Correlation between cystatin C-based formulas, Schwartz formula and urinary creatinine clearance for glomerular filtration rate estimation in children with kidney disease

Afshin Safaei-Asl 1, Mercede Enshaei 1, Abtin Heydarzadeh 2, Shohreh Maleknejad 1

1Department of Pediatrics, Guilan University of Medical Sciences, Guilan, Iran
2Department of Community Medicine, Guilan University of Medical Sciences, Guilan, Iran

ABSTRACT

Introduction: Assessment of glomerular filtration rate (GFR) is an important tool for monitoring renal function. Objectives: Regarding to limitations in available methods, we intended to calculate GFR by cystatin C (Cys C) based formulas and determine correlation rate of them with current methods. Patients and Methods: We studied 72 children (38 boys and 34 girls) with renal disorders. The 24 hour urinary creatinine (Cr) clearance was the gold standard method. GFR was measured with Schwartz formula and Cys C-based formulas (Grubb, Hoek, Larsson and Simple). Then correlation rates of these formulas were determined. Results: Using Pearson correlation coefficient, a significant positive correlation between all formulas and the standard method was seen (R^2 for Schwartz, Hoek, Larsson, Grubb and Simple formula was 0.639, 0.722, 0.705, 0.712, 0.722, respectively) (P<0.001). Cys C-based formulas could predict the variance of standard method results with high power. These formulas had correlation with Schwarz formula by R^2 0.62-0.65 (intermediate correlation). Using linear regression and constant (y-intercept), it revealed that Larsson, Hoek and Grubb formulas can estimate GFR amounts with no statistical difference compared with standard method; but Schwartz and Simple formulas overestimate GFR. Conclusion: This study shows that Cys C–based formulas have strong relationship with 24 hour urinary Cr clearance. Hence, they can determine GFR in children with kidney injury, easier and with enough accuracy. It helps the physician to diagnosis of renal disease in early stages and improves the prognosis.

ARTICLE INFO

Article Type: Original

Article History:
Received: 2 May 2016
Accepted: 12 June 2016
Published online: 19 June 2016

Keywords:
Child
Creatinine
Cystatin C
Glomerular filtration rate
Kidney disease

Implication for health policy/practice/research/medical education:
Glomerular filtration rate (GFR) is a calculation that determines how well the blood is filtered by the kidneys, which is one way to measure remaining kidney function. Assessment of GFR is an important tool for monitoring renal function. GFR is best measured by injecting compounds such as inulin, chromium-EDTA or iohexol, however these techniques are complicated, costly, time-consuming and have potential side-effects. Cystatin C is cysteine proteases inhibitor and has a low molecular weight that freely filters across the glomerulus and is neither reabsorbed nor metabolized by the kidney. Regarding to limitations in available methods, in this study we intended to calculate GFR by cystatin C based formulas and determine correlation rate of them with current methods.


Introduction
Glomerular filtration rate (GFR) is summation of filtration in all functional nephrons, thus it is used as the best estimation of kidney function (1,2). This amount depends on age, gender and body surface area (3). An ideal marker for calculating GFR is a marker with constant production, water soluble, not binding to protein, not having tubular excretion or reabsorption, not having ex-
extra renal elimination or metabolism, accurate and reliable, and having rapid results, cost-effectiveness and availability (4,5).

GFR is best measured by injecting compounds such as inulin, radioisotopes such as 51Cr-EDTA or radiocontrast agents such as iohexol, however these techniques are complicated, costly, time-consuming and have potential side-effects (6,7).

In clinical use, GFR is measured by serum creatinine (Cr) or Cr clearance that requires accurate urine collection over a long time. It is impossible in non-toilet trained children (without using a urinary catheter) and is challenging in other children (8,9).

Schwartz formula which is used widely in pediatrics is calculated based on serum Cr too (10-13).

Cys C is cysteine protease inhibitor and has a low molecular weight (approximately 13.3 kDa) as a chain of 120 amino acids. It is encoded by the CST3 gene (5,9).

It is produced by all nucleated cells freely filters across the glomerulus and is neither reabsorbed nor metabolized by the kidney (14). Cr measurement has some problems. It is very variable and depends on age, gender, diet and muscle mass (5). Indeed it is influenced by factors other than kidney function (15,16). Measurement of Cys C is available increasingly and leads to rapid and accurate results (5). Serum Cys C has a steady level after first year of life (2), but Cr level increases until puberty that makes interpretation problematic for pediatric patients (17-20). Although in the presence of some conditions such as diabetes with ketonuria, increases of C-reactive protein (CRP), glucocorticoid therapy, known cancer, thyroid dysfunction (hypothyroidism or hyperthyroidism) (24-28).

Results

Seventy-two patients with renal disease were studied. Thirty-eight patients (52.8%) were boys and 34 patients (47.2%) were girls. Their age ranged from 2 to 14 years old (7.92 ± 3.79 years old); their age ranged from 2 to 14 with the average of 7.92 ± 3.79 years old. The Underlying renal diseases were 14 nephrotic syndrome (19.4%), 12 congenital malformation including hypoplasia or agenesis (16.7%), 10 nephrolithiasis (13.8%), 9 reflux nephropathy (12.5%), 8 glomerulonephritis (11.1%), 6 anatomic disorders like ureteropelvic junction obstruction, ureterovesical junction obstruction, posterior urethral valve (8.3%), 5 urinary tract infection (UTI) (6.9%), 4 hereditary kidney disease including Autosomal recessive polycystic kidney disease (ARPKD) and medullary sponge kidney (MSK) (5.5%), 2 neurogenic bladder (2.8%) and 2 had Barter syndrome (2.8%). In this study, the value of Cys C level was 1.029 ± 0.7924 mg/l. Urinary Cr clearance that was gold standard test which determined by this formula: 

\[ C_{cr} = \frac{U_{cr} \times V}{P_{cr}} \] reported by ml/min (29-32).

Schwartz formula: 

\[ GFR = \frac{K \times \text{Height} (cm)}{S_{cr} (mg/dL)} \]

GFR also determined by Cys C-based formulas:

Hoek formula: 

\[ GFR = -4.32 + \left( 80.35 \times \frac{1}{\text{cystatin C (mg/l)}} \right) \]

Larsson formula: 

\[ GFR = 77.24 \times \text{cystatin C (mg/l)} \]

Grubb formula: 

\[ GFR = 89.12 \times \text{cystatin C (mg/l)} \]

Simple formula: 

\[ GFR = 100/ \text{cystatin C (mg/l)} \]

Then the correlation between each of these results and 24 hour urinary Cr clearance and Schwartz formula were estimated.

Ethical issues

1) The research followed the tenets of the Declaration of Helsinki; 2) Informed consent was obtained; and 3) the research was approved by the Ethics Committee of Guilan University of Medical Sciences.

Statistical analysis

Data analysis was done by SPSS and R2 between the mentioned methods were calculated by Pearson correlation coefficient. Then linear regression test was conducted and y-intercept was calculated that revealed the presence of overestimation or underestimation of the formulas in comparison with gold standard test and P value < 0.05 was recognized statistically significant.
Discussion
In this study, correlation between Hoek, Larsson, Grub, Simple GFRs and Cr clearance was 0.712, 0.705, 0.722 and 0.722, respectively. $R^2$, the prediction percentage of one variable from another, is interpreted this way; $R^2$ lower than 30%, 30%-49.99%, 50%-69.99% and more than 70% is indicative of lack of correlation, low, intermediate and high correlation between two variables respectively. This study shows a high correlation between Cys C based formulas and Cr clearance. On the other hand, there is intermediate correlation between these formulas and Schwartz formula. Also we used linear regression test and y-intercept. Y-intercept shows that we need to add this amount to the product of regression coefficient in GFR calculated from each method, then we can predict GFR from Cr clearance.

Regarding Simple and Schwartz formulas, this difference was statistically significant and it means that these formulas overestimate GFR. In this study we used Cr clearance (in 24 hour urine) as gold standard test, but in most other studies, clearance of exogenous materials like 51Cr-EDTA (19,33,34) and 99m TC-DTPA (35), was used for gold standard test, which has more accuracy. In a similar study in Iran, Japan and France they used Cr clearance for gold standard test too (36-38) that shows less availability to these materials in our country and it leads to less diagnostic accuracy. In the study by Hoek et al in 2003, Hoek formula was introduced. This formula was compared with Cr-based formulas and showed more accurate results. However, the gold standard test was 125I-iothalamate, thus we cannot compare their result with our study (29).

In the study of Larsson et al, in 2004, Larsson formula was introduced. The gold standard test was iohexol clearance and correlation between Cyst C and standard test was de-

| Table 2. Y-intercept and corrected R between each method and gold standard test (Cr clearance) |
| Method | Constant B±SE | P value | Corrected R | P value |
| Schwartz Formula | 26.62±6.56 | <0.001 | 0.799 | <0.001 |
| Hoek Formula | 11.52±6.25 | 0.07 | 0.85 | <0.001 |
| Larsson Formula | 3.57±7.69 | 0.64 | 0.84 | <0.001 |
| Grubb Formula | 8.88±8.15 | 0.28 | 0.84 | <0.001 |
| Simple Formula | 18.74±7.84 | <0.05 | 0.85 | <0.001 |

GFR unit in all above methods is ml/min/1.73 m$^2$.

There is some difference between GFR calculated by Cys C formulas and Cr clearance, but after determining $P$ value, it was demonstrated that these differences about Grubb, Hoek and Larsson formulas were statistically insignificant. In other words, these formulas can estimate GFR according to Cr clearance accurately.

In the study by Hoek et al in 2003, Hoek formula was introduced. This formula was compared with Cr-based formulas and showed more accurate results. However, the gold standard test was 125I-iothalamate, thus we cannot compare their result with our study (29).
Correlation between Cr and standard test (24 hour Cr clearance) was $R^2 = 0.84$ that was indicative of more correlation of Cys C. Also they distinguished that Larsson formula had more diagnostic value rather than isolated serum Cys C level. In 2005, Grubb formula was introduced. The gold standard test was Iohexol clearance, too. This formula had more diagnostic accuracy comparing to Cr-based formulas. In 2005 Perkins introduced Simple formula too. In that study the gold standard test was 125I-Iothalamate. There was high correlation between simple formula and standard test. (Spearman test; $r = 0.77$), however correlation between Cr-based formulas and standard test was low (Spearman test; $r < 0.35$) (32). In study of Hojs et al (39) in 2009, gold standard test was 51 Cr-EDTA. Correlation between Larsson, Hoek, Grubb, Simple formulas and standard test was 0.895, 0.905, 0.899, and 0.906, respectively. All of the above formulas underestimated GFR, except Simple formula with little overestimation of GFR. Correlation in all formulas was high. They reported that Simple formula has acceptable diagnostic accuracy in clinical practice (39). In our study, as mentioned, a high correlation between Cys C-based formulas and our gold standard test (24 hour urinary Cr clearance) was seen.

Conclusion
In conclusion using Cys C and mentioned formulas, which are more accurate than isolated serum Cys C level (40), we can determine GFR in children suspected to renal dysfunction easily, with high accuracy. Therefore, it is possible to early diagnosis and lead to better prognosis for patients.

Limitations of the study
The study had some limitations such as small sample size in comparison of methods of calculating GFR in them, thus we recommend conducting of similar studies as multicentric. Further studies with larger populations are suggested to better detect this aspect in children. One of the limitations of this study was the heterogeneity kidney disease among the study population.

Acknowledgments
There is no doubt that conduction of the present study might not be feasible without cooperation of the patients, the respected colleagues. Authors wish to thank and appreciate efforts of Dr. Saba Hoda and Dr. Habib Habibzadeh for their assistance in performing the tests in Razi laboratory. In addition we are extremely grateful to the nurses of 17 Shahrivar children hospital for the support of the study.

Authors’ contribution
ASA, AH and SM contributed to design and conducted the research. ME conducted data gathering and data interpretation. AS, AH and SM analyzed the data. All authors prepared the manuscript read, revised, and approved the final manuscript.

Conflicts of interest
The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

Ethical considerations
Ethical issues (including plagiarism, data fabrication, double publication) have been completely observed by the authors.

Funding/Support
This study was financially supported by Guilan University of Medical Sciences (Grant # 650). This study extracted from residential thesis.

References

Copyright © 2016 The Author(s); Published by Nickan Research Institute. This is an open-access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.