Predicting the Progression of Chronic Renal Failure using Serum Creatinine factored for Height

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= **Abstract** =

Purpose : Efforts to predict the progression of chronic renal failure (CRF) in children, using mathematical models based on transformations of serum creatinine (Scr) concentration, have failed. Error may be introduced by age-related variations in creatinine production rate. Height (Ht) is a reliable reference for creatinine production in children. Thus, Scr, factored for Ht, could provide a more accurate predictive model. We examined this hypothesis.

Methods : The progression of CRF was detected in 63 children who proceeded to end-stage renal disease. Derivatives of Scr, including 1/Scr, log Scr & Ht/Scr, were defined for the period Scr was between 2 and 5 mg/dl. Regression equation were used to predict the time, in months, to Scr > 10 mg/dl. The prediction error (PE) was defined as the predicted time minus actual time for each Scr transformation.

Result : The PE for Ht/Scr was lower than the PE for either 1/Scr or log Scr (median: -0.01, -2.0 & +10.6 mos respectively; $p < 0.0001$). For children with congenital renal diseases, the PE for Ht/Scr was also lower than for the other two transformations (median: -1.2, -3.2 & +8.2 mos respectively; $p < 0.0001$). However, the PE's for children with glomerular diseases was not as clearly different (median: +0.9, +0.5 & +9.9 respectively). In children < 13 yrs, PE for Ht/Scr was the lowest, while in older children, 1/Scr provided the lowest PE, but not significantly different from that for Ht/Scr. The logarithmic transformation tended to predict a slower progression of CRF than actually occurred.

Conclusion : Scr, factored for Ht, appears to be a useful model to predict the rate of progression of CRF, particularly in the prepubertal child with congenital renal disease.

Key words : prediction error, chronic renal failure, progression, children

Introduction

As chronic renal failure develops, glomerular filtration rate (GFR) decreases increasingly more rapidly. The progression of chronic renal failure (CRF) has been claimed to be predictable by means of mathematical models. These models have used the serum creatinine (Scr) concentration as either a reciprocal or logarithmic plot against time[1,2]. These prediction follows from the well known

inverse relation between the clearance and serum concentration of substances whose excretion rate is

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constant.

These prediction of early renal failure is of special importance to estimate the progression of CRF and to provide optimal management of patients with end-stage renal diseases. And it is also used to assess patient response to various therapeutic modalities and to monitor various kidney disorders[3-6].

However, it has failed to predict accurately the course of CRF in children[7-10]. Although the serum creatinine concentration varies inversely with GFR, this relationship is not a simple one in growing children. Error may be introduced by age-related variations in creatinine production rate in children[11,12]. Height (Ht) is a reliable reference for creatinine production in children[13,14]. Thus, Scr, factored for height, should provide a more accurate prediction model. We examined this hypothesis in patients who have CRF with various causes.

To determine whether this hypothesis was reliable and whether the age at the last serum creatinine value before renal replacement therapy could have been accurately predicted, we conducted a retrospective study of dialysis and transplant patients at the Childrens' hospital in Boston.

Patients and Methods

The medical records of 267 children who proceeded to end-stage renal diseases were reviewed. Patients were selected based on the presence of the following criteria; 1) a first Scr value of ≥ 2 mg/dl but < 5 mg/dl, 2) at least 10 determinations recorded (per patient), 3) at least 4 determinations of Scr value from 2 to 5 mg/dl, 4) a record of height and the date of start of renal replacement therapy. We excluded 204 patients from this study: of these, 116 had been in end-stage renal disease (Scr>5 mg/dl) when first seen, 67 had fewer than four Scr values from 2 to 5 mg/dl, 18 had not yet start renal replacement therapy and 3 had been no value of height immediately before renal replacement therapy. We also excluded certain Scr values as follows; 1) preoperative serum creatinine values whose value dramatically decreased after surgical correction of obstructive uropathy and 2) temporary changes in serum creatinine value coincident with acute illness (e.g., dehydration, viral illness).

The remaining 63 patients (46 men, 17 women) in the study ranged in age at zero time from 15 days to 22 years 9 months (median age: 10 years 3 months).

The date of the first Scr determination was designated as zero time. Time intervals between this date and each of the following Scr determination was expressed in months. The following derivatives of Scr were plotted on the abscissa against time (which was expressed in months) on the ordinate; 1/Scr. log Scr, and Ht/Scr, after all Scr values >5.0 mg/dl were discarded. Regression equations were calculated by the method of least squares for each of these relationships.

Thereafter, the first actual Scr value >10.0 mg/dl was inserted into the regression equations, and the corresponding predicted time was calculated. If a patient had to be dialyzed before reaching a Scr of >10.0 mg/dl, the last predialytic value was entered into the equation. In each patient the prediction error (PE) defined as the predicted time minus the actual time ((PT - AT, Fig 1)

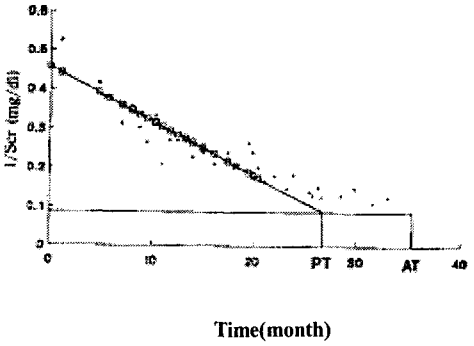

Fig. 1. Definition of prediction error and prediction line. Prediction Error. PT-AT

Separate regression equations and PE's were calculated for the following groups; all males, all females, children aged 6 months to 5 years, 6 to 12 years, all prepubertal ages and adolescent ages and disease groups according to the underlying diseases: congenital and hereditary disease (40 cases except cystinosis); renal dysplasia and hypoplasia (21 cases), obstructive uropathy (10 cases), prune belly syndrome (3 cases), nephronophthisis (1 case), medullary cystic disease (1 case), polycystic kidney disease (2 cases), congenital nephrotic syndrome (2 cases); cystinosis (3 cases); glomerulonephritis (14 cases); chronic tubulointerstitial disease (4 cases); hemolytic uremic syndrome (1 case); diabetes mellitus (1 case). Infants aged less than 6 months excluded in age groups because it has been documented that before this age GFR does not bear a constant relationship to surface area 15,16). However, Ht/Scr also correlated with creatinine clearance (Ccr) which was congruent with GFR (Cin) during infancy 11,16) as demonstrated by Schwartz et al 17). We included 2 patients whose age were 15 days and 5 months for analysis of other subgroups.

For the three model - 1/Scr, log Scr and Ht/Scr - the following scatter plots were prepared and analyzed: PE versus correlation coefficient of the three models, PE versus correlation coefficient squared of regression line of the each Scr transformation, PE versus prediction interval and PE versus follow-up period.

Table 1. Summary of all patients data (63 cases)

	Median	25percentile	75percentile	Mean	SD*6
No. of Scr per patient*1	7	5	10	8.79	5.22
First Scr (mg/dl)	2.4	2.12	2.7	2.5	0.48
Last Scr (mg/dl)*2	9.55	7.7	10.6	9.22	1.79
duration of observation(mos)*3	32.125	15.75	53.75	41.54	34.52
prediction interval(mos)*4	12.375	5.875	23.75	18.42	17.46
r (Ht/Scr)*5	-0.9187	-0.9581	-0.7965	-0.8525	0.1669
r (1/Scr)	-0.9398	-0.9694	-0.8362	-0.8820	0.1327
r (log Scr)	0.9394	0.8577	0.9684	0.8833	0.1335

p value
r (Ht/Scr) vs r (1/Scr) NS
r (1/Scr) vs r (log Scr) < 0.05
r (log Scr) vs r (Ht/Scr) < 0.05

*1.: Scr value ranged from 2 to 5 mg/dl
*2: The first actual Scr value > 10.0 mg/dl or last predialytic value if a patient had to be dialyed before reaching a Scr > 10.0 mg/dl
*3: Period Scr was between 2 and 5 mg/dl
*4: Actual time minus time at Scr 5 mg/dl
*5: Correlation coefficient for Ht/Scr as a function of time
*6: Standard deviation

Table 2. Prediction error of 63 pediatric patients (mos)

	Median*	25percentile	75percentile	Mean**	SD
Ht/Scr	-0.005	-4.78	4.77	2.31	16.28
1/Scr	-1.99	-7.31	1.61	-3.58	11.05
log Scr	10.65	0.72	18.4	11.50	15.21

* : $p < 0.0001$ **: $p < 0.05$; compared to each other group

Table 3. Median and mean prediction error of male and female patients (mos)*

	Male (n= 46)	Female (n= 17)
Ht/Scr	0.90	-3.86
	(3.94±18.16)	(-2.11±8.44)
1/Scr	-1.64	-4.77
	(-3.73±11.91)	(-3.19±8.59)
log Scr	12.37	8.70
	(12.60±16.50)	(8.86±10.94)
Median difference	< 0.0001	< 0.05
p value	< 0.05	NS
Ht/Scr vs 1/Scr	< 0.05	< 0.05
1/Scr vs log Scr	< 0.05	< 0.05
log Scr vs Ht/Scr		

*median: mean±SD are in paracenthesis

Table 4. Prediction error of subgroups according to age (mos)*

Age(no)	6M-5Y(16)**	Prepubertal group 6-12Y(25)	0-12Y(43)	Adolescent group > 13Y(20)
Ht/Scr	-3.23	1.92	-0.82	1.44
	(1.14±28.07)	(1.21±9.03)	(1.59±18.64)	(3.85±9.64)
1/Scr	-5.94	-0.66	-3.17	-0.09
	(-0.69±11.59)	(-2.19±9.20)	(-5.92±11.84)	(1.43±7.05)
log Scr	0.35	14.82	7.91	13.02
	(-0.27±8.73)	(16.61±12.27)	(9.29±13.88)	(16.56±17.04)
median difference	< 0.05	< 0.0001	< 0.0001	< 0.001
p value				
Ht/Scr vs 1/Scr	NS	NS	< 0.05	NS
1/Scr vs log Scr	NS	< 0.05	< 0.05	< 0.05
log Scr vs Ht/Scr	NS	< 0.05	< 0.05	< 0.05

* median: mean±SD are in paracenthesis

** aged 6 months to 5years

Table 5. Prediction error of disease group according to underlying disease(mos)*

	Congenital disease**(n= 40)	Dysplasia (n= 21)	Obstructive uropathy(n= 10)	Glomerulonephritis*** (n= 14)
Ht/Scr	-1.18	-2.45	3.05	0.87
	(2.68±19.95)	(-.21±16.11)	(11.24±30.88)	(0.99±6.85)
1/Scr	-3.23	-5.71	-1.53	0.46
	(-6.24±12.38)	(-7.48±13.16)	(-5.79±15.47)	(0.40±6.38)
log Scr	8.18	3.63	16.54	9.88
	(10.92±17.05)	(8.55±20.44)	(18.27±11.68)	(11.29±14.02)
median difference	< 0.0001	< 0.001	< 0.005	< 0.05
p value				
Ht/Scr vs 1/Scr	< 0.05	NS	NS	NS
1/Scr vs log Scr	< 0.05	< 0.05	NS	< 0.05
log Scr vs Ht/Scr	< 0.05	< 0.05	< 0.05	< 0.05

* median: mean±SD are in paracenthesis
exclude 9 cases, because of few cases

** include dysplasia, hypoplasia, obstructive uropathy, prunebelly syndrome, nephronophthisis, medullary cystic disease, polycystic kidney disease and congenital nephrotic syndrome except cystinosis and Alport syndrome

*** include 1 case of Alport syndrome

Table 6. Comparison of the prediction error (PE) of the three models used for calculating the progression of renal failure

Expected relationship between	Observed		
	Ht/Scr	1/Scr	log Scr
PE vs r	0.2115	-0.0591	-0.0674
PE vs r2*3	-0.2207	0.0695	-0.0679
PE vs prediction interval	0.3308*1	-0.7748*2	-0.0232
PE vs follow-up period*4	0.4984*2	-0.5906*2	0.2183

*1 $p < 0.05$
*2 $p < 0.001$
*3 correlation coefficient squared
*4 period of observation time from first to last Scr value

Statistic analysis was performed by one way ANOVA (analysis of variance) followed by Duncan multiple comparisons[18], and nonparametric testing using the Kruskal- Wallis test statistics for comparison among the median values[19]. Statistical significance was defined as $p < 0.05$.

Result

Clinical profile of all patients data is shown in table 1: the number of Scr determinations between Scr 2 and 5 mg/dl, the first and last Scr value, period Scr was between 2 and 5 mg/dl, prediction interval (actual time minus time at Scr 5 mg/dl) and correlation coefficient after each transformation of all Scr values between 2 and 5 mg/dl of a given patient. Prediction interval ranged from 3 weeks to 6 years 6 months. The correlation coefficient (r) of Ht/Scr as a function of time yielded the high value and was not significantly different from that for 1/Scr. Likewise, high correlation coefficient presented between each Scr transformation and time.

The median and mean PE's of patients studied are displayed in table 2. The PE for Ht/Scr was lower than the PE's for either 1/Scr or log Scr ($p < 0.0001$). In addition, the logarithmic transformation showed larger PE's than did either 1/Scr or Ht/Scr model.

Presented in table 3 is the PE's for boys and girls.

PE's for subgroups according to age are given in table 4.

The children < 13 years, PE for Ht/Scr was lowest, while the older children 1/Scr provided the lowest PE, but was not significantly different PE for Ht/Scr.

PE's for disease groups according to the underlying disease are shown in Table 5. We excluded 9 cases in the Table because of few cases: of these, 4 tubulointerstitial disease, 3 cystinosis, 1 hemolytic uremic syndrome and 1 diabetes mellitus. This table inferred that for children for congenital renal diseases, the PE for Ht/scr was also lower than for the other two models. However, the PE's for children with glomerular diseases were not clearly different.

In general, the logarithmic transformation tended to predict a slower progression of CRF that actually occurred as demonstrated by positive median value of the PE.

Table 6 shows no correlation between PE and either correlation coefficient or correlation coefficient squared of Scr data between 2 to 5 mg/dl and shows PE's for either 1/Scr or Ht/Scr in related to either prediction interval or follow-up period.

Discussion

The purpose of our study was to derive an accurate predicator of the progression of CRF in children. Although the prediction of each Scr transformation became more accurate when high Scr values were inserted in calculation for the prediction equation10), worth nothing is the fact that high Scr values were used for an accurate prediction. Because the attending physicians, patients and their families were generally prepared for dialysis and transplantation when the Scr value was between 2 and 5 mg/dl.

The result of our study confirmed that the error to predict the progression of CRF is considerable with two models (reciprocal and logarithmic transformations) presently applied in clinical pediatric nephrology. These results are in agreement with the results of some authors7, 8, 20). Only they have made to assess the accuracy of these models. The previous other attempts to predict the progression of CRF have focused, in general, on the high correlation coefficient present between Scr data and time to ensure the accuracy1,22).

Our data indicated that more accurate prediction can be made from serial measurement of Scr concentration after reciprocal transformation and serial measurement of height (body length). It seems that most children of CRF lose renal function as estimated by GFR at a constant rate rather than at constant fractional rate2), for PE for log Scr is larger than that for either Ht/Scr or 1/Scr.

Reasons for the accurate prediction of Ht/Scr model and considerable prediction error of the other two models are follows. The Scr changes with age and thus, is a poor indicator of GFR in growing children, because the accretion of muscle mass effects the production of creatinine1,17,22). Likewise, the urinary excretion of creatinine increases with age, height, and weight. The lean body mass was found to show highly significant relationship with creatinine excretion and growth. It has mentioned above that height is a reliable reference for creatinine production, urinary excretion of creatinine, and lean body mass in children13,14). Height can be also be accurately assessed in children and is independent of fluctuation in the quantity of total body water and fat. And some children of CRF continue to grow at their centile with a lower GFR23-26).

Data of Counahan et al27) and Schwartz et al28) reported that the correlation between GFR and the reciprocal values of Scr was poor but improved when Scr was corrected for height in children. Several authors were followed and approved the above theory 12,29-31). They also observed a better prediction of GFR from Ht/Scr if the GFR was reduced than if it was in the normal range. The amount of muscle mass wasting likely to occur in patients with advanced renal disease does not appear to significantly alter the relationship between height and Scr. Because the decline in creatinine production rate progressing with advancing renal failure, does not appear to be clinically significant until Scr is higher than 6 mg/dl10,32). However, a change in this ratio might occur in severe reduction of muscle mass.

Although Scr is inversely proportional to Ccr, Ccr exceeds GFR due to secretion, with deterioration of renal function28,33). Shemesh et al33) suggest that neither Ccr nor formulation based on the Scr alone will reliably detect, much less quantity, changes in the actual GFR, for fractional creatinine secretion varies inversely with GFR. Likewise, creatinine excretion does not remain constant throughout the course of CRF, the apparent incompatibility of a linear decrease in the reciprocal of Scr is also happened. A determination of Scr, therefore, is of limited value in prediction the level of endogenous creatinine clearance as suggested Doolan et al34) and renal function is more adequately estimated by

relating height to Scr value.

The occurrence of systemic deviation of data to one side of the calculated regression lines as described by Gretz et al[10] is another reason for the large PE's. These authors and Talwalker and Mandel[35] point out that systemic deviations of Scr values during the course of CRF are caused by different factors: underlying renal disease, age of the patient, hypertension, hyperlipidemia, hyperphosphatemia, urinary tract infections, protein intake and drugs and other factors that may influence the Scr concentration are changes of extracellular volume and creatinine production rate, which is reduced by muscle-wasting. However, these deviations decrease in the current study by relating height to Scr values.

We found that the logarithmic transformation of Scr values yields larger PE than either Ht/Scr or 1/Scr model ($p < 0.05$), even though, log Scr showed lower PE than the other two transformations in children aged 6months to 5years, we failed to demonstrate any significant difference among three models ($p > 0.05$). This result is also in accordance with the results of Reimold[7], Arbus and Bacheyie[8], and Gretz et al[20]. However, they described median and mean value of the PE of the reciprocal and logarithmic models, but made no mention of a reliable estimates of variance. We notes wide scattering of the PE's of three models like these three studies do. It seems that we calculated prediction equation using the low Scr values between 2 and 5 mg/dl. Obviously, the higher Scr values inserted into the prediction equation, the lower were the scattering[7,8,10]. Reimold[7] also showed that rise in Scr concentration from 2 to 5 mg/dl followed a variable time interval.

Most studies predicting the progression of CRF by using reciprocal and logarithmic models assumed exclusively a high degree of accuracy because of high correlation coefficient of the transformed Scr data[1,2]. Some authors suggest that the two slope of linear equation with the transformed Scr data versus time has higher correlation coefficient than the one slope in some patients[2,36,37]. Single regression line in our data was enough because of short period of observation Scr value was between 2 and 5 mg/dl. However, these studies may be also criticized on the basis that data outside the range of the original data set was predicted[38]. As pointed out by Feinstein[38], high correlation coefficient is meaningless if graphical portraits demonstrate systemic deviations. Correlation is considered to be better that each Scr transformations, when 1/Scr model is corrected for 1/Ht, but the PE is not significantly different from 1/Scr models.

As demonstrated by our study and study of Gretz et al[20], no relationship exists between PE and correlation coefficient. As a result, high correlation coefficient does not guarantee a good prediction of the progression of CRF. Likewise, there is no relation between PE and correlation coefficient squared, which is a good indicator of fitness of regression line. The association between PE's for Ht/Scr and 1/Scr and either prediction interval or follow-up period, although statistically significant, is of little practical value in that neither measurement can reliably be predicted from each other, as shown by low value of r^2[38]. Gretz et al[20] were concerned PE in relation to the prediction interval, but displayed no relationship between these variables.

Our reason for examining data in subgroups based on sex, age, and underlying renal diseases was that changes in the proportion between muscle mass and body length might effect Ht/Scr transformation differently in different group. Although value for Ht/Scr for prepubertal ages (< 13 years), males, and congenital renal diseases are consistently lower PE than the other two models, we still couldn't confirm that which factor is more important for prediction. Thus, Scr, factored for Ht, appears to be a useful model to predict the rate of progression of CRF in

children, particularly in the prepubertal child with congenital renal disease. We concluded that more accurate prediction of progression of CRF in children can be made from serial measurement of Scr concentration after reciprocal transformation and measurement of height (body length).

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References

1. Mitch WE, Walser M, Buffington GA, Lemann J Jr: A simple method of estimating progression of chronic renal failure. Lancet 2:1326-8, 1976
2. Rutherford WE, Blondin J, Miller JP, Greenwalt AS, Vavra JD: Chronic progressive renal disease: Rate of change of serum creatinine concentration. Kidney Int 11:62-70, 1977.
3. Boaz M, Biro A, Katzir Z, Smetana S: Patterns of dietary intake and serum lipids interact with proteinuria as risk factor for progression of chronic renal failure. Ren Fail 20:383-90, 1998
4. Brazy PC, Fitzwilliam JF: Progressive renal disease: Role of race and antihypertensive medications. Kidney Int 37:1113-9, 1990
5. Claris-Appiani A, Galato R, marra G, Assael BM, Seveso M: Prediction of the progression of renal failure in adult and in pediatric patients with malignant focal glomerulosclerosis. Clin Nephrol 26:87-90, 1986
6. Modena FM, Hostetter TH, Salahudeen AK, Najarian JS, Matas AJ, Rosenberg ME: Progression of kidney disease in chronic renal transplant rejection. Transplantation 52:239-44, 1991
7. Reimold EW: Chronic progressive renal failure. Rate of progression monitored by change of serum creatinine concentration. Am J Dis Child 135:1039-43, 1981
8. Arbus GS, Bacheyie GS: Method of predicting when children with progressive renal disease may reach high serum creatinine levels. Pediatrics 67:871-3, 1981
9. Tabak MA, Christenson PC, Fine RN: Prediction of the progression of chronic renal failure in children: Are current models accurate? Pediatrics 78:1007-12, 1986
10. Gretz NM: How to assess the rate of progression of chronic renal failure in children? Pediatr Nephrol 8:499-504, 1994
11. Rosenthal DA, Pyle WK: Creatinine generation rate in infants and children. Dial Trans 11:968, 1982
12. Morris MC, Allanby CW, Toseland P, Haycock GB, Chantlar C: Evaluation of height/plasma creatinine formula in the measurement of glomerular filtration rate. Arch Dis Child 57:611-5, 1982
13. Graystone JE: Creatinine excretion during growth in Cheek DB: Human growth. body composition, cell growth, energy and intelligence. Lea & Febiger, Philadelphia, 1968, pp182-97.
14. Viteri FE, Alvarado J: The creatinine height index: its use in the estimation of degree of protein depletion and repletion in protein calorie malnourished children. Pediatrics 46:696, 1970
15. Schwatz GJ, Haycock GB, Edelmann CM, Spitzer A: A simple estimate of glomerular filtration rate in children derived form body length and plasma creatinine. Pediatrics 28: 259-63, 1976
16. Arant BS: Estimating glomerular filtration rate in infants. J Pediatr 104:890, 1984
17. Schwatz GJ, Feld LG, Langford DJ: A simple estimate of glomerular filtration rate in full-term infants during the first year of life. J Pediatr 104:849-54, 1984

18. Snedecor GW, Cochran WG: Statistical methods. 6th ed., Iowa University Press, Ames, Iowa, 1967, pp268-275.
19. Hollander M, Wolfe DA: Nonparametric statistical methods. John Wiley & sons, N.Y., 1973, pp115-120
20. Gretz N, Manz F, Strauch M: Predictability of the progression of chronic renal failure. Kidney Int 24:s2-5, 1983
21. Leumann EP: Progression of renal insufficiency in pediatric patients: estimation from serum creatinine. Helv Paediatr Acta 33;25-35, 1978
22. Schwartz GJ, Haycock GB, Chir B, Spitzer A: Plasma creatinine and urea concentration in children. Normal values for age and sex. J Pediatr 88:828-30, 1976.
23. Rizzoni G, Basso T, Setari M: Growth in children with chronic renal failure on conservative treatment. Kidney Int 26:52, 1984
24. Kleinknecht C, Broyer M, Huot D, Marti-Henneberg C, Dartois A: Growth and development of nondialyzed children with chronic renal failure. Kidney Int 24:s40, 1983.
25. Fine RN, Salusky IB, Ettenger RB: The therapeutic approach to the infant, child, and adolescent with end-stage renal disease. Pediatr Clin N Am 34:789-801,1984
26. Warady BA, Jabs K: New hormones in the therapeutic arsenal of chronic renal failure. Growth hormone and erythropoietin. Pediatr Clin N Am 42:1551-78, 1995
27. Counahan R, Chantler C, Ghazali S, Kirkwood B, Rose F, Barratt TM: Estimation of glomerular filtration rate from plasma creatinine concentration in children. 51:875-8, 1976.
28. Schwartz GJ, Brion LP, Spitzer A: The use of plasma creatinine concentration for estimating glomerular filtration rate in infants, children, and adolescents. Pediatr Clin North Am 34:571-90, 1987
29. Szelid ZS, Mehes K: Estimation of glomerular filtration rate from plasma creatinine concentration in children of various ages. Arch Dis Child 52:669-70, 1977.
30. Schwartz GJ, Gauthier B: A simple estimate of glomerular filtration rate in adolescent boys. J Pediatr 106:522-8, 1985
31. Zacchello G, Bondie M, Sala OS, Largaiolli G, Vedaldi R, Rubaltelli FF: Simple estimate of creatinine clearance form plasma creatinine in neonates. Arch Dis Child 57:297-300, 1982
32. Crockcroft DW, Gault MH: Prediction of creatinine clearance form serum creatinine. Nephron 16:31-41, 1976
33. Shemesh O, Golbetz H, Kriss JP, Myers BD: Limitations of creatinine as a filtration marker in glomerulopathic patients. Kidney Int 28:830, 1985
34. Doolan CPD, Alpen EL, Theil GB: A clinical appraisal of the plasma concentration and endogenous clearance of creatinine. Am J Med 32:65, 1962
35. Talwalker YB, mandel S: Monitoring progress of chronic renal failure. Lancet 1:366, 1977
36. Rowe PA, Richardson RE, Burton PR, Morgan AG, Burden RP: Analysis of reciprocal creatinine plots by two-phase linear regression. Am J Nephrol 9:38-43, 1989
37. Kirschbaum BB: Analysis of reciprocal creatinine plots in renal failure. Am J Med Sci 291:401-4, 1986
38. Feinsein AR: Clinical Biostatics. Saint Louis, Mosby, 1977

< 한 글 요 약 >

소아 만성신부전의 진행 예측에 관한 연구

건국의대 소아과, 미국 하바드의대 보스턴소아병원 소아신장과*

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목 적 : 만성신부전 환자에서 1/scr, log Scr을 연속적으로 측정하여 신부전의 진행을 예측하고 있으나 연령에 따라 creatinine 생성율의 차이가 있는 소아에서는 정확한 진행예측에 어려움이 있다. 신장 (height, Ht) 은 creatinine 생성율에 관여하는 중요한 인자이므로 따라서 저자들은 1/scr에 신장 (height, ht)을 도입한 Ht/Scr과 1/Scr, log Scr을 연속적으로 측정하여 만성 신부전의 진행 예측도의 정확성을 비교하고저 하였다.

방 법 : 말기신부전으로 진행된 환아 63 명을 대상으로 혈청 크레아티닌 (Scr) 이 2 mg/dl에서 5 mg/dl 될 때까지 매 환자에서 1/Scr, log Scr, Ht/Scr을 연속적으로 측정하여 이들로부터 회기방정식을 구하여 Scr 이 10 mg/dl 이상인 시기를 예견하였다. 예측오차는 Scr 이 10 mg/dl 이상인 예측시기에서 실제시기를 뺀 것으로 하고 세군 간의 예측오차를 비교함으로써 만성신부전증 진행 예측의 정확도를 관찰하였다.

결 과 : 1) Ht/Scr 의 예측오차는 0.01 개월로 1/Scr, log Scr 의 예측오차인 2 개월, 10.6 개월보다 적었다 ($p< 0.0001$).

2) 선천성 신질환 환아의 Ht/Scr의 예측오차는 1.2 개월로 1/Scr, log Scr 의 예측오차인 3.2 개월, 8.2 개월보다 적었다 ($p< 0.0001$). 사구체신염 환아의 경우 Ht/Scr, 1/Scr, Ht/Scr의 예측오차는 각각 0.9 개월, 0.5 개월, 9.9 개월이었고 통계적인 차이는 없었다.

3) 13 세이전의 경우는 Ht/Scr 의 예측오차가 가장 적었고 그 이후 연령의 경우는 1/Scr의 예측오차가 적었으나 Ht/Scr과 통계적인 차이는 없었다.

4) Log Scr의 예측시기는 실제시기보다 늦었다.

결 론 : 소아 만성신부전 환아에서 시간에 따른 혈청 크레아티닌의 역수와 신장의 변화를 연속적으로 관찰함으로서 신부전의 진행 및 투석시기를 정확히 예측할 수 있었다.

중심단어 : 소아, 만성신부전, 진행예측