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Comparison of Blood Gas Analysis on Hemodialysis in Patients with Chronic Kidney Diseases

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ABSTRACT

Chronic Kidney Disease (CKD) is defined as a renal failure that has lasted for more than three months. Hemodialysis is the type of kidney replacement therapy that is mostly used, and blood gas analysis can be used to identify this condition. This study is to compare the blood gas analysis on pre-and post-dialysis in patients with CKD using pH, $PaCO_2$, PaO_2, HCO_3, SO_2, and BE as markers of improvement in the patients'condition. The population was all patients diagnosed with CKD and hemodialysis at Wahidin Sudirohusodo Hospital, and eligible according to the criteria in this study. The sample size was determined using Federer's calculation, and the statistical analysis using paired T-test and Wilcoxon signed-rank test with α=0.05. Subjects were 34 patients, consisting of 18 females (52.9%) and 16 males (47.1%). Hemodialysis had the most significant impact on the PaO_2 and SaO_2 variables. Relation between PaO_2 and SaO_2 was illustrated in a sigmoid curve. Oxygen-bound hemoglobin increased after the first molecule was bound. An almost full PaO_2 pressure will cause a slight increase in SaO_2. Whereas at <90% saturation, a slight decrease in PaO_2 will cause a large decrease in SaO_2. PaO_2 and SaO_2 determine cardiac efficiency and the markers for assessing the metabolic conditions of the lungs and heart that correlate with oxygen. Chronic kidney disease patients experienced improved conditions after undergoing hemodialysis with increased blood gas values, especially in PaO_2 and SaO_2.

Keywords: Chronic kidney disease, hemodialysis, blood gas analysis, PaO_2, SaO_2

INTRODUCTION

Chronic Kidney Disease (CKD) is defined as kidney damage lasting for more than three months, consisting of both structural or functional damage, with or without a decrease in Glomerular Filtration Rate (GFR). Pathological clinical manifestations are a sign of kidney damage, consisting of a difference in blood composition, urine sediment, a change discovered by imaging, and a decrease in GFR of <60 mL/minutes/1.73m^2 for more than 3 months with or without kidney damage.[1]

Chronic kidney disease is a worldwide health problem. In 2017 the number of patients with CKD was 9.1% of the world population (697.5 million cases), and almost one-third of the cases were from China and India. Chronic kidney disease can become End-Stage Renal Disease (ESRD) and can increase the risk of cardiovascular disease that can cause early death. The end-stage renal disease does not only affect the kidney but can also affect multiple organs.[2,3]

In patients with CKD, hemodialysis is the most used renal replacement therapy, due to its' contribution to an increase in the patients' livelihood. Not using renal replacement therapy can cause a decrease in kidney function and can decrease the patients' quality of life.[4,5] The indications for initiating dialysis have been divided into two broad categories: absolute and relative indications. Absolute indications that are generally agreed on include the presence of uremic pericarditis, uremic encephalopathy, intractable fluid overload, and/or electrolyte abnormalities that cannot be managed without dialysis. Relative indications include the presence of a constellation of symptoms that are attributable to advanced renal failure.[6] Hemodialysis can cause an accumulation of interdialytic acid, complications related to chronic acidosis, and sometimes even death.[7] Examining the Blood Gas Analysis (BGA) before and after hemodialysis is one way to predict these conditions.

Blood gas analysis measures the oxygen and carbon dioxide inside the blood; the acidity (pH) of the blood; and find out whether the problem comes from the respiratory system, blood flow, and/or kidney metabolism. The components of BGA are pH, PaO_2, $PaCO_2$, HCO_3, Base Excess (BE), and oxygen saturation (SaO_2).[8]

The serum pH is an indicator of acid-base balance in hemodialysis patients. This is caused due to the decrease of ammonia and hydrogen ions in the tubules and the sodium loss accompanied by the retention of bound acid (phosphate and sulfate) and organic acids by the glomerulus, in patients with kidney disease. The normal value for serum pH is 7.35–7.45. PaO_2 depicts partial pressure that is produced by oxygen that is saturated in the plasma. This value shows the capability of the lungs to give blood oxygen with the normal value of 75–100 mmHg. $PaCO_2$ is the pressure given by saturated CO2 in the plasma, that can determine the effectivity of ventilation in a normal acid-base environment with the normal value of 35–45 mmHg. HCO_3- portrays the concentration of CO_2 in normal plasma (95% of total CO_2 is in the form of bicarbonate ions, 5% as saturated CO_2 and carbonate acid) with the normal value of 22–26 mmol/L. O_2 saturation is the number of oxygen that is transported by hemoglobin, as the percentage of total oxygen bound to hemoglobin with the normal value of 95–99%. Base Excess (BE) is the most practical way to find out the metabolic acid-base damage is, by in-vitro titration of the blood sample with a strong base/acid to return the normal pH levels (pH 7.4) with a normal BE of -2 till 2 mEq/L. Blood gas analysis in patients with CKD undergoing hemodialysis, PO_2, PCO_2 and BE show the capability of the body in compensating the decrease of serum pH due to kidney damage. Disturbance in acid-base stability can cause complications in many diseases and can be a risk factor that is harmful to the body.[9,10]

Studies have analyzed the relationship between blood gas analysis and hemodialysis in patients with CKD. A study by Tadashi *et al*. about the correlation of pH and bicarbonate examination before and after hemodialysis and cardiovascular cause of death. pH is related to the significant increase of the cause of death due to cardiovascular changes, pH before hemodialysis can be a reference for correcting metabolic acidosis.[11] This study doesn't explain the difference in acid-base parameters. Subjects in this study are patients with cardiovascular damages. Javier *et al*. studied acid-base disturbances in acute hemodialysis patients in plateaus. Blood gas examinations were done before and after hemodialysis in CKD patients who had a difference in pH, $PaCO_2$, HCO_3, and SO_2, while the PaO_2 was relatively the same. These study limitations are that the HCO_3 value might not correlate with pH and $PaCO_2$ values, and there are still a minimal number of studies about acid-base damages in hemodialysis patients.[12]

METHODS

This was a cross-sectional study, that used the medical record data of patients from Wahidin Sudirohusodo Hospital in the January 2018–August 2020 period. The population was all data of patients that were diagnosed with CKD and had hemodialysis who fulfilled the inclusion and exclusion criteria. The inclusion criteria for subjects in this study are a CKD patient that is treated (Inpatient or Outpatient), underwent BGA examinations before and after hemodialysis. The exclusion criteria were if the patients' data couldn't be accessed during the period of collecting data.

The number of minimal samples in this study used the Federer equation and had a minimal of 15 samples. The variables that were measured are as follows pH, $PaCO_2$, PaO_2, SaO_2, HCO_3, and BE. All variables in this study had a ratio scale, where the base value was zero, and couldn't be changed. Data collected were analyzed to see the percentage of acid-base disturbances in hemodialysis patients. This study compared the results of BGA before and after hemodialysis using pH, $PaCO_2$, PaO_2, HCO_3, SO_2, and BE as parameters. Statistical analysis used was the paired T-test and Wilcoxon signed-rank test with a $p<0.05$ to be considered statistically significant.

RESULTS AND DISCUSSIONS

From 34 patients whose data fulfilled the inclusion criteria, there were 18 (52.9%) female patients with a mean age of 51 years old, and 13 (47.1%) male patients with a mean age of 46 years old. In Table 1, mean pH before and after hemodialysis were 7.41 (7.38–7.45) and 7.43 (7.39–7.46), this value had an increase but was insignificant statistically, this also happened to $PaCO_2$, HCO_3, and BE. A statistically significant difference before and after hemodialysis was found for PaO2 and SaO2 ($p < 0.01$). Studies by Tadashi *et al*. showed that the pH and bicarbonate levels before and after hemodialysis were correlated to cardiovascular death. pH was correlated with a significant increase in the risk of death due to cardiovascular damage, pH before hemodialysis can be a reference for metabolic acidosis correction.[11] The difference in the study mentioned was, the subjects were patients with cardiovascular disease. Javier *et al*. did a study on acid-base disturbances in acute hemodialysis patients on high land. Blood gas analysis was done before and after hemodialysis in CKD patients who had differences in pH, $PaCO_2$, HCO_3, and SO_2, whereas the PaO_2 was relatively the same. The study had its limitations were HCO_3 might not be correlated with the pH and $PaCO_2$ levels, there was also a minimum amount of study on acid-base disorders of hemodialysis patients.[12]

Interpretation of the acid-base disorders examination was done by the bedside approach, this method helps determine the main cause of acid-base disturbances and whether there was compensation or not. The first step of this method was to see the pH value and assess if there was acidemia (pH < 7.3) or alkalemia (pH > 4.5). If the pH is within normal limits (7.35–7.45), pH 7.4 was used as the determining factor. A pH of 7.35 would be categorized as acidosis and a pH of 7.42 would be deemed alkalosis. After that, the respiratory and metabolic component must be evaluated by both $PaCO_2$ and HCO_3 from the BGA. $PaCO_2$ showed whether the alkalosis or acidosis was from respiratory or metabolic changes. $PaCO_2$ > 40 with a pH <7.4 showed a respiratory acidosis while a $PaCO_2$ < 40 and pH < 7.4 showed a respiratory alkalosis (but this is usually caused by hyperventilation due to anxiety or compensation of metabolic acidosis). After that proof of compensation must be found for primary acidosis or alkalosis by finding the value ($PaCO^2$ or HCO_3) that was not consistent with the pH. PaO_2 was the last variable to be assessed, to see if there was a problem in oxygenation.[13] The interpretation of an acid-base disorder using the method mentioned in 34 patients with CKD before hemodialysis showed 11 (32.35%) experiencing simple disorders; 16 (47.05%) had compensation disorders; 4 (11.76%) had mixed disorders and 3 (8.82%) had normal results. The most common type of disorder of the patients was respiratory alkalosis and totally compensated metabolic acidosis (Table 2).

Blood gas analysis results after hemodialysis showed 11 (32.35%) patients with simple acid-base disorders, 21 (61.76%) had compensated disorders and 2 (5.88%) had normal results. The most common acid-base disorder was partially compensated

Table 1. Blood gas analysis before and after hemodialysis

Parameter	Pre-Hemodialysis		Post-Hemodialysis		T-values	p-value
	Mean±SD	Inter-quartile	Mean±SD	Inter-quartile		
pH	7.41±0.10	7.38–7.45	7.43±0.10	7.39–7.46	-0.812	0.417[a]
$PaCO_2$	30.88±8.68	27.85–33.91	33.64±10.94	29.83–37.46	-1.616	0.106[a]
PaO_2	94.69±34.55	82.63–106,75	13.22±46.76	118,90–151,54	-4.275	<0.001[a]*
SaO_2	95.93±2.15	95.18–96.68	97.67±2.88	96.67–98.68	-3.274	<0.001[a]*
HCO_3	20.47±6.73	18.12–22.82	21.93±5.55	19.98–23.86	-1.549	0.131[b]
BE	-4.20±7.76	-6.91 – -1.49	-2.67±6.05	-4.78 – -0.55	-1.388	0.175[b]

a Using Wilcoxon signed-rank test
a* Significantly different (p<0.05)
b Used paired T-test
* The results of the T-test < T-value from the table, which was 1,71387

Table 2. Distribution of acid-base disorder interpretation in patients with CKD before hemodialysis

Acid-Base Disorder	Number of Patients	Percentage (%)
Metabolic acidosis	2	5.88
Partially compensated metabolic acidosis	2	5.88
Total compensated metabolic acidosis	6	17.65
Acidosis (metabolic and respiratory)	1	2.94
Metabolic alkalosis	3	8.82
Respiratory alkalosis	6	17.65
Partially compensated respiratory alkalosis	4	11.76
Completely compensated respiratory alkalosis	4	11.76
alkalosis (respiratory and metabolic	3	8.82
within normal limits)	3	8.82
Total	**34**	**100%**

Table 3. Distribution of acid-base disorder interpretation in patients with CKD after hemodialysis

Acid-Base Disorder	Number of Patients	Percentage (%)
Metabolic acidosis	2	5.88
Partially compensated metabolic acidosis	2	5.88
Complete compensated metabolic acidosis	3	8.82
Respiratory acidosis	1	2.94
Partially compensated respiratory	2	5.88
Completely compensated respiratory acidosis	1	2.94
Metabolic alkalosis	4	11.76
Completely compensated metabolic alkalosis	1	2.94
Respiratory alkalosis	4	11.76
Partially compensated respiratory alkalosis	9	26.47
Completely compensated respiratory alkalosis	3	8.82
Within normal limits	2	5.88
Total	**34**	**100%**

respiratory alkalosis, metabolic alkalosis, and respiratory alkalosis (Table 3).

This study did not find any significant differences before and after hemodialysis, in all parameters of the BGA. Significant differences were only found in PaO_2 and SaO_2 (oxygen saturation) ($p<0.01$). According to Camnos *et al.*, this might be due to the increase of blood oxygen-carrying capacity during hemodialysis.[14] The results of this study were in line with Sombolos, stating that there was an increase of PaO_2 before and after hemodialysis where the sample obtained from the vein increased from 86.8 mmHg into 88.8 mmHg.[15] In 1611 patients studied by Zhang there was also an increase in SaO_2 patients undergoing hemodialysis from a mean of 92.4% into 93%, which was also in line with this study.[16]

The most common acid-base disorder before hemodialysis in this study was respiratory alkalosis and completely compensated metabolic acidosis. This is in concordance with a study by Ghatak that states that the most interpreted acid-base disorder from BGA with a bedside approach method was respiratory alkalosis and metabolic acidosis.[2] Marano *et al*. did a study on pH, PCO_2, and HCO_3 in patients before hemodialysis that showed from 362 samples, most suffered from metabolic acidosis, alkalosis and a mix of metabolic acidosis, and respiratory alkalosis.[17]

Acid-base disorders found after hemodialysis were as follows 13 (38.24%) had simple disorders and 21 (61.76%) had mixed disorders. The most common disorder was partially compensated respiratory alkalosis, metabolic alkalosis, and respiratory alkalosis. This was different with Javier *et al.*, where most acid-base disorders following hemodialysis were metabolic alkalosis and mixed metabolic and respiratory alkalosis.[1]

Respiratory alkalosis before hemodialysis did not change significantly after hemodialysis, because they became partially compensated respiratory alkalosis, respiratory alkalosis, and metabolic alkalosis. Other acid-base disturbances that occur before hemodialysis such as compensated metabolic acidosis have a significant difference after hemodialysis become partial respiratory alkalosis, respiratory alkalosis and metabolic alkalosis, this may happen due to the reduction of acid, causing the blood to be less acid (base) and an increase in HCO_3, in concordance to the explanation by Oian where the production of acid in CKD patients that undergo hemodialysis is less compared to before hemodialysis, the author also found that HCO_3 in the serum increased from 23.6 mEq/L before hemodialysis into 27.8 mEq/L after hemodialysis. The CO_2 pressure ($PaCO_2$) also increased from a baseline under 39 mmHg before hemodialysis into 41.9 mmHg following hemodialysis.[18]

Madan state that the correlation between PaO_2 and SaO_2 have a nonlinear relationship (oxygen disassociation curve). In low oxygen pressure, there is a relatively small increase of SaO_2, PaO_2 above 20 mmHg, the flow of SaO_2 increases sharply, and lessens after reaching 60 mmHg. In certain situations when the PaO_2 is over 90 mmHg, the increase of SaO_2 is almost flat, and only increases a little even though the PaO_2 increases. PaO_2 is the determinant of SaO_2 that is the most important (but not the only one). SaO_2 determinant for certain PaO_2 is a condition that can shift the oxygen disassociation curve to the left or right, like temperature, pH, $PaCO_2$, and the 2.3-DPG in blood.[19]

The results of this study were relatively the same as the main reference by Javier et al., showing an increase in pH, $PaCO_2$, PaO_2, BE, and SO_2 only after hemodialysis. One variable was different, HCO_3, where in the previous study decreased after hemodialysis, while in this study is increased. This difference might be due to the condition of the bicarbonate solution and sodium in the hemodialysis equipment Nipro Surdial 55 plus, while in Javier's study the bicarbonate, Potassium, Chloride, Calcium, Magnesium and Acetic Acid solution with the Gambro Phoenix instrument, the condition of the height can also be a factor that affects the BGA results after hemodialysis.[12]

The limitation to this study is the number of samples that were not adequate due to the inability to obtain several medical records, there was also no standardization of the time BGA was evaluated before and after hemodialysis, and the duration of CKD was also not included.

CONCLUSIONS AND SUGGESTIONS

Patients with CKD that have had hemodialysis show an elevation in pH, PCO_2, PO_2. HCO_3-, SaO_2, and BE were obtained from a blood gas analysis. Hemodialysis gives a significant impact on PaO_2 and SaO_2 values. Further studies should include more specific variables such as a history of operation, comorbidities, congestive heart failure, diabetes, age, gender, the degree of kidney damage, and the duration of CLD. Studies showing the effect of hemodialysis towards BGA variables correlated with other diseases should also be done.

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