Original Article

Comparison of arterial and venous blood gases in patients with obesity hypoventilation syndrome and neuromuscular disease

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Abstract:

OBJECTIVES: Obesity hypoventilation syndrome (OHS) and some neuromuscular diseases (NMD) present with hypercapnic respiratory failure. Arterial blood gas (ABG) analysis is important in the diagnosis, follow-up, and treatment response of these diseases. However, ABG sampling is difficult in these patients because of excessive subcutaneous fat tissue, muscle atrophy, or contracture. The aim of this study is to investigate the value of venous blood gas (VBG), which is an easier and less complicated method, among stable patients with OHS and NMD.

METHODS: The study included stable OHS and NMD patients who had been previously diagnosed and followed up between March 2017 and May 2017 in the outpatient clinic. ABG was taken from all patients in room air, and peripheral VBG was taken within 5 min after ABG sampling.

RESULTS: Thirty-six patients with OHS and 46 patients with NMD were included in the study. There was a moderate positive correlation between arterial and venous pH values for all patients ($r_s = 0.590$, $P < 0.001$). There were a strong and very strong positive correlations between arterial and venous pCO_2 and HCO_3 values ($r_s = 0.725$ and $r_s = 0.934$, respectively) ($P < 0.001$). There was no correlation between arterial and venous pO_2 and saturation values. There was an agreement in Bland–Altman method for the values of ABG and VBG (pH, pCO_2, and HCO_3).

CONCLUSIONS: There was a correlation between ABG and VBG values (pH, pCO_2, and HCO_3). VBG parameters (pH, pCO_2, and HCO_3) can be used safely instead of ABG parameters which have many risks, during treatment and follow-up of patients with OHS and NMD.

Keywords:

Arterial blood gases, neuromuscular diseases, obesity hypoventilation syndrome, venous blood gases

Obesity hypoventilation syndrome (OHS) and some neuromuscular diseases (NMD) often present with hypercapnic respiratory failure. In patients with OHS who have daytime hypercapnia ($PaCO_2$ >45 mmHg), arterial blood gas (ABG) analysis is important in the diagnosis, follow-up, and treatment response.[1-3] However, in these patients, it is very difficult to obtain ABG because of morbid obesity and excessive subcutaneous fat. In some NMD patients, nocturnal hypoventilation and daytime hypercapnic respiratory failure are common respiratory complications.[4-9] Hypercapnic respiratory failure is an important cause of mortality, especially in rapidly progressive NMD.[5,6] Therefore, ABG analysis is important in patients with NMD.[7-10] However, in these patients, it is difficult to obtain ABG due to muscular atrophy and contracture problems.

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There are many known complications and risks of ABG analysis such as pain, hemorrhage, hematoma, embolism, thrombosis, ischemia, and infection of health personnel.[11] For this reason, ABG sampling requires experience. It is recommended to be performed by a doctor. On the other hand, venous blood gas (VBG) sampling is an easy and less complicated method. The use of VBG may prevent the complications and risks related to ABG sampling.[11,12]

In literature, there is no study about VBG usability in the place of ABG in stable patients with NMD and OHS. Most of the studies in literature have been performed in patients with acute respiratory diseases or ketoacidosis who were admitted to emergency unit or intensive care unit.[11,13-15] Therefore, we aimed to investigate the utility of VBG analysis in stable patients with OHS and NMD.

Methods

This study included patients with OHS and NMD who were admitted to the outpatient polyclinic of Istanbul University, Istanbul Faculty of Medicine, Department of Pulmonary Medicine, between March 2017 and May 2017. All the patients voluntarily signed their informed consent. The study was carried out according to the principles of the Helsinki declaration. It was approved by the Institutional Board of Istanbul Medical Faculty, Istanbul University (Ethic no: 2017/276).

Inclusion criteria

Stable patients with OHS and NMD diagnosis over 18 years old.

Exclusion criteria

Patients with chronic obstructive pulmonary disease (COPD), congestive heart failure, renal failure or liver failure; patients with active inflammatory/infectious disease; patients with hemodynamic instability; and patients using anticoagulants (heparin, low-molecular-weight heparin, warfarin, etc.)

Peripheral VBG samples were obtained from each patient in the consecutive 5 min after ABG sampling in room air. All patients rested at least 30 min preprocedure, and Allen test was done before ABG sampling. Radial artery was the first choice for ABG sampling, and the brachial artery was the second choice in cases of failure. VBG was obtained by puncture of the brachial vein. All samples were taken by the first author (HO). Heparinized injector (2cc) was used for both ABG and VBG sampling. The puncture area was pressed for 5 min after ABG sampling. As soon as the arterial sample was taken, air was removed from the syringe, and the needle tip was closed with plastic caps. The samples were studied as soon as possible (within a maximum of 5 min) with the ABL 800 Flex blood gas analyzer (I902-754R0598N0010, Copenhagen, Denmark). Regular calibrations and controls of the blood gas analyzer were done according to the operating instructions. pH, pCO_2, pO_2, HCO_3, and SO_2 values of blood gases were recorded. For ABG analysis, normal range of pH was accepted as 7.35–7.45. pH <7.35 was accepted as acidosis, and pH >7.45 was accepted as alkalosis. In case of pH <7.35, $PaCO_2$ >45 mmHg was considered as respiratory acidosis, and in case of pH >7.45, $PaCO_2$ <35 mmHg was considered as respiratory alkalosis. $PaCO_2$ >45 mmHg was considered as hypercapnic respiratory failure.

Statistical analysis

Statistical analysis was performed using the Statistical Package for the Social Sciences software version 21.0 (AIMS, Istanbul, Turkey) and NCSS software version 10, 2015 (Kaysville, Utah, USA). Continuous variables were presented as mean, standard deviation, median, and minimum–maximum. For discrete variables, data were expressed as numbers and percentages. The distribution of the variables was evaluated for their assumption of normality with the Kolmogorov–Smirnov test and Shapiro–Wilk test. Pearson's or Spearman's correlation tests were used to determine the relationship between the measurement methods, and a regression model was performed. Bland–Altman method was used to evaluate the agreement between ABG and VBG measurements. Receiver operating characteristic curves were performed for the cutoff values of ABG and VBG pCO_2. $P < 0.05$ was considered statistically significant.

Results

A total of 82 patients (36 OHS and 46 NMD) were included in the study. Characteristics of the patients are summarized in Table 1.

Of OHS patients (n = 36), 18 (50%) were female and 18 (50%) were male. The mean age was 57.17 ± 12.37 years, and the mean body mass index (BMI) was 42.11 ± 8.4 kg/m^2. Hypercapnic respiratory failure was present in 38.9% (n = 14) of the patients. Of OHS patients, 83.3% (n = 30) had obstructive sleep apnea syndrome and 86.1% (n = 31) were using noninvasive mechanical ventilation (NIMV). The remaining 13.9% of the patients refused to use NIMV.

Table 1: Characteristics of all patients

Characteristics	Mean ± standard deviation (range)
Age (year)	46.93±17.3 (18-79)
Female (*n*) (%)	33 (40.2)
Male (*n*) (%)	49 (59.8)
Smoking history (*n*) (%)	26 (31.7)
BMI (kg/m^2)	31.72±11.3 (15-67)
Hypercapnic respiratory failure (*n*) (%)	24 (29.3)

BMI, body mass index

Of patients with NMD (n = 46), 15 (32.6%) were female and 31 (67.4%) were male. The mean age was 38.91 ± 16.49 years, and the mean BMI was 23.50 ± 4.92 kg/m^2. The diagnoses of the patients were muscular dystrophy (43.5%), amyotrophic lateral sclerosis (23.9%), myotonic dystrophy (10.9%), and others (Pompe disease and myasthenia gravis). Hypercapnic respiratory failure was present in 21.7% (n = 10) of the patients. Of patients with NMD, 34.7% (n = 16) were using NIMV.

In all patients (36 OHS and 46 NMD), there was a moderate positive correlation between arterial and venous pH values (r_s = 0.590, P < 0.001). There were strong and very strong positive correlations between the arterial and venous pCO_2 and HCO_3 values (r = 0.725 and r = 0.934, P < 0.001, respectively). There was no correlation between arterial and venous pO_2 and SO_2 values (r_s = 0.120 and r_s = 0.100, respectively). Table 2 summarizes the ABG and VBG values of all patients.

In NMD group, there was a moderate positive correlation between the arterial and venous pH and pCO_2 (r_s = 0.542 and r_s = 0.540, P < 0.001, respectively). There was a very strong positive correlation between arterial and venous HCO_3 values (r_s = 0.924, P < 0.001). There was no correlation between arterial and venous pO_2 and SO_2 values. ABG and VBG values of the patients with NMD are summarized in Table 3.

In OHS patients, there was a very strong positive correlation between arterial and venous pH, pCO_2, and HCO_3 values (r = 0.703, r = 0.765, and r = 0.849, P < 0.001, respectively). There was no correlation between arterial and venous pO_2 and SO_2 values. Table 4 summarizes the values of ABG and VBG of OHS patients.

When all patients who had pCO_2 >45 mmHg in ABG were analyzed, the cutoff value was found to be >50 mmHg for VBG (sensitivity 87.5% and specificity 72.4%). It is predictable that, if pCO_2 is <50 mmHg in VBG, it should be normal in ABG [Figure 1].

The following equations were developed to calculate the ABG values from the VBG values using linear regression graphics between arterial and venous pH, pCO_2, and HCO3 values [Figures 2-4]:

pH artery = 3.393 + 0.545 × pH vein

PCO_2 artery = 8.940 + 0.663 × pCO_2 vein

HCO_3 artery = 6.844 + 0.739 × HCO_3 vein.

When the Bland–Altman plots (pH, pCO_2, and HCO_3) were examined, it was observed that the distribution of the differences was balanced above and below the mean value and found more intense in the closest fields of the mean value. The dots were distributed around the mean value within a 95% confidence interval. This suggests a good agreement between the measurements of the two methods. On the graphic of pO_2, it was also observed that the differences were distributed evenly above and below the mean value, but scattered near the mean value. Therefore, the Bland–Altman method showed a good agreement between arterial and venous PH, pCO_2, and HCO_3 values, but no agreement for pO_2 values [Figures 5-8].

Table 2: ABG and VBG values of all patients

	ABG	VBG	Correlation coefficient	*P*
pH	7.41±0.02	7.37±0.03	0.590	<0.001
pCO_2 (mmHg)	41.7±6.86	49.4±7.62	0.725	<0.001
HCO_3 (mmol/L)	26.1±2.82	26.0±3.49	0.934	<0.001
pO_2 (mmHg)	83.4±14.16	33.8±11.00	0.120	NS
SO_2 (%)	95.1±2.62	57.0±20.13	0.100	NS

ABG, arterial blood gas; NS, not significant; VBG, venous blood gas

Table 3: ABG and VBG values of the patients with NMD

	ABG	VBG	Correlation coefficient	*P*
pH	7.41±0.03	7.37±0.03	0.542	<0.001
pCO_2 (mmHg)	40.0±7.00	47.4±7.75	0.540	<0.001
HCO_3 (mmol/L)	25.39±3.14	25.2±4.00	0.924	<0.001
pO_2 (mmHg)	87.9±14.82	35.1±12.23	0.198	NS
SO_2 (%)	95.91±2.17	59.4±21.48	0.248	NS

ABG, arterial blood gas; NS, not significant; VBG, venous blood gas

Table 4: ABG and VBG of patients with OHS

	ABG	VBG	Correlation coefficient	*P*
pH	7.41±0.02	7.37±0.02	0.703	<0.001
pCO_2 (mmHg)	43.8±6.12	51.9±6.75	0.765	<0.001
HCO_3 (mmol/L)	27.0±2.07	27.2±2.32	0.849	<0.001
pO_2 (mmHg)	77.6±10.96	32,1±9.07	0.120	NS
SO_2 (%)	94.1±2.85	53.4±17.99	0.065	NS

ABG, arterial blood gas; NS, not significant; VBG, venous blood gas

Discussion

ABG analysis is an important test used in the diagnosis, follow-up, and treatment response of respiratory and metabolic diseases. However, the procedure is difficult and has some complications and risks. For this reason, the applicability of VBG, which has less risk and complications, has been investigated in some studies.[12] Previous studies investigated the usability of VBG instead of ABG in patients with acute respiratory diseases (COPD exacerbation, pneumonia, and pulmonary embolism), in postoperative patients, and in patients with ketoacidosis in emergency units or intensive care units.[11,13-15] However, no study has been performed in stable outpatients, especially patients with OHS and NMD, in whom obtaining ABG is technically

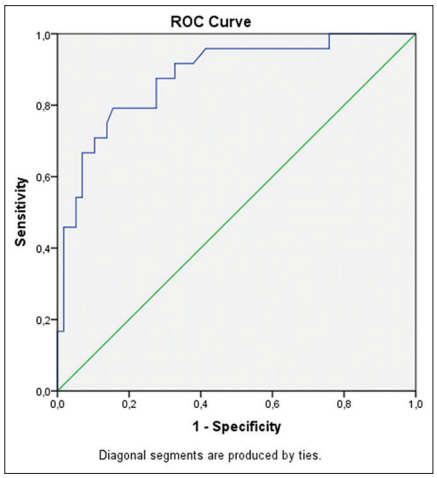

Figure 1: The ROC curve for the cut-off values of ABG and VBG pCO_2

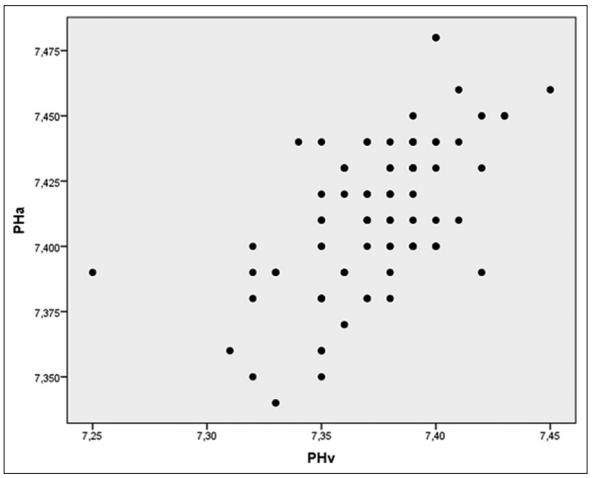

Figure 2: Regression graphic of arterial and venous pH

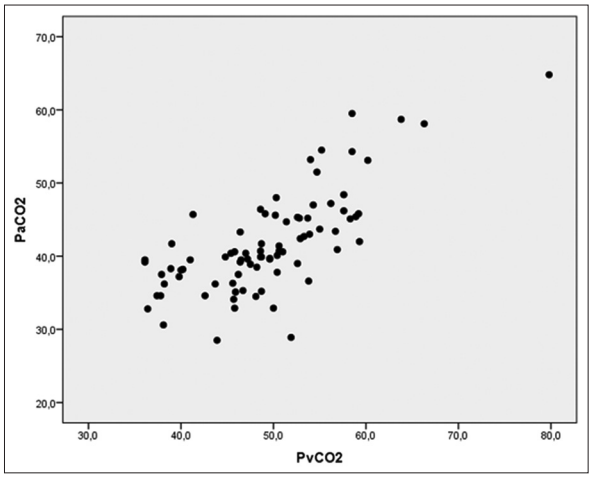

Figure 3: Regression graphic of arterial and venous pCO_2

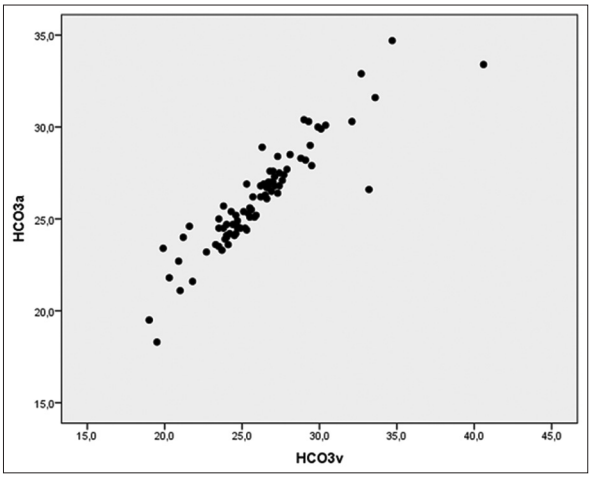

Figure 4: Regression graphic of arterial and venous HCO_3

difficult. OHS and NMD are diseases which may lead to hypercapnic respiratory failure. Values of pH and $PaCO_2$ in ABG are important in the treatment plan and follow-up of these patients.

A study evaluating arterial and central venous blood samples in critically ill patients reported that there was a correlation between arterial and central venous pH values and that central venous blood samples can be used instead of arterial blood samples.[14] Branderburg and Dire investigated the usability of pH value in peripheral VBG instead of pH in ABG for the diagnosis, treatment, and follow-up of patients with diabetic ketoacidosis. They found a correlation between arterial and venous pH values and pointed out that a peripheral VBG specimen can be used instead of ABG in emergency departments, especially for the pH value.[15] Kelly *et al*. performed a study on patients with acute respiratory disease (COPD exacerbation, acute pulmonary embolism, asthma attack, pneumonia, hemoptysis, etc.) in emergency unit and reported that venous pH is an acceptable datum to calculate arterial pH, thus reducing the complications.[11] In another study conducted by McKeever *et al*., arterial and venous pH values were compared in patients with COPD exacerbation, and a strong agreement was found between arterial and venous pH values by Bland–Altman method.[16] In our study, we evaluated stable outpatients with OHS and NMD and found similar strong agreement between arterial and venous pH values by Bland–Altman method. According to our results, venous pH values can be used instead of arterial pH values in stable patients with OHS and NMD.

In the study conducted by Dilber *et al*., there was a strong correlation between the arterial and venous blood samples (r = 0.778, 0.728, and 0.823, $P < 0.0001$, respectively) in terms of pH, pCO_2, and HCO_3 values in COPD patients with acute respiratory failure.[17] In that study, formulas were developed to calculate arterial pH, pCO_2, and HCO_3 values using venous blood values. The authors concluded that venous blood samples could be used instead of arterial blood samples in COPD patients with acute respiratory failure who cannot have an arterial cannula, who have blood-borne disease, and

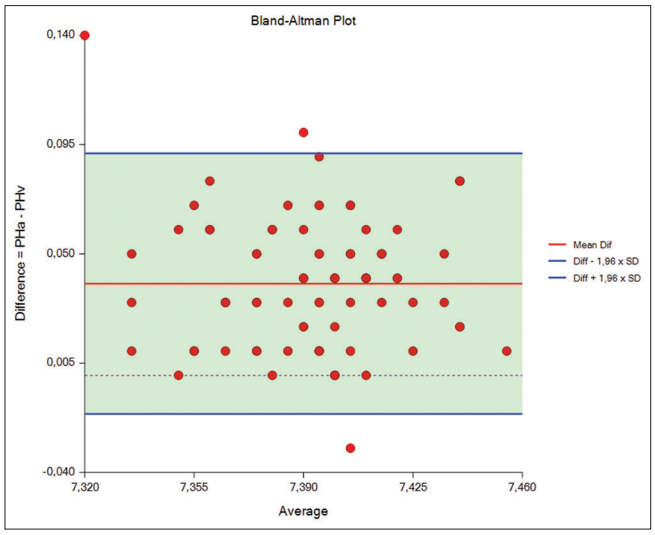

Figure 5: Comparison of arterial and venous pH with Bland-Altman method

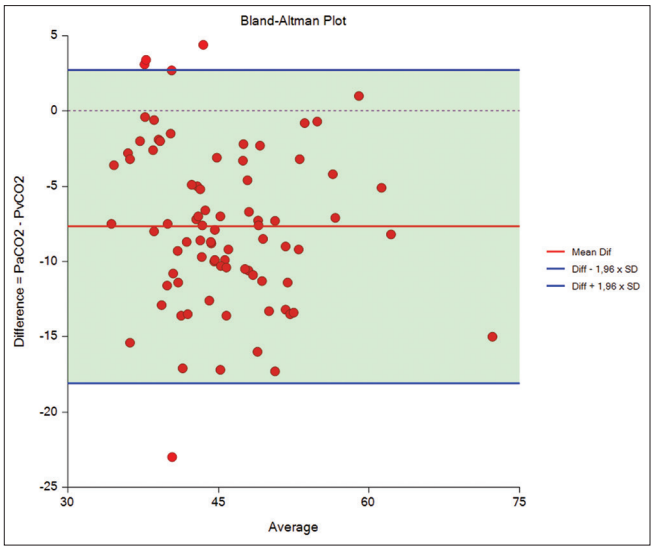

Figure 6: Comparison of arterial and venous pCO_2 with Bland-Altman method

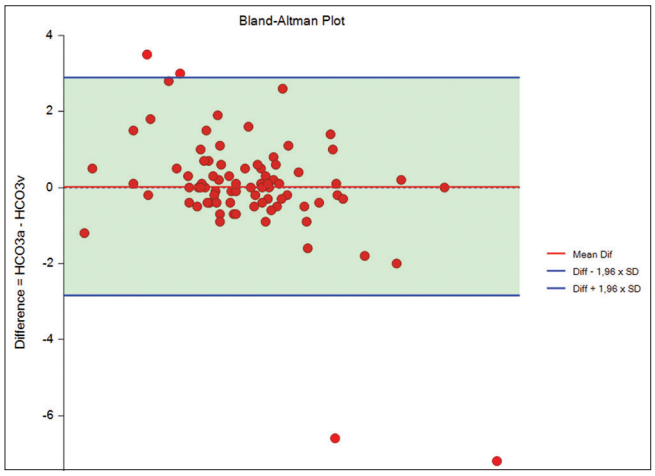

Figure 7: Comparison of arterial and venous HCO_3 with Bland-Altman method

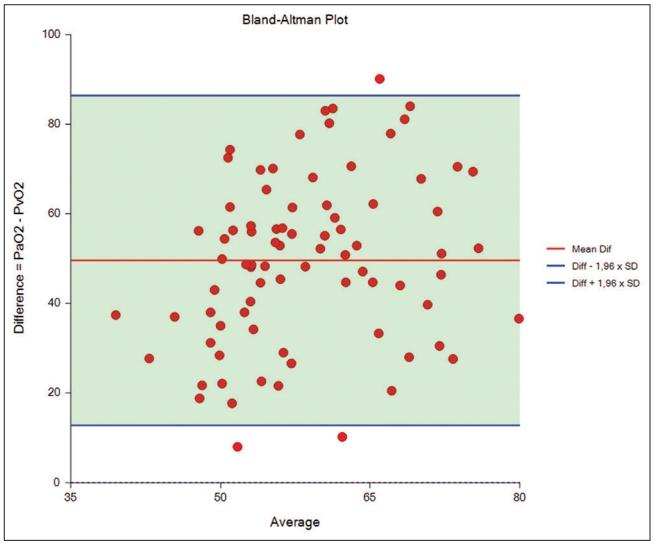

Figure 8: Comparison of arterial and venous pO_2 with Bland-Altman method

who need frequent blood gas analysis. Esmaeilivand *et al*. found a strong correlation between pH values of ABG and central VBG in patients who underwent coronary artery bypass graft surgery and followed up in the intensive care unit in the postoperative period.[18] Because of the strong correlation between arterial and venous pH, pCO_2, and HCO_3 values, they formulated equations for finding arterial values from venous values.[18] In our study, there was also a strong positive correlation between arterial–venous HCO_3 and pCO_2 values ($r = 0.9334$ and 0.725, $P < 0.001$, respectively) with 95% confidence level. Therefore, the following equations were created to find arterial values from venous values [Figures 2-4].

pH artery = 3.393 + 0.545 × pH vein

PCO_2 artery = 8.940 + 0.663 × pCO_2 vein

HCO_3 artery = 6.844 + 0.739 × HCO_3 vein.

The applicability of the equations was checked with the data in our study, and the results were compatible with the actual data. It is thought that these equations should be validated with larger studies in different populations before using in routine practice.

Kelly *et al*. found that the venous pCO_2 value was 5.8 mmHg higher than the arterial pCO_2 value in a study including patients with acute respiratory disease (COPD exacerbation, acute pulmonary embolism, asthma attack, pneumonia, hemoptysis, etc.). They concluded that there were insufficient data to use venous pCO_2 instead of arterial pCO_2 in that study.[11] Ertan *et al*. found a strong correlation between arterial and venous pCO_2 values.[19] Because this result statistically did not fully support the use of venous pCO_2 value instead of arterial pCO_2 value, venous pCO_2 value may only provide insight into the respiratory function. They found that all parameters of ABG were within normal limits in all cases, in which

the venous pCO_2 value was lower than 40 mmHg in that study. Of the 52 patients with a value of venous pCO_2 >50 mmHg, 8 of them had ABG values within normal limits. In our study, we found a cutoff value of pCO_2 at 50 mmHg in VBG for patients who had a pCO_2 value of 45 mmHg (with hypercapnic respiratory failure) in ABG (sensitivity 87.5% and specificity 72%). We concluded that if pCO_2 value in VBG is <50 mmHg, it may be predictive of normal pCO_2 value in ABG.

There was no correlation between arterial and venous pO_2 and SaO_2 values in studies investigating agreement between artery–vein pO_2 and SO_2 values.[16,18,19] Furthermore, there was no correlation between arterial and venous pO_2 values in our study (r = 0.120). No correlation was found between arterial and venous values (r = 0.100).

When the subgroups in our study were analyzed, there was a very strong positive correlation (r_s = 0.703, r_s = 0.765, and r_s = 0.849, respectively, $P < 0.001$) in all the three arterial and venous pH, pCO_2, and HCO_3 values of patients with OHS. There was a moderate positive correlation between the arterial and venous pH and pCO_2 values of the patients with NMD (r_s = 0.542, $P < 0.001$, r_s = 0.540, $P < 0.001$, respectively). A very strong positive correlation was found between arterial and venous HCO_3 values (r_s = 0.924, $P < 0.001$). There was no correlation between arterial and venous pO_2 and SO_2 values in the two subgroups. As a result, all the parameters showed better compliance in the OHS group than in the NMD group. This suggests that agreement in ABG and VBG is better in OHS group than in the NMD group.

The basic limitation of our study is that the number of patients is small, and the work was done in one center. We included patients with stable OHS and NMD who had previously been diagnosed and had regular outpatient follow-up in a specified period. For this reason, our sample size was not large. The reliability of the results may increase if multicentric studies can be performed with more cases.

Conclusions

During routine follow-up and treatment of OHS and NMD, an agreement was found between ABG and VBG values (pH, pCO_2, and HCO_3). In addition, if the pCO_2 value in the VBG is <50 mmHg, pCO_2 can be predicted to be normal in the ABG. It was thought that, during routine follow-up and treatment of OHS and NMD, VBG parameters (pH, pCO_2, and HCO_3) can be used safely instead of ABG which has many risks.

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Conflicts of interest
There are no conflicts of interest.

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