Original Article

Blood gas analysis of healthy people in Diqing Tibetan Autonomous Prefecture in Yunnan Province

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Background: To investigate the reference value of blood gas analysis and related factors in healthy adults in Diqing Tibetan Autonomous Prefecture in Yunnan Province.

Methods: From August 24, 2018 to August 11, 2020, healthy people between the ages of 18 and 70 years were observed at the Physical Examination Center of People's Hospital of Diqing Tibetan Autonomous Prefecture in Yunnan province. Participant information and clinical characteristics were collected. Blood gas analyzer was used to measure PH value, arterial partial oxygen pressure (PaO_2), arterial partial pressure of carbon dioxide ($PaCO_2$), arterial oxygen saturation (SaO_2), acidity (pH), actual bicarbonate (AB) and residual base (BE). The participants' basic and blood gas indicator data were analyzed, and the blood gas reference values and related factors were analyzed using chi-squared tests, Mann-Whitney-Wilcoxon Test, and Spearman's correlation analysis.

Results: A total of 1,218 eligible health examination participants were included. They had an average age of 40 [31–47] years, and males accounted for 51.0%. In terms of blood gas reference values, the average pH value was moderate, and the values of PaO_2, SaO_2, $PaCO_2$, AB, and BE were low. PaO_2 was basically matched with the estimated value of the domestic model formula. These indexes were found to be correlated with social demographic characteristics such as sex, age, and smoking history.

Conclusions: The correlations between the indexes and social demographic characteristics may be helpful in the prediction of blood gas analysis results in clinical practice. For men, middle-aged and elderly people, or adults with a history of active smoking/biofuel exposure, blood gas PaO_2 and $PaCO_2$ should be monitored to facilitate the early intervention of respiratory failure. The PaO_2 data basically matched the estimated values of the domestic model formula, suggesting that other regions in the Prefecture could use comprehensive epidemiological data and model methods to guide clinical work.

Keywords: Diqing Prefecture; blood gas analysis; healthy people

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Introduction

Blood gas analysis, also referred to as a blood gas test, is a common clinical examination that serves as the gold standard for evaluating respiratory failure and various disorders of acid-base balance. Blood gas tests are of great value for the differential diagnosis of clinical acute critical illnesses and in guiding the application of mechanical ventilation.

Currently, the reference values for arterial partial oxygen pressure (PaO_2) in healthy adults are only applicable in plain areas; in standard conditions (1 atmosphere at sea level, quiet), the reference value for PaO_2 is 10.7–13.3 kPa and decreases slightly with age. For inland high-altitude areas, it is necessary to discuss the corresponding blood gas standards, so as to objectively judge the disease and guide clinical diagnosis and treatment. Xiao *et al.* reported that the reference value for arterial blood oxygen partial pressure in healthy Chinese adults was correlated with altitude and average annual relative humidity (1). Some studies on blood gas analysis of healthy people in Qinghai and other plateau areas showed the characteristics of decreased PaO_2 and partial pressure of carbon dioxide ($PaCO_2$) with an increased pH value (2). There was also a similar report about blood gas analysis in Tibetan region (3). But they had some limitations: only involved one single ethnic group, or didn't distinguish ethnic groups; the number of cases was small; lack of correlation analysis between blood gas indicators and clinical demographic characteristics. The present study aimed to analyze the blood gas of healthy people in multi-ethnic (In the majority of Tibetan) Diqing Tibetan Autonomous Prefecture in Yunnan Plateau region and to discuss the corresponding reference values and relations with clinical demographic characteristics, expand the sample size to be representative, in an effort to create a foundation for a reference standard for respiratory failure.

We present the following article in accordance with the MDAR reporting checklist (available at http://dx.doi.org/10.21037/apm-20-2206).

Methods

Study participants

From August 24, 2018 to August 11, 2020, 1,218 eligible participants were observed at the Physical Examination Center of the People's Hospital of Diqing Tibetan Autonomous Prefecture in Yunnan province.

The inclusion criteria for study participants were: (I) physical examinees aged between 18 and 70 years old who have lived in Diqing for more than 2 years; (II) on the blood routine, biochemical, chest X-ray, and electrocardiogram examination; (III) the ability to attend a hospital visit; (IV) a total score of 0 on the further line Chronic Obstructive Pulmonary Disease Assessment Test (CAT) (chronic cough, sputum, breathing, chest tightness, shortness of breath) and 2 weeks without respiratory symptoms associated with disease; and (V) lung ventilation function test results in the normal range. The exclusion criteria were: (I) the presence of uncontrolled other systemic serious diseases, including heart failure, cirrhosis, and cerebral infarction; and (II) cognitive dysfunction, inability to communicate effectively, or poor compliance with the study.

The sample size required was calculated with PASS 11 Home software (NCSS LCC, America), according to the standard deviation of PaO_2 in healthy people at a similar altitude reported in the literature (1). Target: 1,500 cases (the population of Diqing Prefecture is estimated at 300,000). The ratio of males to females was 1:1. Participants were divided into two age groups, the 18–40 years group and the 40–70 years group, at a ratio of 1:1 (750 people in each group).

Clinical data registration, blood gas collection and analysis

(I) Data of the participants were collected and recorded including their social demographic information (such as sex, age, ethnicity, past medical history, smoking/secondhand smoke exposure history, biofuel exposure history, barbecue diet history) and physical examination results (such as blood pressure, chest radiograph, lung function, hemoglobin).

(II) On the same day of lung function test, the participants rested for 30 minutes to limit the impact of factors, such as physical activity, on the test results. Samples of arterial blood (2 mL) were collected. A cobas b123 blood gas analyzer (Roche, F. Hoffmann-La Roche Ltd) was used to measure the indexes: acidity (PH), PaO_2, $PaCO_2$, arterial oxygen saturation (SaO_2), and actual bicarbonate (AB), and the results were recorded.

Ethics

This study was conducted in adherence to the guidelines of the Declaration of Helsinki (as revised in 2013). The study design was approved by the Ethics Committee of People's Hospital of Diqing Tibetan Autonomous Prefecture (Yunnan, China). Signed informed consent forms were obtained from all participants.

Statistical analysis

Statistical analyses were performed using SPSS 19.0 software (IBM Corporation, America). Descriptive statistics were used to analyze all arterial blood gas data. Measurement data with non-normal distribution were expressed as medians (quartile), and comparisons between different groups were performed

Table 1 Blood gas analysis of healthy adults in Diqing Prefecture

Variable	Median (P25, P75)
pH	7.414 (7.399–7.428)
PaO_2 (mmHg)	58.9 (55.1–61.8)
$PaCO_2$ (mmHg)	32.6 (30.5–34.6)
SaO_2 (%)	91.1 (89.4–92.4)
AB (mmol/L)	20.5 (19.4–21.7)
BE (mmol/L)	−2.76 (−3.82 to −1.91)

pH, acidity; PaO_2, arterial partial oxygen pressure; $PaCO_2$, arterial partial pressure of carbon dioxide; SaO_2, arterial oxygen saturation; AB, actual bicarbonate; BE, residual base.

using the Mann-Whitney U test. They are grouped into subgroups according to different social demography and clinical characteristics. Enumeration data were expressed as percentages, with chi-squared tests used for inter-group comparisons. Univariate and multivariate logistic regression analyses were conducted for factors with statistical significance. $P<0.05$ was considered statistically significant.

Results

Patient characteristics

A total of 1,218 individuals conformed to the eligibility criteria. These individuals ranged in age from 18–70 years old, with an average age of 40 years (31–47 years), and 621 (51.0%) were male. Individuals from 11 ethnic groups were included. Tibetans (38.7%), Han (29.1%), and Naxi (20.2%) were the major ethnic groups, the residents accounted for 91.4%. Of the study participants, 19.8% and 15.0% had a history of active and passive smoking, respectively, and 19.0% had a history of exposure to biofuels.

The results of blood gas analysis showed that pH value was 7.275–7.491, with a median of 7.414 (7.399–7.428); PaO_2 value was 45.8–73.0 mmHg, with a median of 58.9 (55.1–61.8) mmHg; $PaCO_2$ value was 19.3–40.3 mmHg, with a median of 32.6 (30.5–34.6) mmHg; SaO_2 value was 76.8–99%, with a median of 91.1 (89.4–92.4%); AB value was 12.1–28.2 mmol/L, with a median of 20.5 (19.4–21.7) mmol/L. BE value was −11.01–2.57 mmol/L, with a median of −2.76 (−3.82 to −1.91) mmol/L. See *Table 1*.

Correlation analysis between blood gas analysis indexes

The pH value was positively correlated with the values of PaO_2, SaO_2, AB, and BE (P=0.000) and negatively correlated with the value of $PaCO_2$ (P=0.000). The PaO_2 value was positively correlated with the values of SaO_2 and pH (P=0.000), while negatively correlated with the values of AB and BE (P=0.000). The $PaCO_2$ value was positively correlated with the values of AB and BE (P=0.000), while negatively correlated with the values of pH, PaO_2 and SaO_2 (P=0.000). The SaO_2 value was positively correlated with PaO_2 and pH (P=0.000), while negatively correlated with the values of AB and BE (P=0.000). The value of AB was significantly positively correlated with that of BE, pH, and $PaCO_2$ (P=0.000), and negatively correlated with those of PaO_2 and SaO_2 (P=0.000). The value of BE was significantly positively correlated with the values of AB, pH, and $PaCO_2$ (P=0.000), but negatively correlated with the values of PaO_2 and SaO_2 (P=0.000). *Table 2* shows the results of correlation analysis.

Comparison and correlation analysis of blood gas indexes between different subgroups

In healthy adult males, the pH value was significantly lower than that of female adults; however, the values of $PaCO_2$, AB, and BE were significantly higher in men than in women ($P<0.05$). The values of PaO_2 and SaO_2 in healthy adults aged under 40 were significantly higher than those in adults aged 40 and above, and the values of $PaCO_2$, AB, and BE were significantly lower than those aged under 40 ($P<0.05$). The values of $PaCO_2$, AB, and BE in healthy adults with an active smoking history were significantly higher than those in participants without a history of active smoking ($P<0.05$). The pH and PaO_2 values of Diqing inhabitants (Generation dweller) were significantly lower than those of settlers (People who have migrated from other areas to live for more than 2 years) ($P<0.05$), and the pH value of the Han population was significantly higher than that of other ethnic groups ($P<0.05$). The $PaCO_2$ levels of healthy adults with a history of exposure to biofuels were significantly higher than those of individuals without a history of exposure to biofuels ($P<0.05$) (*Table 3*).

Discussion

Diqing Tibetan Autonomous Prefecture is located in a high-altitude area of Yunnan province in southwest China, with a cold temperate climate. Tibetan and other ethnic minorities account for 88.5% of the Diqing total population.

Due to factors such as smoking, wood burning, cooking, and burning carbon for heating chronic obstructive

Table 2 Spearman's correlation analysis among blood gas analysis indicators

Variable	The correlation coefficient (P value)					
	PH	PaO_2 (mmHg)	$PaCO_2$ (mmHg)	SaO_2 (%)	AB (mmol/L)	BE (mmol/L)
PH	–	0.160 (0.000)	–0.265 (0.000)	0.232 (0.000)	0.115 (0.000)	0.309 (0.000)
PaO_2 (mmHg)	0.160 (0.000)	–	–0.452 (0.000)	0.780 (0.000)	-0.411 (0.000)	–0.336 (0.000)
$PaCO_2$ (mmHg)	–0.265 (0.000)	–0.452 (0.000)	–	–0.493 (0.000)	0.736 (0.000)	0.577 (0.000)
SaO_2 (%)	0.232 (0.000)	0.780 (0.000)	–0.493 (0.000)	–	–0.398 (0.000)	–0.302 (0.000)
AB (mmol/L)	0.115 (0.000)	–0.411 (0.000)	0.736 (0.000)	–0.398 (0.000)	–	0.797 (0.000)
BE (mmol/L)	0.309 (0.000)	–0.336 (0.000)	0.577 (0.000)	–0.302 (0.000)	0.797 (0.000)	–

P values were all less than 0.01. pH, acidity; PaO_2, arterial partial oxygen pressure; $PaCO_2$, arterial partial pressure of carbon dioxide; SaO_2, arterial oxygen saturation; AB, actual bicarbonate; BE, residual base.

Table 3 Comparison of blood gas index between different factor groups (1,218 cases)

Variable	N (%)	Median (U test for P)					
		pH	PaO_2 (mmHg)	$PaCO_2$ (mmHg)	SaO_2 (%)	AB (mmol/L)	BE (mmol/L)
Sex							
Male	621 (51.0)	7.413 (0.000)*	58.3 (0.077)	33.2 (0.000)*	91.0 (0.223)	20.8 (0.000)*	–2.60 (0.006)*
Female	597 (49.0)	7.416	59.4	32.1	91.3	20.3	-2.88
Age (years)							
≥40	622 (51.1)	7.414 (0.168)	56.6 (0.000)*	33.2 (0.000)*	90.5 (0.000)*	20.8 (0.000)*	–2.47 (0.000)*
<40	596 (48.9)	7.415	60.4	32.1	91.7	20.3	–3.06
Nation							
Han	355 (29.1)	7.415 (0.039)*	59.1 (0.411)	32.4 (0.354)	91.1 (0.344)	20.6 (0.601)	–2.64 (0.404)
Others	863 (70.9)	7.414	58.7	32.7	91.1	20.5	-2.83
Living status							
Localized	1113 (91.4)	7.414 (0.040)*	58.7 (0.006)*	32.7 (0.304)	91.0 (0.162)	20.6 (0.364)	–2.75 (0.255)
Emigrated	105 (8.6)	7.420	60.1	32.2	91.7	20.3	–2.91
History of active smoking							
Yes	241 (19.8)	7.414 (0.063)	58.0 (0.175)	33.5 (0.000)*	91.0 (0.327)	21.2 (0.000)*	–2.38 (0.000)*
No	977 (80.2)	7.414	59.1	32.3	91.2	20.4	–2.89
History of passive smoking							
Yes	183 (15.0)	7.414 (0.416)	58.4 (0.654)	33.0 (0.096)	91.0 (0.758)	20.5 (0.270)	–2.87 (0.572)
No	1,035 (85.0)	7.414	59.0	32.5	91.2	20.5	–2.73
Biofuel exposure history							
Yes	231 (19.0)	7.413 (0.164)	58.1 (0.089)	33.0 (0.013)*	91.0 (0.939)	20.4 (0.691)	–2.89(0.935)
No	987 (81.0)	7.415	59.0	32.5	91.1	20.5	–2.72

*, P values were all less than 0.05. pH, acidity; PaO_2, arterial partial oxygen pressure; $PaCO_2$, arterial partial pressure of carbon dioxide; SaO_2, arterial oxygen saturation; AB, actual bicarbonate; BE, residual base.

pulmonary disease (COPD), bronchial asthma, and other chronic airway diseases are common among permanent residents of Diqing Perfecture. In severe cases, COPD may be complicated by hypoxemia, respiratory failure, or pulmonary heart disease. Colder weather also tends to promote acute respiratory infection, pneumonia, and even severe pneumonia and other acute and critical diseases. The morbidity and mortality rates associated with these diseases are relatively high, which makes timely and reasonable diagnosis and treatment critical.

Arterial blood gas analysis is the gold standard for the diagnosis of hypoxemia and respiratory failure, and it was important to guide treatment. The current diagnostic criteria for respiratory failure are: PaO_2 below 8 kPa (60 mmHg) with or without $PaCO_2$ higher than 6.65 kPa (50 mmHg) at sea level breathing indoor air, and excluding cardiac anatomic shunt and reduction of cardiac output. However, Diqingzhou is located on a plateau and has an average altitude of 3,294 m. Due to this high altitude, the air is relatively thin, and the atmospheric pressure and oxygen content are reduced. In this hypoxic environment, the body reacts by stimulating peripheral chemoreceptors, leading to enhanced ventilation activity.

This study found that, compared with previous data from China (2), the mean pH value of blood gas in healthy adults in Diqingzhou was higher than that in plain areas such as Beijing, and the mean values of PaO_2, $PaCO_2$, SaO_2, and BE were lower than those in individuals in plain areas, while the mean values of AB were only slightly lower. Compared with Qinghai and other regions at a similar altitude, the characteristics of blood gas are similar.

The mechanism of blood gas differences such as low oxygen. The plateau environment is characterized by low atmospheric pressure and low oxygen partial pressure, which reduces arterial blood oxygen partial pressure and stimulates the chemical receptors of the aortic body, causing excessive ventilation and subsequently leading to increased excretion of HCO_3, increased blood pH, and gradual equilibrium (4). Previous studies have reported that with the increase of altitude, blood gas indexes of healthy crowd get changed, among which arterial blood oxygen partial pressure influence the most, followed by CO_2 partial pressure of arterial blood and standard bicarbonate, residual alkali, oxygen saturation, the pH value also gradually alkali (1,2,5-7), Mexican studies have also shown a negative correlation between $PaCO_2$ and altitude (8,9).

The mechanism of blood gas differences such as low oxygen. The low oxygen partial pressure of plateau environments can cause the blood to carry low oxygen levels and the percentage, human body ventilatory function reduces CO_2 partial pressure in the arterial blood and pH value tend to be alkaline (4). Kidney starts compensatory function along with the change of blood CO_2 partial pressure; respiratory alkalosis with metabolic acidosis, or conversely, bicarbonate, residual alkali synchronous change. This study found PaO_2 to be positively correlated with SaO_2, $PaCO_2$ to be negatively correlated with pH value, both PaO_2 and $PaCO_2$ are positively correlated with AB and BE values. All of these results are consistent with the previous literature reports. However, it is worth noting that PaO_2 and $PaCO_2$ were negatively correlated, and positively related to the pH value, which seems to contrast with the findings of previous studies. However, as the population of this study comprised individuals who had lived in DiQingZhou for at least 2 years, rather than those with short-term exposure to the environment of the plateau region, the enrolled individuals had adapted to the plateau environment (enhancement was gradually ease, the body compensatory ventilation function, coupled with living habits, partial contact smoke environment in national regions), which can lead to low oxygen and prone to arterial blood increased CO_2 partial pressure, acidic pH.

In this study, healthy adults with a history of active smoking or exposure to biofuels were found to have higher $PaCO_2$ than those with no relevant exposure history, which was related to long-term exposure to smoke, chronic inflammatory damage of airway mucosa caused by particulate inhalation, and airflow subsidence. Similarly, $PaCO_2$ in men and individuals aged 40 and under was found to be higher than in women and elderly people, which may result in pathophysiological changes due higher exposure to the relevant harmful and stimulating environmental factors. We found that lower PaO_2 and SaO_2 levels in people aged 40 and under may be related to the high activity level and relatively increased oxygen consumption in young people under the same hypoxic environment. The PaO_2 value of the inhabitants is lower than that of the settlers, which is consistent with the literature (2). While due to the increase of ventilation, the processing ability of long-term good oxygen utilization, and somehow genetic gene factor, the inhabitants still don't have anoxic clinical symptoms such as dizziness, headache, and genetic gene has certain correlation at even low blood oxygen level (10). The incidence of oxygenation fluctuation and acute altitude sickness when returning to high-altitude areas is lower among the Tibetan ethnic group than among the Han population (11), which also suggests such a phenomenon. In this study, the pH value of the Han population was higher than that of other ethnic groups, which may because that the majority of Han participants being migrants and the use of enhanced ventilation, leading to the tendency of blood pH toward alkalinity.

PaO_2 is a measurable index of the pressure produced by oxygen molecules in the arterial blood. According to Henry's law, the amount of O_2 dissolved in the blood is proportional to its partial pressure; therefore, the measurement of PaO_2 can help us to evaluate the oxygen content in blood and subsequent analysis of tissue metabolism in the body. The normal value of PaO_2 in healthy people at sea level is 10.7–13.3 kPa, while PaO_2 <10.7 kPa indicates hypoxemia, 8–10.7 kPa indicates mild hypoxemia, and 5.3–8 kPa indicates moderate hypoxemia. PaO_2 <5.3 kPa is judged as severe hypoxemia (1). Literature reports have shown that the hypoxic conditions of plateau environment can damage retinal blood vessels in the human body (12), and also increase the risk of metabolic diseases (13). Therefore, the determination of PaO_2 in plateau-dwelling populations is of great significance for screening disease and guiding prognosis and treatment.

In Yan-Fei Xiao's study on Chinese adults showed the correlation between the arterial blood oxygen partial pressure reference value and the altitude in adults aged 18–40 years old, the regression model as: Y1 = 12.8447 * e – 0.0001 X1, Y1 prediction interval was: (Y1 –1.59, Y1 + 1.59); and in 40–65-year-old healthy adults, the arterial blood oxygen partial pressure reference value is correlated with the area above sea level and annual average relative humidity, the regression model as: Y2 = 10.429 – 0.00123 X1 + 0.02536 X7, Y2 prediction interval was: (Y1 – 1.22, Y1 + 1.22) (1). Diqing prefecture, which is located on the southeastern margin of the Qinghai-Tibet Plateau, has an average altitude of 3,294 meters and an average annual relative humidity of 65%, which is lower than in most plain areas in China. According to the regression model described above, in Diqing Prefecture, the average of the arterial blood oxygen partial pressure reference value for healthy adults aged between 18–40 years old is (9.24±1.59) kPa (69.3±11.9 mmHg), and the arterial blood oxygen partial pressure reference value for adults aged 40–70 is 8.03±1.22 kPa (60.0±9.2 mmHg). In this study, the value of PaO_2 in people aged under 40 years old and people aged 40 years and above was 60.4 and 56.6 mmHg, respectively, which was in line with the model for estimating the value of the range, further proving the practicability of the national standard.

In remote areas that lack the resources for drawing blood from the radial or femoral artery or a blood gas analyzer, the collection of arterialized earlobe blood and use of simple portable instrument such as Abbott i-stat, can also be considered, which have certain application value according to the literature (1,14).

This study has some limitations. First, the three counties of Diqing Prefecture have different altitudes. However, due to limited manpower and facilities, and because the researchers were based in the state capital, only data from Shangri-la County People's Hospital were included in the analysis; however, the altitudes of the counties vary, and the data used and the reference values obtained from them were not representative of all of the counties. The scope of future investigations will be expanded to more objectively reflect the reference values of blood gas in different areas under the jurisdiction of the state.

Conclusions

Diqing Tibetan Autonomous Prefecture is located on a plateau. It is inhabited by many ethnic groups, including Tibetans, Han, and Naxi. In the healthy adults aged 18–70 years included in this analysis of blood gas reference values, the average PH was found to be moderate, while arterial PaO_2, SaO_2, low $PaCO_2$, AB, residual base (BE) on the low side, present "low oxygen level, hyperventilation, moderate acidity" after partial acid, compensatory. These characteristics suggest that the human body can gradually adapt to the unique geographical environment of Diqing Prefecture. Correlations were found between participants' blood gas indexes and social demographic characteristics such as gender, age, and smoking history. This may help with the prediction of the results of blood gas analysis in clinical practice. For men, middle-aged and elderly people, and adults with a history of active smoking or exposure to biofuel, blood gas PaO_2 and $PaCO_2$ should be followed up and monitored to support the early detection, diagnosis, and treatment of respiratory failure. The PaO_2 data obtained from the flow survey basically matched with the values estimated using the domestic model formula, suggesting that other regions in the state could provide targeted guidance for future clinical work based on their specific situation using comprehensive epidemiological data and model methods.

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Footnote

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in adherence to the guidelines of the Declaration of Helsinki (as revised in 2013). The study design was approved by the Ethics Committee of People's Hospital of Diqing Tibetan Autonomous Prefecture (Yunnan, China). Signed informed consent forms were obtained from all participants.

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