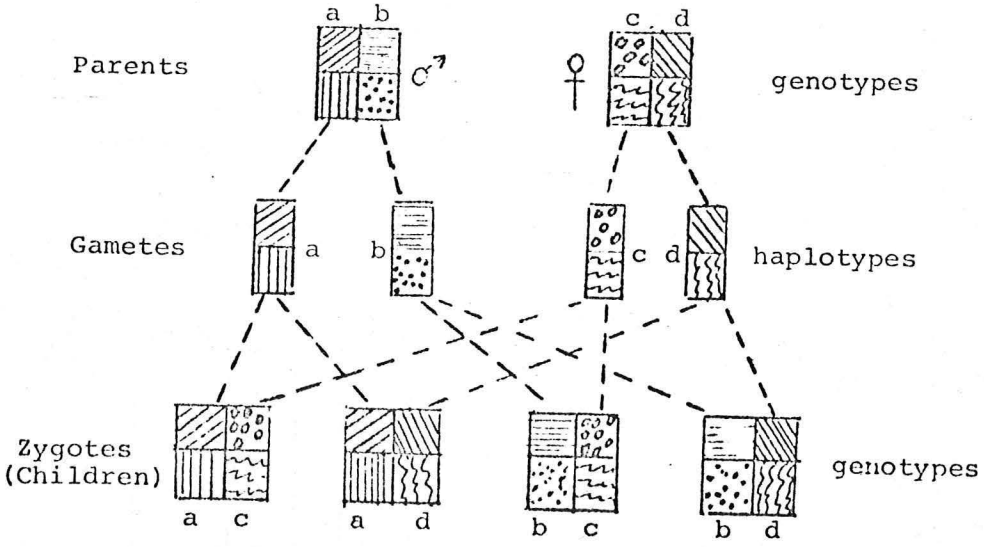
ANTIGENIC COMPLEXITY, CROSSREACTIONS AND INCLUSIONS



TERMINOLOGY

Genetic determinants	:	alleles or genes
Genetic localization	:	loci or subloci
Genetic information		
on one chromosome	:	haplotype
on one pair of chromosomes	:	genotype
Antigens detectable	:	phenotype (= tissue type)

INHERITANCE IN THE HL-A SYSTEM



ANTIGENS RELEVANT TO ORGAN TRANSPLANTATION

ABO	each individual has	2
HL-A	each individual has	4
Total	in each individual	6

CROSS-REACTIONS BETWEEN HL-A ANTIGENS THAT MAY INFLUENCE HISTOCOMPATIBILITY

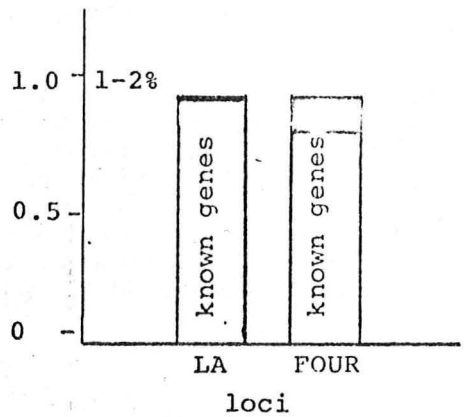
HL-A2	Ba*	(Da15)
HL-A1	HL-A3	HL-A11
HL-A5	R*(Da20)	LND Da24
HL-A7	FJH	BB

MATCH GRADES (From Kissmeyer-Nielsen)

A1	=	identity between sibs
A2	=	identity between sib and parent
A3(0)*	=	identity between unrelated
B(0)	=	recipient has antigen not present in donor
C(1)	=	donor has 1 antigen not present in recipient
D(2)	=	donor has 2 antigens not present in recipient
E(3)	=	donor has 3 antigens not present in recipient
G(4)	=	donor has 4 antigens not present in recipient
F	=	recipient has leukocyte antibody active against donor

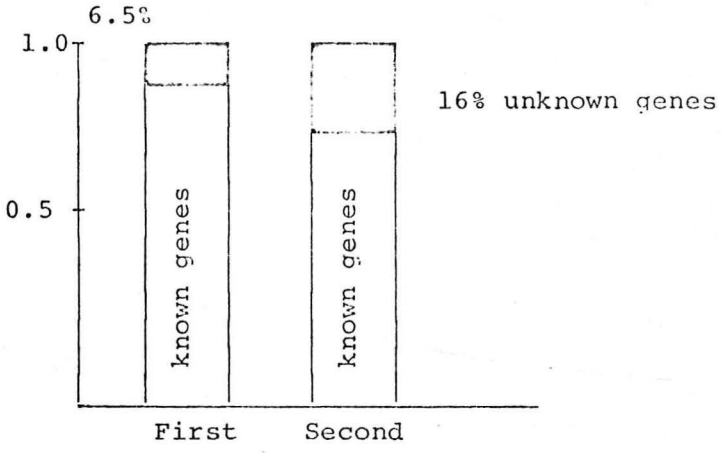
*0, 1, 2, 3 and 4 is terminology used in Eurotransplant. When the typing implies possible mismatches for unknown antigens, the poorest possible match grade should be indicated.

HL-A SYSTEM - GENE FREQUENCIES (SCANDINAVIA)



<10% unknown genes

SOUTHWESTERN MEDICAL SCHOOL
TISSUE TYPING REFERENCE PANEL
(31 Individuals)



SELECTION OF DONORS IN KIDNEY TRANSPLANTATION

1. ABO typing of recipient and donor
2. HL-A typing of recipient and donor
3. Direct cross-match between serum from recipient and cells from donor, to detect HL-A antibodies in the recipient active against antigen(s) in the donor.

REFERENCES

1. Walford, R.L. The isoantigenic systems of human leukocytes. Medical and biological significance. Series Haematol. II, No. 2, 1969.

2. Kissmeyer-Nielsen, F. and Thorsby, E. Human Transplantation Antigens. Transplantation Reviews, vol. 4, 1970.

   Excellent comprehensive reviews of all the current information on human transplantation antigens and tissue typing. Including various medical and biological applications and in particular their current role in donor selection for kidney transplantation.

3. Allen, et al. Joint report of the fourth international histocompatibility workshop. In: Histocompatibility Testing 1970. The Williams & Wilkins Co., Baltimore, 1970, p. 17.

4. Dausset, J., Colombani, J., Legrand, L. and Fellows, M. Genetics of the HL-A system. Deduction of 480 haplotypes. In: Histocompatibility Testing 1970. The Williams & Wilkins Co., Baltimore, 1970, p. 53.

5. Kissmeyer-Nielsen, F., Nielsen, L.S., Lindholm, A., Sanberg, L., Svejgaard, A. and Thorsby, E. The HL-A system in relation to human transplantations. In: Histocompatibility Testing 1970. The Williams & Wilkins Co., Baltimore, 1970, p. 105.

   Most recent information and genetic interpretation of the HL-A system.

6. Rapaport, F.T., Casson, P.R., Converse, J.M., Legrand, L., Colombani, J. and Dausset, J. Approach to the study of the comparative immunogenicity of human transplantation (HL-A) antigens. In: Histocompatibility Testing 1970. The Williams & Wilkins Co., Baltimore, 1970, p. 411.

   Attempt to evaluate the relative strength of the HL-A antigens by skin grafting among family members. Suggests that some weaker reactions may be due to mismatched cross-reactive antigens.

7. Patel, R., Mickey, M.R., and Terasaki, P.I. Serotyping for homotransplantation. XVI. Analysis of kidney transplants from unrelated donors. New Eng. J. Med. 279:501, 1968.

8. Terasaki, P.I., Mickey, M.R., Singal, D.P., Mittal, K.K. and Patel, R. Serotyping for homotransplantation. XX. Selection of recipients for cadaver donor transplants. New Eng. J. Med. 279:1101, 1968.

   104 cadaver transplants studied. Donors and recipients typed for 5 specificities only. Compares matched against mismatched groups (excluding patients who died within first 3 months) and shows highly significant differences in creatinine clearance ($p = 0.003$), clinical ranking ($p = 0.02$) and number of rejection episodes ($p = 0.001$).

9. Morris, P.J., Kincaid-Smith, P., Ting, A., Stocker, J.W. and Marshall, V.C. Prospective leucocyte typing in cadaveric renal transplantation. Lancet 2:803, 1968.

10. Batchelor, J.R. and Joysey, V.C. Influence of HL-A incompatibility on cadaveric renal transplantation. Lancet 1: 790, 1969.

11. Festenstein, H., Oliver, R.T.D. and Hyams, A. A collaborative scheme for tissue typing and matching in renal transplantaion. Lancet 2:389, 1969.

12. Kountz, S.L., Cochrum, K.C., Perkins, H.A., Douglas, K.S. and Belzer, F.O. Selection of allograft recipients by leukocyte and kidney cell phenotyping. Surgery 68:69, 1970.

Similar reports confirming the benefit from HL-A matching in cadaveric kidney transplantation.

13. Rapaport, F.T. and Dausset, J. Ranks of donor-recipient histocompatibility for human transplantation. Science 167:1261, 1970.

Describes a mathematical method for ranking donor-recipient histocompatibility which takes into account the existence of as yet unknown antigens. Calculation is expressed as a "net histocompatibility ratio (NHR)."

The following 5 papers presented at the 3rd International Congress of the Transplantation Society summarize the current role of HL-A typing in cadaveric renal transplantation.

14. Batchelor, J.R., Joysey, V.C. and Crome, P. Further studies on influence of HL-A incompatibility on cadaveric renal transplantation. Proceedings 3rd International Congress of the Transplantation Society. Transplantation Proc. (in press).

Studied 78 cadaver grafts followed from 1 to 2 years. Find highly significant effect of HL-A incompatibility on the rate of graft failure.

15. Horn, J., Bigot, M., Zapetaria, D., Fradellizi, D., Rapaport, F.T. and Dausset, J. Importance of haplotype identity and crossreactions in the survival of kidney grafts. Proceedings 3rd International Congress of the Transplantation Society. Transplantation Proc. (in press).

Data on related living and cadaveric kidney allografts. 24 HL-A identical sibs followed from 6 months to 11 years showed 100% success. In cadaveric transplantation correlation of number of incompatibility and fate of grafts, $p<0.01$. Cross-reactions thought to explain good function in 9 cases with known incompatibilities.

16. Kountz, S.L., Payne, R., Perkins, H.A., Belzer, F.O. Achievements and limitations of histocompatibility testing for 10 HL-A factors in kidney transplantation. Proceedings 3rd International Congress of the Transplantation Society. Transplantation Proc. (in press).

Identical or compatible sibs, survival 100% cadavers: B match 100%, C match 90%, D match 42%.

17. Morris, P.J., Ting, A. and Forbes, J. Further studies of HL-A. Proceedings 3rd International Congress of the Transplantation Society. Transplantation Proc. (in press).

110 cadaveric transplants, degree of HL-A compatibility showed good correlation with severity of rejection episodes, histology and long-term function of grafts.

18. Terasaki, P.I., Kreisler, M., Mickey, M.R., and Sengar, D.P.S. Analysis of histocompatibility data from 1000 kidney transplants. Proceedings 3rd International Congress of the Transplantation Society. Transplantation Proc. (in press).

1000 transplants. HLA identical sibs clearly superior. In other related and unrelated donors correlation not good. Many incompatible kidneys seem to do well. Data based on typing over past 6 years with the aid of more than 50 different transplant centers.

PREFORMED ANTIBODIES AND HYPERACUTE REJECTION

19. Kissmeyer-Nielsen, F., Olsen, S., Petersen, V.P. and Fjeldborg, O. Hyperacute rejection of kidney allografts, associated with pre-existing humoral antibodies against donor cells. Lancet 2:662, 1966.

First description of the phenomenon.

20. Starzl, T.E., Lerner, R.A., Dixon, F.J., Groth, C.G., Brettschneider, L. and Terasaki, P.I. Schwartzman reaction after human renal homotransplantation. New Eng. J. Med. 278:642, 1968.

21. Williams, G.M., Hume, D.M., Hudson, R.P., Morris, P.J., Kano, K. and Milgrom, F. "Hyperacute" renal homograft rejection in man. New Eng. J. Med. 279:611, 1968.

22. Terasaki, P.I., Trasher, D.L. and Hanker, T.H. Serotyping for homotransplantation. XIII. Immediate kidney transplant rejection and associated preformed antibodies. In: Advances in Transplantation. Copenhagen, Munksgaard, 1968. p. 225.

Similar case reports.

23. Patel, R. and Terasaki, P.I. Significance of the positive crossmatch test in kidney transplantation. New Eng. J. Med. 280:735, 1969.

Stresses the importance of the cross-match test. Gives data on the frequency of preformed antibodies: random patients 19.2%, kidney transplant recipients, women 25.7%, men 15%.

24. Myburgh, J.A., Cohen, I., Geceiter, L., Meyer, A.M., Abraham, C., Furman, K.I., Goldberg, B. and van Bleck, P.J.P. Hyperacute rejection in human-kidney allografts--Shwartzman or arthus reaction? New Eng. J. Med. 281:131, 1969.

Evidence of intravascular coagulation in some cases; however, rejection has occurred while patient heparinized; antibodies, complement and clotting factors probably all play a role.

25. Carpenter, C.B. and Winn, H.J. Hyperacute rejection. New Eng. J. Med. 280:47, 1969. (Letter to the Editor)

Patient was transfused during nephrectomy 29 days prior to transplant. Direct cross-match was negative on two occasions (27 and 26 days before transplant). When hyperacute rejection occurred serum obtained 2 days before operation showed positive cross-match to a titer of 1/32.

26. Lucas, Z.J. An assay for antibodies to histocompatibility antigens based on inhibition of radioiodine-labelled antibody binding. Transplantation 10:512, 1970.

27. Lucas, Z., Caplon, N., Kempson, R. and Cohn, R. Early renal transplant failure associated with subliminal sensitization. Transplantaion 10:522, 1970.

Describes a new highly sensitive method for detection of preformed antibodies based on inhibition of radioactive antibody binding. It is claimed that this technique can detect antibodies against donor antigen associated with early transplant failure even when the usual cytotoxicity test is negative.

28. Shorter, R.G., O'Kane, H., Neva, C., Hallenbeck, G.A. Lymphocytotoxins in sera from patients receiving renal allografts. Surgery 65:793, 1969.

29. Stewart, J.H., Sheil, A.G.R., Johnson, J.R., Wyatt, K.M., Sharp, A.M. and Johnston, J.M. Successful renal allotransplantation in presence of lymphocytotoxic antibodies. Lancet 1:176, 1969.

Preformed antibodies not directed against antigens present in the donor organ do not appear to cause trouble. In one case antibody titer against other donors was as high as 1/128, transplantation of kidney with negative cross match into this recipient was successful.

30. Amos, D.B. Hyperacute rejection. New Eng. J. Med. 280:48, 1969.

Subjects immunized with lymphocytes can lose their antibodies in 2 to 3 months but can be boosted with as little as 2 x 10^6 lymphocytes (2 ml of blood). In such cases antibody appears rapidly and may reach titer of 1/32 in 10 days. Multiparous women develop antibodies more readily after transfusions. Suggests doing cross-match with serum obtained immediately before transplantation.

KIDNEY TRANSPLANTATION IN DALLAS
November, 1964 to December, 1970

Type of Donor	Number Patients	Clinical Result (Jan. 1970)				
		Good	Fair	Poor	Kidney Removed	Patient Deceased
Related						
Identical twin	2	2	0	0	0	0
Parent or sib	24	15	1	2	2	4
Unrelated						
1965-1968	6	0	0	0	1	5*
1969-1970	5	0	3	1	0	1

*Survival periods from 2 weeks to 5 months.

CORRELATION BETWEEN HL-A MATCHING AND CLINICAL RANK IN 40 TRANSPLANTS FROM UNRELATED DONORS (Kissmeyer, modified)

Match Grade	Clinical Rank		Total
	Exc.-Good	Fair-Poor	
0 or 1 mismatch	22	6	28
2 mismatches	2	10	12
Total	24	16	40

p = 0.0004

31. Starzl, T.E. et al. Long-term survival after renal transplantation in humans. Ann. Surg. 172:437, 1970.

Long-term survival (1-7½ years) kidney transplants in the Denver series: Related donors 70%, unrelated donors 33%.

32. Golby, M. Fertility after renal transplantation. Transplantation 10:201, 1970.

In response to a questionnaire 28 transplant recipients were reported to have become pregnant, 18 normal children were born, the rest were abortions (3 provoked, 7 spontaneous). 38 male transplant recipients were reported to have become fathers of normal children.

RECURRENCE OF GLOMERULAR DISEASE IN THE TRANSPLANTED KIDNEY

33. Glassock, R.J., Feldman, D., Reynolds, E.S., Dammin, G.J. and Merrill, J.P. Human renal isografts: a clinical and pathologic analysis. Medicine 47:411, 1968.

22 patients who received kidney transplants from identical twin donors (isografts) were studied. Of 17 in whom the original disease was known to have been glomerulonephritis, 11 developed glomerulonephritis in the transplant. Recurrences were recognized from 1 day to 6 years (average 2 years) after transplantation. 7 patients died as a result of renal failure due to recurrent glomerular disease. Only 2 recipients with original disease of less than 1 year duration did not develop recurrence.

34. Posborg, Petersen, V., Olsen, S., Kissmeyer-Nielsen, F. and Fjeldborg, O. Transmission of glomerulonephritis from host to human-kidney allotransplant. New Eng. J. Med. 275: 1269, 1966.

Recurrence of glomerular disease in allografted kidneys is less frequent and was first recognized in this case report.

35. O'Brien, J.P. and Hume, D. M. Membranous glomerulonephritis in two human renal homotransplants. Ann. Int. Med. 65:504, 1966.

Glomerular disease in allografts may not necessarily represent recurrence. In this report 2 patients developed membranous GN in the transplant. The original disease in one of them was chronic pyelonephritis, the other had had "proliferative glomerulonephritis."

36. Hume, D.M., Sterling, W.A., Weymouth, R.J., Siebel, H.R., Madge, G.F. and Lee, H.M. Glomerulonephritis in human renal homotransplants. Transplantation Proc. 2:361, 1970.

17 out of 94 patients developed proteinuria; 5 were thought to have recurrence of previous disease, 12 developed glomerular disease thought to be related to rejection or other mechanisms.

MECHANISMS OF GLOMERULAR INJURY IN TRANSPLANTED KIDNEYS
(from Hume et al)

A. Unique to Transplanted Kidneys:

1. Isoimmune attack against endothelial cells.
2. Soluble histocompatibility antigen-antibody complexes
3. Antibody to isoantigens of GBM
4. Anti-lymphocyte serum (ALS) injury
5. Radiation, prednisone, azathioprine and ischemia
6. Glomerular ischemia due to arteriolar intimal proliferation

B. Recurrent or De Novo Glomerulonephritis:

7. Antibody to tissue-specific (GBM) antigens
8. Soluble antigen-antibody complex nephritis

37. Porter, K.A., Calne, R.Y. and Zukoski, C.F. Vascular and other changes in 200 canine renal homotransplants treated with immunosuppressive drugs. Lab. Invest. 13:809, 1964.

Glomerular basement membrane thickening was observed in 36% of dog kidney allografts that functioned for more than 70 days in recipients receiving immunosuppression (Imuran).

38. Porter, K.A. et al. Human renal transplants. I. Glomerular changes. Lab. Invest. 16:153, 1967.

39. Porter, K.A., Andres, G.A., Calder, M.W., Dosselor, J.B., Hsu, K.C., Rendall, J.M., Seegal, B.C. and Starzl, T.E. Lab. Invest. 18:159, 1968.

71 human renal homografts studied. 3 showed subepithelial deposits and IgG by immunofluorescence thought to represent recurrence of GN. 54 had subendothelial deposits, IgM and complement, this was thought to be related to rejection since 5 of the recipients with this change did not have GN originally.

40. Dixon, F.J., McPhaul, J.J. and Lerner, R. Recurrence of glomerulonephritis in the transplanted kidney. Arch. Int. Med. 123:554, 1969.

A group of 39 selected patients with renal allografts were studied. All had GN prior to transplantation. In 13 this was thought to be due to anti GBM antibodies and in 26 due to immune complexes. Recurrences were as follows: 7/13 had immunopathological anti-GBM, in 3 additional patients there was clinical evidence only (total = 10/13). 6/26 had evidence of recurrence due to immune complexes.

41. Lerner, R.A., Glassock, R.J. and Dixon, F.J. The role of anti-glomerular basement membrane antibody in the pathogenesis of human glomerulonephritis. J. Exp. Med. 126:989, 1967.

42. Dixon, F.J. The pathogenesis of glomerulonephritis. Amer. J. Med. 44:493, 1968.

43. Rockein, R.E., Lewis, E.J. and David, J.R. In vitro evidence for cellular hypersensitivity to glomerular basement-membrane antigens in human glomerulonephritis. New Eng. J. Med. 283:497, 1970.

44. Heptinstall, R.H. Pathology of end-stage kidney disease. Am. J. Med. 44:656, 1968.

45. Gocke, D.J., Morgan, C., Lockshin, M., Hsu, K., Bombardieri, S. and Christian, C.C. Association between polyarteritis and Australia antigen. Lancet 2:1149, 1970.

46. Carpenter, C.B., Gill, T.J., Merrill, J.P. and Dammin, G. Instability of the complement system in patients with renal allografts. Transplantation 5:864, 1967.

47. Hill, J.H. and Ward, P.A. C3 leukotactic factors produced by a tissue protease. J. Exp. Med. 130:505, 1969.

48. Kronwall, G. and Williams, R.C. Immunologic "short circuits." Ann. Int. Med. 70:1043, 1969.

49. Alper, C.A. and Rosen, F.S. Studies of the in vivo behavior of human C'3 in normal subjects and patients. J. Clin. Invest. 46:2021, 1967.

50. Carpenter, C.B., Ruddy, S., Shehadeh, I.H., Muller-Eberhard, H.J., Merrill, J.P. and Austen, K.F. Complement metabolism in man: hypercatabolism of the fourth (C_4) and third (C_3) components in patients with renal allograft rejection and hereditary angioedema (HAE). J. Clin. Invest. 46:1495, 1969.

PRETRANSPLANT COMPLEMENT C3 LEVEL AND CLINICAL OUTCOME IN DALLAS

Pre-transplant C3 Level	Number Patients	Clinical Result			
		Good	Poor	Kidney Removed	Patient Deceased
<90 mg%	7[1]	0	2	3	2
>90 mg%	15[2]	10	2	0	3

1 Donors: 6 related, 1 unrelated.
2 Donors: 12 related, 3 unrelated.