Comparison of Renal Function between Cyanotic and Acyanotic Congenital Heart Disease in Children and Adolescent

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Background: *Glomerular and tubular dysfunction can be found in congenital heart disease (CHD) especially in older children and adults.*
Objective: *To evaluate the prevalence renal dysfunction and to compare glomerular and tubular function between cyanotic and acyanotic CHD in children and adolescent. Correlations among clinical factors, urinary glomerular and tubular markers for kidney injury were also determined.*
Material and Method: *Renal function was determined by estimated glomerular filtration rate, urine protein/creatinine, urine microalbumin/creatinine, FE Na^+, FE Mg^2, and urine NAG/creatinine in children and adolescent with CHD.*
Results: *Forty-six patients, 15 cyanotic (group 1), and 31 acyanotic CHD (group 2), were studied. Only the differences of urine NAG/creatinine (median, 3.59 vs. 1.64 unit/gram creatinine; p = 0.008), FE Mg^{2+}(mean, 5.03 ± 3.61% vs. 2.48 ± 1.8%; p = 0.019), and urine protein/creatinine between the two groups were statistically significant (0.16 vs. 0.08; p = 0.001). No significant differences of clinical features, BUN, creatinine, eGFR, diastolic blood pressure, FE Na^+ , and urine microalbumin/creatinine were found between the two groups. Significantly higher prevalence of abnormal biochemical markers in group 1 compared to those of group 2: 86.6% vs. 43.38% (p = 0.02) for FE Mg^{2+}; 46.6% vs. 9.67% (p = 0.008) for urine NAG/creatinine; 46.6% vs. 6.45% for significant proteinuria (p = 0.003); and 40% and 9.67% (p = 0.042) for microalbuminuria, respectively. The authors found moderate correlation between hemoglobin and functional class of the patients (r = 0.58) and highly negative correlation between oxygen saturation and functional class (r = -0.716). The relationships among other clinical or biochemical makers showed only low correlations.*
Conclusion: *Cyanotic CHD patients had more prevalence and higher abnormal biochemical markers for renal dysfunction than those of acyanotic CHD. Their urine protein/creatinine, FE Mg^2 and urine NAG/creatinine were higher than those of acyanotic CHD. Only low correlation among biochemical markers was found.*

Keywords: *Renal dysfunction, Glomerular dysfunction, Tubular dysfunction, Cyanotic congenital heart disease, Acyanotic congenital heart disease*

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Among many short- and long-term consequences of congenital heart disease (CHD), renal disorders are quite common[1,2]. The risk of developing renal impairments is particularly higher in patients with cyanotic heart diseases compared to non-cyanotic heart diseases[1,2]. Furthermore, the incidence of renal abnormalities is directly associated with degree and duration of cyanosis[3]. Impaired renal function in CHD may take place at either the glomeruli or tubules. To date, there are more numbers of studies reporting on the relationship of CHD and glomerular dysfunction compared to the studies reporting on tubular dysfunction[2,4,5].

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The tests that are usually used to assess renal function are level of serum BUN and creatinine. However, they are not sensitive to detect early stage of renal impairment. Focusing on the glomerular function, the impaired function can be determined by many means *e.g.* glomerular filtration rate, and presence of proteinuria specified as microalbumin or total protein. For tubular function, several biomarkers can reflect its integrity: fractional excretion or urine to serum ratio of sodium (FE Na^+), fractional excretion of magnesium (FE Mg^{2+}), β2-microglobulin, retinol binding protein, α1-microglobulin, and NAG (N-acetyl-β-D-glucosaminidase)[6-8]. The latter four were reported to have better diagnostic function than simple FE Na^+ or FE Mg^{2+}[9]. However, their use may not be available in all laboratories.

Previous studies assessing renal function were conducted in older children or adults and especially in those having cyanotic CHD[1-3]. Therefore, data of renal dysfunction in younger children and adolescents in acyanotic CHD were limited. The present study assessed the prevalence of overall renal dysfunction (determination of glomerular filtration rate) and glomerular (measurement of urinary microalbumin and protein) as well as tubular dysfunction (measurement of FE Na^+, FE Mg^{2+}, and urine NAG/creatinine) in young children and adolescents with cyanotic and acyanotic CHD. The biochemical markers between the patients with the two types of CHD were compared. The correlation between clinical factors, urinary glomerular, and tubular markers for renal injury was also determined.

Material and Method

This cross-sectional analytic study was approved by the Institutional Review Boards of the three participating institutions: Faculty of Medicine Vajira Hospital, College of Medicine Pramongkutklao Hospital, and Faculty of Medicine Ramathibodi Hospital. The present study was conducted in children and adolescents with CHD who were admitted in each hospital between March 1, 2011 and January 31, 2012. Eligibility criteria were patients aged 1 to 18 years old, had CHD, and had not taken diuretics 12 hours prior to enrollment. The CHD may be either cyanotic or non-cyanotic types. Exclusion criteria were the patients who had diabetes mellitus, history of renal disease, use of the following medication within the past five days prior to enrollment: allopurinol, corticosteroid, aminoglycosides, vancomycin, penicillin, received contrast media within the past 48 hours, or has current urinary tract infection. Patients who had undergone complete surgical correction of their heart disease were also excluded. All participants gave informed consent prior to entering into the present study.

Procedures

A review of systems, history taking, and physical examination were conducted in each participant before the blood and urinary tests. The tests comprised of CBC and blood chemistry including serum BUN, creatinine, sodium, and magnesium. Urinary creatinine, sodium, and magnesium were also determined. Approximately 20 cc of urine was collected and divided into two separated containers. The first containers were frozen at -70 degree Celsius and subsequently sent for NAG analysis at Biochemistry Department of Chulalongkorn University. The second containers were sent to Clinical Chemistry section, Department of Clinical Pathology, Faculty of Medicine Vajira hospital for quantitative analysis of microalbumin, protein, sodium, magnesium, and creatinine. Assay techniques used for biochemical markers were as the following: serum creatinine by Jaffe method[10]; microalbumin by immunoturbidimetric technique[11]; protein by pyrogallol assay[12], NAG by colorimetric assay[13], urine sodium by ion-selective method[14], urine magnesium by photometric color test[15].

Data collected were age, body weight, and height, blood pressure on admission, oxygen saturation, and functional class. Laboratory data determined were CBC, blood chemistry including serum BUN, creatinine, sodium, and magnesium. Urinary creatinine, sodium, and magnesium were also measured. The other renal markers were determined as the following.

Estimated glomerular filtration rate (eGFR) was calculated from Schwartz formula[16] as follows:

$$GFR = \frac{\text{Height (cm)} \times \text{constant (K)}}{\text{Serum creatinine}}$$

(K values: children and adolescent girls = 0.55; adolescent boys = 0.7)

Renal dysfunction[16] was defined when eGFR < 90 ml/min/1.73 m^2 and was classified as mild when eGFR = 60-89 ml/min/1.73 m^2, moderate when eGFR = 30-59 ml/min/1.73 m^2, and severe when eGFR = 15-29 ml/min/1.73 m^2. Glomerular dysfunction was defined if spot urine protein/urine creatinine ratio > 0.2 in children older than two years old and > 0.5 in children 6 to 24 months old[16], or spot urine micro-albumin/urine creatinine > 30 milligram/milligram creatinine[16]. Tubular dysfunction was defined when

urine NAG/urine creatinine > 5.2 unit/gram creatinine[17] or FE Mg^{2+} > 2.2%[18], or FE Na^{+} > 1%. FE Mg^{2+} and FE Na^{+} were obtained from the following formulas:

$$FE\ Mg^{2+} = \frac{\text{Urine Magnesium x Plasma creatinine}}{\text{0.7 x Plasma Magnesium x Urine creatinine}} \times 100$$

$$FE\ Na^{+} = \frac{\text{Urine sodium x Plasma creatinine}}{\text{Plasma sodium x Urine creatinine}} \times 100$$

Statistical analysis

Results were carried out using SPSS version 13.0 statistical package. Data were presented as mean ± SD for those with normal distribution and median (min-max) for non-normal distribution. Comparisons between groups were performed using independent t-test for parametric data whereas the nonparametric data were analyzed by Mann-Whitney U test. Categorical data were compared by Chi-square test or Fisher's exact test for non-parametric data. Correlation coefficients among clinical factors (age, Hb, O_2 saturation), tubular urinary markers (urine NAG/creatinine, FE Mg^{2+}, FE Na^{+}), and glomerular urinary markers (urine protein/creatinine, urine microalbumin/creatinine) were analyzed by Spearman's rho correlation. Correlation coefficient (r) 0.7 to 0.9 was defined as high correlation, 0.5 to 0.7 as moderate correlation, and 0.3 to 0.5 as low correlation[19]. P-value of < 0.05 was regarded as significant.

Results

Forty-six patients with CHD were enrolled into the present study. Group 1 comprised of 15 cyanotic CHD while group 2 were 31 acyanotic CHD patients. There were no statistically significant differences between the two groups regarding age, bodyweight, height, diastolic blood pressure, BUN, serum creatinine, estimated glomerular filtration rate, spot urine microalbumin/creatinine, and FE Na^{+} (Table 1, 2).

The present study found statistically significant differences in three biochemical markers between group 1 and group 2: 3.59 (0-32) vs. 1.64 (0-29.3) unit/gram creatinine for urine NAG/creatinine (p = 0.008); 5.03 ± 3.61% vs. 2.48 ± 1.8% for FE Mg^{2+} (p = 0.019); and 0.16 (0.075-10.78) vs. 0.08 (0.02-0.5) for urine protein/creatinine (p = 0.001). No significant differences of FE Na^{+} and urine microalbumin/creatinine between the two groups were found: 0.86 ± 0.75% vs. 0.92 ± 0.63% (p = 0.780) and 20.6 (0.22-5,102.75) vs. 10.45 (1.4-206.25) milligram/gram (p = 0.073), respectively. The comparison of these markers is shown in Table 2.

Significantly higher prevalence of abnormal biochemical markers in group 1 compared to those of group 2: 86.6% vs. 43.38% (p = 0.02) for abnormal FE Mg^{2+}, 46.6% vs. 9.67% (p = 0.008) for abnormal urine NAG/cr, 46.6% vs. 6.45% (p = 0.003) for significant proteinuria, and 40% and 9.67% (p = 0.042)

Table 1. Summary of demographic and baseline data of two groups

	Cyanotic CHD (n = 15)	Acyanotic CHD (n = 31)	p-value
Age (years)	9.33 ± 5.56	7.00 ± 3.50	0.153
Body weight (kg)	25.50 ± 15.37	21.70 ± 8.54	0.387
Height (cm)	119.80 ± 27.00	116.90 ± 18.40	0.666
Systolic blood pressure (mmHg)	94.70 ± 9.97	106.90 ± 16.31	0.011*
Diastolic blood pressure (mmHg)	58.87 ± 10.46	57.35 ± 10.10	0.640
Hemoglobin (g/dl)	17.88 ± 4.43	12.01 ± 1.23	0.000*
Oxygen saturation (%)	77.00 ± 11.73	97.00 ± 2.32	0.000*
Cardiac surgery (palliative)	9 (60)	4 (12.9)	0.001**
BUN (mg/dl)	16.58 ± 11.50	11.81 ± 3.10	0.135
Serum creatinine (mg/dl)	0.68 ± 0.32	0.61 ± 0.18	0.363
Functional class			
Class I	2 (13.3)	30 (96.77)	0.000**
Class II	9 (60)	1 (3.22)	
Class III	3 (20)	0	
Class IV	1 (6.66)	0	

Data presented are mean ± SD or number (%)

* p-value < 0.05 using independent t-test, ** p-value < 0.05 using Fisher's exact test

for microalbuminuria, respectively. The prevalence of abnormal FE Na^+ and eGFR between the two groups were not significantly different: 40% in group 1 vs. 38.71% in group 2 (p = 0.585) and 20% vs. 22.5% (p = 0.503), respectively. The comparison of these markers is shown in Table 3.

Regarding the correlation of hemoglobin and other factors, the authors found moderate correlation between hemoglobin and functional class of the patients (r = 0.58). The comparisons among other clinical or biochemical makers showed only low correlations. For oxygen saturation, only the correlation between oxygen saturation and functional class was highly negative correlated (r = -0.716). The other correlations were only low negative. For urine NAG/creatinine, we found only low correlation between urine NAG/creatinine and urine protein/creatinine (r = 0.375) and functional class of the patients (r = 0.395). Table 4 shows correlation of these clinical and biochemical markers.

Discussion

With emerging technologies of therapeutic intervention for CHD in children, these patients can have a long life span. Any long-term complications from CHD should be prevented or well attended to minimize the severity. Regarding an impairment of renal function in CHD, a detection of early renal dysfunction is important. The patient's renal reserve function will be useful for the physicians to be cautious especially when a use of any nephrotoxic agents is considered. For the patients who already have glomerular or tubular dysfunction, they should be closely followed up and be monitored regularly. Intervention by medication and education the patients to avoid nephrotoxic substances would slow progression of renal deterioration.

The present study demonstrated both glomerular and tubular dysfunctions among children and adolescents aged 1 to 18 years old who had cyanotic (group 1) and acyanotic CHD (group 2).

Table 2. Biochemical data of cyanotic and acyanotic congenital heart disease

	Cyanotic CHD (n = 15)	Acyanotic CHD (n = 31)	p-value
Estimated GFR (ml/min/1.73 m^2)	117.04 ± 37.18	113.98 ± 34.05	0.783
Fractional excretion of sodium (%)	0.86 ± 0.75	0.92 ± 0.63	0.780
Fractional excretion of magnesium (%)	5.03 ± 3.61	2.48 ± 1.8	0.019*
U NAG/creatinine (unit/gram creatinine)	3.59 (0-32)	1.64 (0-29.3)	0.008**
Urine protein/creatinine	0.16 (0.075-10.78)	0.08 (0.02- 0.5)	0.001**
Urine microalbumin/creatinine (microgram/milligram)	20.60 (0.22-5,102.75)	10.45 (1.4-206.25)	0.073

Data presented are mean ± SD or median (min-max)
* p-value < 0.05 using independent t-test, ** p-value < 0.05 using Mann-Whitney U test

Table 3. Prevalence of glomerular and tubular dysfunction

	Cyanotic CHD (n = 15)	Acyanotic CHD (n = 31)	p-value
Estimated GFR (ml/min/1.73 m^2)			
Normal (GFR > 90)	11 (73.33)	24 (77.4)	0.503
Mild decrease(GFR 60-89)	3 (20)	7 (22.5)	
Moderate decrease (GFR 30-59)	1 (6.66)	0	
Urine protein/creatinine (> 0.2)	7 (46.6)	2 (6.45)	0.003*
Urine microalbumin/creatinine (> 30 microgram/milligram)	6 (40)	3 (9.67)	0.042*
U NAG/creatinine (> 5.2 unit/gram creatinine)	7 (46.6)	3 (9.67)	0.008*
Fractional excretion of sodium (> 1%)	6 (40)	12 (38.71)	0.585
Fractional excretion of magnesium (> 2.2%)	13 (86.6)	15 (48.38)	0.020*

Data presented are number (%)
* p-value < 0.05 using Chi-square test and Fisher's exact test

Table 4. Correlation coefficient (r) between age, oxygen saturation, hemoglobin, urine glomerular and tubular marker in congenital heart disease

	Age (y)	Oxygen sat (%)	Functional class	Hb (g/dl)	eGFR	Tubular function			Glomerular function	
						FE Na^+ > 1 (%)	FE Mg^{2+} > 2.2 (%)	Urine NAG/cr > 5.2 U/gram cr	Urine protein/cr > 0.2	Urine microalbumin/cr > 30 µg/mg
Age (y)	1	-0.167	0.367**	0.499**	0.065	0.167	0.10	0.037	0.239	0.295*
Oxygen saturation (%)	-0.167	1	-0.716**	-0.448**	-0.064	0.007	-0.334*	-0.354**	-0.475**	-0.436**
Functional class	0.367**	-0.716**	1	0.580**	0.176	0.026	0.34*	0.395*	0.474**	0.285
Hb (g/dl)	0.499**	-0.448**	0.580**	1	0.019	0.148	0.347**	0.138	0.366*	0.305*
FE Na^+ (> 1%)	0.167	0.007	0.026	0.148	0.020	1	0.308**	-0.042	0.141	-0.032
FE Mg^{2+} (> 2.2%)	0.100	-0.334	0.340*	0.347**	-0.109	0.308**	1	0.255	0.373*	0.095
Urine NAG/cr	0.037	-0.354**	0.395*	0.138	0.184	-0.042	0.255	1	0.375*	0.273
Urine protein/cr	0.239	-0.475**	0.474**	0.366*	0.135	0.141	0.373*	0.375*	1	0.484**
Urine microalbumin/cr	0.295*	-0.436**	0.285	0.305*	0.022	0.022	0.095	0.273	0.484**	1
eGFR	0.065	-0.064	0.176	0.019	1	0.020	-0.109	0.184	0.135	0.022

Hb = hemoglobin; FE Na = fractional excretion of sodium; FE Mg = fractional excretion of magnesium; NAG/cr = N-acetyl-β-D-glucosaminidase)/creatinine; eGFR = estimated glomerular filtration rate

* Correlation is significant at the 0.05 level, ** Correlation is significant at the 0.01 level

Several previous studies in cyanotic CHD included children with older age than the present study[2,20]. Although the present study could not demonstrate significant difference of mild renal dysfunction between the two groups, group 2 patients tended to have more degree of renal dysfunction. This was evidenced by higher prevalence of decrease eGFR in group 2 than that of group 1 was found (p = 0.503) together with higher mean eGFR in group 1 (p = 0.783). This could have been caused by mean age and height of group 1 were older and higher than group 2: 2 years older and 2.9 cm taller, respectively. These certainly affected to the eGFR (obtained by Schwartz formula) which were based partly on age and height. The confounding effect of age and height on renal function was found in another study by Agras et al[21]. Their study found that renal dysfunction of their children with cyanotic CHD was worse than the acyanotic group. Their patients in the cyanotic group had younger age and shorter than those of the other group. We do not know the actual difference of renal dysfunction between cyanotic vs. acyanotic CHD. Hence, the eGFR should not be a single tool to assess renal function until these confounding factors are well controlled in a future randomized control trial or a well designed prospective study with balanced characteristic features of the participants.

Regarding renal tubular function, the present study enrolled patients who had stopped diuretics at least 12 hours prior to entering into the present study to prevent its effect on the levels of FE Na^+ and FE Mg^2. The authors found significantly more tubular dysfunction of the patients in group 1 than that of group 2. This was evidenced by higher prevalence and higher mean level of abnormal FE Mg^{2+} (p = 0.020 and 0.019, respectively) and of urine NAG/cr (p = 0.008, both). Unfortunately, the authors could not find significant difference of abnormal FE Na^+ of the two groups (p = 0.585 for prevalence and p = 0.780 for mean level). The authors do not know whether the actual difference between the two groups existed or the other factors *e.g.* salty diet and volume status may have influenced on its value.

For glomerular function, the present study found more glomerular dysfunction in group 1 than group 2. This was evidenced from statistically significant higher prevalence and mean level of significant proteinuria (p = 0.003 and p = 0.001, respectively) and marginally or nearly significance microalbuminuria (p = 0.042 and p = 0.073, respectively). Agras et al[21]. also found more frequent microalbuminuria

(17% vs. 10%) and higher level of microalbuminuria (0.28 g/mol vs. 0.17 g/mol) in cyanotic than that of acyanotic patients. However, the differences were not statistically significant. They proposed that because their cyanotic patients had young age (mean 2.2 years) hence, the glomerular dysfunction was not clearly evidenced clinically due to the short term of pathologic changes especially chronic hypoxia. This proposal was supported by the present study wherein the mean age of cyanotic patients was 9 years old or long enough for the patient to have chronic hypoxia and glomerular damage to be clinically evidenced. One clinicopathological study by Inatomi et al[22] compared gloemerular histomorphologic changes of cyanotic CHD with or without proteinuria. They found larger glomerular size and more glomerular capillary in patients with significant proteinuria than those without proteinuria.

For acyanotic CHD, the mechanisms of renal dysfunction is unknown due to very few available studies focusing in this particular group of patients. Further study should be done to evaluate risk factors of renal dysfunction in acyanotic CHD.

In studying the correlation of these biochemical makers with other clinical factors or with other biochemical makers, the present study found only low correlations of all biochemical makers studied with other biochemical makers or with other clinical factors. To emphasize on the low correlation between tubular function (FE Mg^{2+} and urine NAG/creatinine) and glomerular function (urine protein/creatinine), the physician could not assume that normal or abnormal levels of glomerular markers would reflect to the status of tubular markers. Nevertheless, FE Mg^{2+} and urine NAG/creatinine appeared to have some correlation with urine protein/creatinine while FE Na^{+} did not show any correlation. Hence, the two markers might be of some clinical use. FE Mg^{2+} was probably the more appropriate test than urine NAG/creatinine because it is more readily available in a general laboratory.

Only hemoglobin and functional class of the patients were moderately correlated. This relationship has been well recognized clinically. Unfortunately, the present study found only low correlation between hemoglobin and proteinuria. Previous study by Dittrich and colleagues[23] found a high correlation between these two factors in an adult with cyanotic CHD. They postulated the hyperviscosity inducing a decrease in peritubular capillary blood flow, which will lead to an increase in glomerular capillary pressure with an ultimate result of proteinuria. Older age and long standing cyanotic CHD of their population with chronic hypoxia may accentuate their abnormal glomerular dysfunction. The present study found highly negative correlation between oxygen saturation and functional class. This relationship has also been well recognized clinically.

In conclusion, the prevalence of glomerular and tubular dysfunction in cyanotic congenital heart disease was higher than acyanotic CHD. The screening of tubular function by using FE Mg^{2+} was more practical than urine NAG/creatinine, and the two markers did better than FE Na^{+} to detect early tubular dysfunction. For glomerular function screening, spot urine protein/creatinine and urine microalbumin/creatinine can detect pathological proteinuria.

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การศึกษาเปรียบเทียบการทำงานของไตระหว่างโรคหัวใจแต่กำเนิดชนิดเขียวและไม่เขียวในผู้ป่วยเด็กและวัยรุ่น

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ภูมิหลัง: ความผิดปกติในการทำงานของไตทั้ง การทำงานของหน่วยกรองไต (glomerular function) และการทำงานของท่อไตที่ผิดปกติ สามารถพบได้ในผู้ป่วยโรคหัวใจแต่กำเนิด โดยเฉพาะในผู้ป่วยเด็กโตและผู้ใหญ่ที่เป็นโรคหัวใจแต่กำเนิดชนิดเขียว

วัตถุประสงค์: เพื่อประเมินการทำงานของหน่วยกรองไต (glomerular function) และการทำงานของท่อไต เปรียบเทียบความชุกของการพบความผิดปกติในการทำงานของไตระหว่างผู้ป่วยโรคหัวใจแต่กำเนิดชนิดเขียวและไม่เขียวในเด็กและวัยรุ่น และประเมินความสัมพันธ์ระหว่าง ปัจจัยทางคลินิก glomerular marker กับ tubular marker ในปัสสาวะในผู้ป่วยเด็กและวัยรุ่นที่เป็นโรคหัวใจแต่กำเนิด

วัสดุและวิธีการ: ประเมินการทำงานของไตโดยคำนวณค่า estimated glomerular filtration rate (eGFR), urine protein/creatinine, urine microalbumin/creatinine, fractional excretion of sodium (FE Na^{+}), fractional excretion of magnesium (FE Mg^{2+}) และ urine NAG (N-acetyl-β-D-glucosaminidase)/creatinine ในผู้ป่วยเด็กและวัยรุ่นที่เป็นโรคหัวใจแต่กำเนิด

ผลการศึกษา: ผู้ป่วยจำนวน 46 ราย ประกอบด้วยผู้ป่วยโรคหัวใจแต่กำเนิดชนิดเขียว 15 ราย (กลุ่ม 1) ผู้ป่วยโรคหัวใจแต่กำเนิดชนิดไม่เขียว 31 ราย (กลุ่ม 2) พบเฉพาะความแตกต่างอย่างมีนัยสำคัญทางสถิติของค่า Urine NAG/creatinine (median, 3.59 และ 1.64 U/gram creatinine; $p = 0.008$), FE Mg^{2+} (mean, 5.03 ± 3.61% และ 2.48 ± 1.8%; $p = 0.019$), urine protein/creatinine (median, 0.16 และ 0.08; $p = 0.001$) ระหว่างผู้ป่วย 2 กลุ่ม ไม่พบความแตกต่างกันอย่างมีนัยสำคัญทางสถิติในลักษณะทางคลินิก, BUN, creatinine, eGFR, ค่าเฉลี่ยของ FE Na^{+} และ urine microalbumin/creatinine ระหว่างผู้ป่วย 2 กลุ่ม ความชุกของความผิดปกติในสารบ่งชี้ทางชีวเคมีในกลุ่ม 1 เมื่อเทียบกับกลุ่ม 2 พบว่าสูงกว่าอย่างมีนัยสำคัญทางสถิติ ดังนี้: ความผิดปกติของ FE Mg^{2+}: 86.6% และ 43.38% ($p = 0.02$), urine NAG/creatinine: 46.6% และ 9.67% ($p = 0.008$), significant proteinuria: 46.6% และ 6.45% ($p = 0.003$), microalbuminuria: 40% และ 9.67% ($p = 0.042$) ตามลำดับ ผู้นิพนธ์พบมีความสัมพันธ์ระดับปานกลางระหว่าง hemoglobin กับ functional class โดยมีค่าสัมประสิทธิ์ของความสัมพันธ์ ($r = 0.58$) และพบมีความสัมพันธ์แบบผกผันระดับสูงระหว่าง oxygen saturation กับ functional class ($r = -0.716$) พบมีความสัมพันธ์ระดับต่ำระหว่างปัจจัยทางคลินิกกับสารบ่งชี้ทางชีวเคมีอื่น ๆ

สรุป: โรคหัวใจแต่กำเนิดชนิดเขียวมีความชุกและค่าความผิดปกติของสารบ่งชี้ทางชีวเคมี ที่แสดงถึงความผิดปกติในการทำงานของไตมากกว่าโรคหัวใจแต่กำเนิดชนิดไม่เขียว ค่าเฉลี่ยของ urine protein/creatinine, FE Mg^{2+} และ Urine NAG/creatinine ในโรคหัวใจแต่กำเนิดชนิดเขียวมากกว่าชนิดไม่เขียว พบมีความสัมพันธ์ในระดับต่ำระหว่างสารบ่งชี้ทางชีวเคมี