

Wilhelm Kriz

## Progression of chronic renal failure in focal segmental glomerulosclerosis: consequence of podocyte damage or of tubulointerstitial fibrosis?

Published online: 31 October 2003  
© IPNA 2003

### Pediatr Nephrol (2003) 18:617–622

In the above article, reference citations were numbered in order of appearance in the text. The reference list, however, was erroneously printed in alphabetical order. The corrected list appears below.

#### References

1. Nagata M, Schärer K, Kriz W (1992) Glomerular damage after uninephrectomy in young rats. I. Hypertrophy and distortion of capillary architecture. *Kidney Int* 42:136–147
2. Nagata M, Kriz W (1992) Glomerular damage after uninephrectomy in young rats. II. Mechanical stress on podocytes as a pathway to sclerosis. *Kidney Int* 42:148–160
3. Kretzler M, Koeppen-Hagemann I, Kriz W (1994) Podocyte damage is a critical step in the development of glomerulosclerosis in the uninephrectomised-desoxycorticosterone hypertensive rat. *Virchows Arch* 425:181–193
4. Floege J, Hackmann B, Kliem V, Kriz W, Alpers CE, Johnson RJ, Kuhn KW, Koch KM, Brunkhorst R (1997) Age-related glomerulosclerosis and interstitial fibrosis in Milan normotensive rats: a podocyte disease. *Kidney Int* 51:230–243
5. Kriz W, Hosser H, Hähnel B, Simons JL, Provoost AP (1998) Development of vascular pole-associated glomerulosclerosis in the Fawn-hooded rat. *J Am Soc Nephrol* 9:381–396
6. Gassler N, Elger M, Kranzlin B, Kriz W, Gretz N, Hähnel B, Hosser H, Hartmann I. (2001) Podocyte injury underlies the progression of focal segmental glomerulosclerosis in the fa/fa Zucker rat. *Kidney Int* 60:106–116
7. Kriz W, Hähnel B, Rösener S, Elger M (1995) Long-term treatment of rats with FGF-2 results in focal segmental glomerulosclerosis. *Kidney Int* 48:1435–1450
8. Kriz W, Hosser H, Hähnel B, Gretz N, Provoost AP (1998) From segmental glomerulosclerosis to total nephron degeneration and interstitial fibrosis: a histopathological study in rat models and human glomerulopathies. *Nephrol Dial Transplant* 13:2781–2798
9. Kriz W, Hartmann I, Hosser H, Hähnel B, Kranzlin B, Provoost A, Gretz N (2001) Tracer studies in the rat demonstrate misdirected filtration and peritubular filtrate spreading in nephrons with segmental glomerulosclerosis. *J Am Soc Nephrol* 12:496–506
10. Remuzzi G, Bertani T (1990) Is glomerulosclerosis a consequence of altered glomerular permeability to macromolecules? *Kidney Int* 38:384–394
11. Burton C, Harris KP (1996) The role of proteinuria in the progression of chronic renal failure. *Am J Kidney Dis* 27:765–775
12. Remuzzi G, Bertani T (1998) Pathophysiology of progressive nephropathies. *N Engl J Med* 339:1448–1456
13. Gandhi M, Olson JL, Meyer TW (1998) Contribution of tubular injury to loss of remnant kidney function. *Kidney Int* 54:1157–1165
14. Abbate M, Remuzzi G (1999) Proteinuria as a mediator of tubulointerstitial injury. *Kidney Blood Press Res* 22:37–46
15. Matsuo S, Morita Y, Mizuno M, Nishikawa K, Yuzawa Y (1998) Proteinuria and damage to tubular cells – is complement a culprit? *Nephrol Dial Transplant* 13:2723–2726
16. Abbate M, Zoja C, Rottoli D, Corna D, Tomasoni S, Remuzzi G (2002) Proximal tubular cells promote fibrogenesis by TGF-beta1-mediated induction of peritubular myofibroblasts. *Kidney Int* 6:2066–2077. Erratum in: *Kidney Int* (2002) 62:731
17. Kriz W, Hähnel B, Hosser H, Ostendorf T, Gaertner S, Kranzlin B, Gretz N, Shimizu F, Floege J (2003) Pathways to recovery and loss of nephrons in anti-Thy-1 nephritis. *J Am Soc Nephrol* 14:1904–1926
18. Le Hir M, Keller C, Eschmann V, Hähnel B, Hosser H, Kriz W (2001) Podocyte bridges between the tuft and Bowman's capsule: an early event in experimental crescentic glomerulonephritis. *J Am Soc Nephrol* 12:2060–2071
19. Le Hir M, Besse-Eschmann V (2003) A novel mechanism of nephron loss in a murine model of crescentic glomerulonephritis. *Kidney Int* 63:591–599
20. Risdon RA, Sloper JC, De Wardener HE (1968) Relationship between renal function and histological changes found in renal-biopsy specimens from patients with persistent glomerular nephritis. *Lancet* 2:363–366
21. Bohle A, Glomb D, Grund KE, Mackensen S (1977) Correlation between relative interstitial volume of the renal cortex and serum creatinine concentration in minimal changes with nephrotic syndrome and in focal sclerosing glomerulonephritis. *Virchows Arch A Pathol Anat Histol* 376:221–232
22. Wehrmann M, Bohle A, Bogenschütz O, Eissele R, Freislederer A, Ohlschlegel C, Schumm G, Batz C, Gartner HV (1989) Long-term prognosis of chronic idiopathic membranous glo-

The online version of the original article can be found at <http://dx.doi.org/10.1007/s00467-003-1172-7>

W. Kriz (✉)

Institut für Anatomie und Zellbiologie I,  
Im Neuenheimer Feld 307,  
69120 Heidelberg, Germany  
e-mail: wilhelm.kriz@urz.uni-heidelberg.de  
Tel.: +49-6221-548680  
Fax: +49-6221-544951

- merulonephritis. An analysis of 334 cases with particular regard to tubulo-interstitial changes. *Clin Nephrol* 31:67–76
23. Schainuck LI, Striker GE, Cutler RE, Benditt EP (1970) Structural-functional correlations in renal disease. II. The correlations. *Hum Pathol* 1:631–641
  24. Yee J, Kuncio GS, Neilson EG (1991) Tubulointerstitial injury following glomerulonephritis. *Semin Nephrol* 11:361–366
  25. Kaplan C, Pasternack B, Shah H, Gallo G (1975) Age-related incidence of sclerotic glomeruli in human kidneys. *Am J Pathol* 80:227–234
  26. McLachlan MS, Guthrie JC, Anderson CK, Fulker MJ (1977) Vascular and glomerular changes in the ageing kidney. *J Pathol* 121:65–78
  27. Chan KW, Leung CY, Chan CW (1990) Age-related glomerular sclerosis: baseline values in Hong Kong. *Pathology* 22:177–180
  28. Nyengaard JR, Bendtsen TF (1992) Glomerular number and size in relation to age, kidney weight, and body surface in normal man. *Anat Rec* 232:194–201
  29. van Essen GG, Apperloo AJ, Rensma PL, Stegeman CA, Sluiter WJ, de Zeeuw D, de Jong PE (1997) Are angiotensin converting enzyme inhibitors superior to beta blockers in retarding progressive renal function decline? *Kidney Int Suppl* 63:S58–S62
  30. Ruggenenti P, Perna A, Benini R, Remuzzi G (1998) Effects of dihydropyridine calcium channel blockers, angiotensin-converting enzyme inhibition, and blood pressure control on chronic, nondiabetic nephropathies. Gruppo Italiano di Studi Epidemiologici in Nefrologia (GISEN). *J Am Soc Nephrol* 9:2096–2101
  31. Bakris GL, Griffin KA, Picken MM, Bidani AK (1997) Combined effects of an angiotensin converting enzyme inhibitor and a calcium antagonist on renal injury. *J Hypertens* 15:1181–1185
  32. Nielsen FS, Rossing P, Gall MA, Skott P, Smidt UM, Parving HH (1997) Long-term effect of lisinopril and atenolol on kidney function in hypertensive NIDDM subjects with diabetic nephropathy. *Diabetes* 46:1182–1188
  33. Gandhi M, Meyer TW, Brooks DP (1999) Effects of eprosartan on glomerular injury in rats with reduced renal mass. *Pharmacology* 59:89–94
  34. Olson JL, Schwartz MM (1998) The nephrotic syndrome: Minimal change, focal segmental glomerulosclerosis, and miscellaneous causes. In: Jenette JC, Olson JL, Schwartz MM, Dilva FG (eds) *Heptinstall's pathology of the kidney*. Lippincott-Raven, Philadelphia, pp 187–257
  35. Bertani T, Mazzucco G, Monga G (2002) How glomerular extracapillary proliferation might lead to loss of renal function: light microscopic and immunohistochemical investigation. *Nephron* 91:74–78
  36. Javaid B, Olson JL, Meyer TW (2001) Glomerular injury and tubular loss in adriamycin nephrosis. *J Am Soc Nephrol* 12:1391–1400
  37. Rasch R, Nyengaard JR, Marcussen N, Meyer TW (2002) Renal structural abnormalities following recovery from acute puromycin nephrosis. *Kidney Int* 62:496–506
  38. Assmann KJ, van Son JP, Dijkman HB, Mentzel S, Wetzels JF (2002) Antibody-induced albuminuria and accelerated focal glomerulosclerosis in the Thy-1.1 transgenic mouse. *Kidney Int* 62:116–126
  39. Marcussen N (1992) Biology of disease: Atubular glomeruli and structural basis for chronic renal failure. *Lab Invest* 66:265–284
  40. Scherberich JE, Wolf G, Albers C, Nowack A, Stuckhardt C, Schoeppe W (1989) Glomerular and tubular membrane antigens reflecting cellular adaptation in human renal failure. *Kidney Int Suppl* 27:S38–S51
  41. Pagtalunan ME, Oberbauer R, Haas M, Barlan M, Mayer G, Olson JL, Meyer TW (1996) Atubular glomeruli in patients with chronic allograft rejection. *Transplantation* 61:1166–1171
  42. Kriz W, Gretz N, Lemley KV (1998) Progression of glomerular diseases: Is the podocyte the culprit? *Kidney Int* 54:687–697
  43. Shirato I, Hosser H, Kimura K, Sakai T, Tomino Y, Kriz W (1996) The development of focal segmental glomerulosclerosis in masugi nephritis is based on progressive podocyte damage. *Virchows Arch* 429:255–273
  44. Farquhar MG, Palade GE (1961) Glomerular permeability: II. Ferritin transfer across the glomerular capillary wall in nephrotic rats. *J Exp Med* 114:699–715
  45. Bliss DJ, Brewer DB (1984) Ultrastructural localization of anionic and cationic ferritin in the rat glomerular basement membrane in protein-overload proteinuria. *J Pathol* 143:57–68
  46. Anderson S, Brenner BM (1995) The role of nephron mass and of intraglomerular pressure in initiation and progression of experimental hypertensive-renal disorders. In: Laragh KH, Brenner BM (eds) *Hypertension: pathophysiology, diagnosis and management*. Raven Press, New York, pp 1553–1568
  47. Ruggenenti P, Mosconi L, Vendramin G, Moriggi M, Remuzzi A, Sangalli F, Remuzzi G (2000) ACE inhibition improves glomerular size selectivity in patients with idiopathic membranous nephropathy and persistent nephrotic syndrome. *Am J Kidney Dis* 35:381–391
  48. Remuzzi A, Monaci N, Bonassi ME, Corna D, Zoja C, Mohammed EI, Remuzzi G (1999) Angiotensin-converting enzyme inhibition prevents loss of glomerular hydraulic permeability in passive Heymann nephritis. *Lab Invest* 79:1501–1510
  49. Remuzzi A, Fassi A, Bertani T, Perico N, Remuzzi G (1999) ACE inhibition induces regression of proteinuria and halts progression of renal damage in a genetic model of progressive nephropathy. *Am J Kidney Dis* 34:626–632
  50. Manley HJ (2000) Role of angiotensin-converting-enzyme inhibition in patients with renal disease. *Am J Health Syst Pharm* 57 [Suppl 1]:S12–S18
  51. Heidet L, Cai Y, Guicharnaud L, Antignac C, Gubler MC (2000) Glomerular expression of type IV collagen chains in normal and X-linked Alport syndrome kidneys. *Am J Pathol* 156:1901–1910
  52. Macconi D, Ghilardi M, Bonassi ME, Mohamed EI, Abbate M, Colombi F, Remuzzi G, Remuzzi A (2000) Effect of angiotensin-converting enzyme inhibition on glomerular basement membrane permeability and distribution of zonula occludens-1 in MWF rats. *J Am Soc Nephrol* 11:477–489
  53. Davis BJ, Cao Z, de Gasparo M, Kawachi H, Cooper ME, Allen TJ (2003) Disparate effects of angiotensin II antagonists and calcium channel blockers on albuminuria in experimental diabetes and hypertension: potential role of nephrin. *J Hypertens* 21:209–216