RESEARCH ARTICLE

The association of hemocyte profile and obstructive sleep apnea

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Background: The hemocyte profile is one of the most frequently requested clinical laboratory tests. However, the analysis of blood cell indexes of obstructive sleep apnea (OSA) patients in previous studies was not comprehensive. And, this study aimed to fully analyze the blood routine in OSA patients.

Methods: A retrospective study was conducted on 1087 male patients, who were admitted to the sleep center of Nanfang Hospital from May 2013 to February 2018. According to the apnea hypopnea index (AHI), patients were divided into four groups: control group ($AHI < 5$, $n = 135$), mild OSA ($5 \leq AHI < 15$, $n = 185$), moderate OSA ($15 \leq AHI < 30$, $n = 171$), and severe OSA ($AHI \geq 30$, $n = 596$). Data collected included sleep parameters, complete blood routine, body mass index (BMI), age, and comorbidities.

Results: In our study, leukocytes, neutrophils, lymphocytes, monocytes, eosinophils, basophils, erythrocytes, hemoglobin, hematocrit, platelets, MPV, and PDW-SD were statistically significant among the four groups based on AHI ($P < 0.05$), but no significant differences were found in MCV, RDW-SD, N/L, and P/L ratio ($P > 0.05$). Neutrophils, lymphocytes, monocytes, eosinophils, basophils, hemoglobin, hematocrit, platelets, and MPV were significantly correlated with AHI. Moreover, multiple linear regression analysis demonstrated that hematocrit ($\beta = 73.254$, $P = 0.001$), neutrophils ($\beta = 1.414$, $P = 0.012$), and lymphocytes ($\beta = 4.228$, $P < 0.001$) were independently associated with AHI.

Conclusion: Neutrophils, lymphocytes, and hematocrit were independently associated with OSA severity. And combining these three blood cell indicators could contribute to the diagnosis of OSA.

KEYWORDS

blood cell, hematocrit, hemocyte profile, lymphocytes, neutrophils, obstructive sleep apnea

1 | INTRODUCTION

Obstructive sleep apnea (OSA) is characterized by recurrent episodes of partial or complete collapse of the upper airway during sleep, resulting in repeated nocturnal hypoxia, daytime sleepiness, and fatigue.¹ It is known that OSA is associated with cardiovascular disease (CVD), hypertension, stroke, and diabetes mellitus (DM).^{2,3} The pathologic mechanisms of these associations may include

sympathetic nervous system activation, endothelial dysfunction, intermittent hypoxia, hypoxia-reoxygenation, oxidative stress, and insulin resistance.^{4,5}

OSA is a low-grade inflammatory disease. In previous studies, elevated inflammatory cytokines, including IL6, IL1, C-reactive protein (CRP), and TNF- α , have been observed in OSA patients.^{6,7} In recent years, a number of studies have focused on leukocyte subsets, red blood cell indexes, platelet indexes, N/L ratio, and/or P/L ratio,

respectively, in patients with OSA.^{8–12} However, the analysis on all these parameters has not been performed. Therefore, we aimed to explore the alternation and meaning of complete hemocyte profile in a large sample with OSA individuals.

2 | MATERIALS AND METHODS

2.1 | Subjects

This retrospective study consisted of 1087 male patients (mean age 44.45 ± 11.18 years) who were admitted to the sleep center of our hospital from May 2013 to February 2018. Demographic characteristics were collected from the electronic medical record, including age, BMI, and past medical history. Our inclusion criteria included male patients aged 18 years and older, and who had an overnight full laboratory polysomnography examination (PSG) and complete blood profile before the administration of any treatment for OSA. Exclusion criteria were age <18 years, the female sex, diagnosed autoimmune disorders, acute respiration tract infection in recent one month, liver or kidney disease, malignant tumor, chronic alcoholism, hyperthyroidism or hypothyroidism, inflammatory bowel disease, inflammatory connective tissue disorders, heart disease (such as coronary artery disease and heart failure), cerebrovascular accident, history of recent blood transfusion (within 2 weeks), or hematologic disorders such as leukemia, anemia, or myelodysplastic syndrome.

2.2 | Polysomnography

According to the overnight PSG monitoring results, AHI, A-SPO₂, and M-SPO₂ were collected in all patients. Apnea events were defined as a $\geq 90\%$ drop of respiratory amplitude, lasting at least 10 seconds. Hypopneas were defined as a reduction in airflow of $\geq 50\%$ of baseline or a $\geq 30\%$ decrease in the airflow for 10 seconds accompanied either by a decrease in hemoglobin saturation for $\geq 3\%$ or an EEG arousal. The average numbers of apnea and hypopnea episodes per hour of sleep were measured as the AHI. Patients were classified into 4 separate groups based on their AHI scores, as follows: control group (AHI < 5), mild OSA ($5 \leq \text{AHI} < 15$), moderate OSA ($15 \leq \text{AHI} < 30$), and severe OSA (AHI ≥ 30).

2.3 | Biochemical parameters

Complete blood profile in all patients was also recorded from the electronic medical record, including leukocytes, neutrophils, lymphocytes, monocytes, eosinophils, basophils, erythrocytes, hemoglobin, hematocrit, platelets, MPV, PDW-SD, MCV, RDW-SD, N/L, and P/L.

2.4 | Statistical analysis

All analyses were performed using SPSS 22.0. Quantitative data were expressed as the mean $\pm$ SD. Qualitative data were expressed

as counts and percentages. Comparisons of categorical variables used chi-square test. One-way analysis of variance (ANOVA) was applied to analyze continuous variables. Multiple linear regression analysis was used to determine the relationship between OSA severity and blood cell indexes. In order to reduce the influence of variable collinearity among hematocrit, erythrocyte counts and hemoglobin, only one of the three variables with the largest *r* value in simple correlation (hematocrit) was added to the multivariate linear regression model. A *P*-value of <0.05 was considered statistically significant.

3 | RESULTS

The clinical characteristics and laboratory parameters of the study population were presented in Table 1. According to AHI, 1087 patients included were divided into four groups: control group (*n* = 135), mild OSA (*n* = 185), moderate OSA (*n* = 171), and severe OSA (*n* = 596). BMI, morbidities of DM, and hypertension were significantly different among groups (*P* < 0.001).

For blood routine indicators, leukocytes, neutrophils, lymphocytes, monocytes, eosinophils, basophils, erythrocytes, hemoglobin, hematocrit, platelets, MPV, and PDW-SD showed statistically significant differences among the four groups (*P* < 0.05). However, there were no significant differences in the MCV, RDW-SD, N/L, and P/L (*P* > 0.05) (Table 1). In Pearson correlation analysis, neutrophils, lymphocytes, monocytes, eosinophils, basophils, hemoglobin, hematocrit, platelets, and MPV were significantly correlated with AHI (Table 2). In addition, stepwise linear multivariate regression model showed that hematocrit ($\beta = 73.254$, *P* = 0.001), neutrophils ($\beta = 1.414$, *P* = 0.012), lymphocytes ($\beta = 4.574$, *P* < 0.001), and BMI ($\beta = 0.566$, *P* < 0.001) were independently associated with OSA (Table 3). Figures 1–3 showed the correlation between AHI and hematocrit (Figure 1, $R^2 = 0.139$), lymphocytes (Figure 2, $R^2 = 0.072$), and neutrophils (Figure 3, $R^2 = 0.062$), respectively.

4 | DISCUSSION

In the present study, we investigated the association of total blood routine and OSA severity in a large sample. Neutrophils, lymphocytes, and hematocrit were independently associated with OSA and may serve as predictors of OSA severity.

4.1 | Leukocyte subtypes

4.1.1 | Neutrophils

Neutrophils, a major category in leukocyte, are proinflammatory cells which could produce large quantities of reactive oxygen species (ROS) and release inflammatory leukotrienes and proteolytic enzymes.¹³ Previous literature has shown that IHR (intermittent

TABLE 1 Blood routine indicators and clinical characteristics of the study population (n = 1087)

	Control group (n = 135)	Mild OSA (n = 185)	Moderate OSA (n = 171)	Severe OSA (n = 596)	P
Age (y)	46.3 ± 12.04	44.9 ± 11.1	46.0 ± 11.17	43.5 ± 10.93	0.007
BMI (kg/m ²)	24.0 ± 3.32	25.4 ± 2.87	26.7 ± 3.22	29.1 ± 7.93	<0.001
Hypertension	23 (17)	39 (21.1)	42 (24.6)	218 (36.6)	<0.001
Diabetes mellitus	9 (6.7)	12 (6.5)	21 (12.3)	107 (18)	<0.001
Leukocyte (10 ⁹ /L)	6.1 ± 1.33	6.5 ± 1.47	6.6 ± 1.75	7.22 ± 1.7	<0.001
Neutrophil (10 ⁹ /L)	3.4 ± 1.01	3.6 ± 1.10	3.7 ± 1.29	4.0 ± 1.30	<0.001
Lymphocyte (10 ⁹ /L)	2.1 ± 0.54	2.2 ± 0.64	2.2 ± 0.59	2.4 ± 0.70	<0.001
Monocyte (10 ⁹ /L)	0.43 ± 0.12	0.43 ± 0.13	0.45 ± 0.16	0.47 ± 0.15	0.003
Eosinophil (10 ⁹ /L)	0.208 ± 0.15	0.205 ± 0.18	0.213 ± 0.15	0.255 ± 0.19	<0.001
Basophil (10 ⁹ /L)	0.018 ± 0.018	0.023 ± 0.021	0.022 ± 0.029	0.027 ± 0.023	<0.001
Erythrocyte (10 ¹² /L)	4.91 ± 0.53	4.97 ± 0.45	5.03 ± 0.50	5.22 ± 0.51	<0.001
Hemoglobin (g/L)	144.5 ± 12.6	148.8 ± 10.9	148.1 ± 10.5	154.1 ± 11.9	<0.001
Hematocrit	0.429 ± 0.032	0.439 ± 0.031	0.439 ± 0.029	0.457 ± 0.033	<0.001
MCV	87.8 ± 7.0	88.6 ± 5.0	86.9 ± 7.1	87.9 ± 6.0	0.083
RDW-SD	40.96 ± 2.79	41.61 ± 2.73	41.01 ± 2.91	41.49 ± 2.88	0.051
Platelet (10 ⁹ /L)	221.5 ± 51.38	226.40 ± 51.08	225.22 ± 52.74	237.47 ± 66.42	0.006
MPV	10.72 ± 0.10	10.60 ± 0.84	10.82 ± 0.93	10.83 ± 0.98	0.023
PDW-SD	12.68 ± 2.12	12.46 ± 1.83	13.05 ± 2.08	13.15 ± 2.55	0.002
N/L	1.72 ± 0.74	1.75 ± 0.95	1.78 ± 0.67	1.76 ± 0.82	0.926
P/L	112.1 ± 36.8	107.5 ± 33.5	108.8 ± 32.3	103.6 ± 42.3	0.078
AHI	2.1 ± 1.44	9.4 ± 2.8	22.1 ± 4.4	59.4 ± 18.2	<0.001
A-SPO2	95.9 ± 1.47	95.1 ± 1.64	94.9 ± 1.59	90.9 ± 4.46	<0.001
M-SPO2	88.1 ± 5.27	84.0 ± 5.12	79.1 ± 7.61	66.6 ± 11.12	<0.001

The data are presented as means ± SD; categorical data as the number (percentage). Differences among the four groups were examined using a one-way analysis of variance (ANOVA) or chi-square test according to the characteristics of the data distribution. BMI: body mass index; N/L: neutrophils/lymphocytes ratio; P/L: platelet/lymphocyte; MCV: the average volume of red blood cells; RDW-SD: the distribution of red blood cells; MPV: the average volume of platelets; PDW-SD: the width of platelet distribution; AHI: apnea hypopnea index; A-spo2: average pulse hemoglobin saturation; M-spo2: minimum pulse hemoglobin saturation.

hypoxia/reoxygenation) could reduce the percentage of apoptotic polymorphonuclear leukocytes (PMNs) *in vitro*.¹⁴ Moreover, a recent study¹⁵ identified that OSA was correlated with elevated neutrophil counts in a cohort of 1298 participants. Accordingly, our study, performed in a large sample, also showed that OSA was closely related to high neutrophil counts, which suggested the existence of inflammatory response in OSA patients. However, some previous researches^{10,12} found no statistical significance in neutrophils, which might be explained by a limited sample.

4.1.2 | Lymphocytes

Lymphocytes, immunomodulatory cells, play an important role in both autoimmune diseases and chronic inflammatory diseases, especially vascular inflammatory diseases.¹⁶ Previous study reported that sleep deprivation was related to high levels of lymphocytes.¹⁷ Furthermore, a decrease in the total lymphocytes and TNF- α levels was observed after CPAP treatment in OSA patients.¹⁸ In the current study, we observed that lymphocyte counts were highly correlated

with the severity of OSA. However, Freire's study¹⁰ identified no difference in lymphocytes; the possible explanation was that they did not exclude patients with CVD when it came to explore the relationship between lymphocyte counts and OSA, because low lymphocyte counts have been found in CVD patients.¹⁹ The presence of CVD, which was excluded in our study, may affect lymphocyte counts in OSA patients.

4.1.3 | Monocytes

Monocytes made a main contribution to proinflammatory cytokine production in sleep deprivation.²⁰ In inflammatory disease, microbial infection promoted monocytes to migrate from bone marrow to circulating blood and then to inflammatory sites.²¹ Moreover, Tamaki's study¹¹ indicated that nocturnal hypoxia activated the invasive ability of monocytes in OSA, which was evaluated by counting the number of cells invading the BD BioCoat Matrigel Invasion Chamber. And in our study, the level of monocytes in OSA patients was significantly higher than that in the control group.

A growing evidence suggested that levels of neutrophils, lymphocytes, and monocytes increased in sleep restriction.^{17,22,23} Consistent with previous reports, our study found that neutrophils and lymphocytes were independently associated with the severity of OSA, which suggested that OSA is a low-level and systematic inflammatory disease.

TABLE 2 The relationship between blood cell indicators and AHI (Pearson correlation)

	<i>r</i>	<i>P</i>
Leukocyte	0.315	<0.001
Lymphocyte	0.268	<0.001
Neutrophil	0.249	<0.001
Monocyte	0.136	<0.001
Eosinophil	0.118	<0.001
Basophil	0.134	<0.001
Erythrocyte	0.298	<0.001
Hemoglobin	0.331	<0.001
Hematocrit	0.373	<0.001
Platelet	0.164	<0.001
MPV	0.079	0.010
PDW-SD	0.118	<0.001
P/L	-0.087	0.004
BMI	0.375	<0.001
A-SPO2	-0.682	<0.001
M-SPO2	-0.774	<0.001

MPV: the average volume of platelets; PDW-SD: the width of platelet distribution; P/L: platelet/lymphocyte; BMI: body mass index; AHI: apnea hypopnea index; A-spo2: average pulse hemoglobin saturation; M-spo2: minimum pulse hemoglobin saturation.

4.1.4 | Eosinophils and basophils

A large number of studies have confirmed that asthma was widespread in OSA patients and that both diseases often coexisted.²⁴ In addition, OSA patients were usually obese people who were more likely to develop asthma.²⁵ Although eosinophils and basophils accounted for a very low percentage in peripheral blood cells, both cells were associated with allergic inflammation, such as asthma.²⁶ Researches²⁷ have found that eosinophils and basophils in peripheral blood decreased with the improvement of asthma. In the present study, our data showed that both eosinophils and basophils had statistical differences in four groups based on AHI. This might suggest that asthma was highly prevalent in patients with OSA.

4.2 | Red blood cells

OSA is characterized by frequent hypoxemia and arousal in sleep. In our present study, significant differences in erythrocytes and hematocrit were observed among four groups, and hematocrit was independently associated with the AHI indexes, in accordance with

TABLE 3 The multiple linear regression for AHI

	β	<i>P</i>
Neutrophil	1.414	0.012
Lymphocyte	4.228	<0.001
Hematocrit	73.254	<0.001
BMI	0.566	<0.001
A-SPO2	-3.913	<0.001

BMI: body mass index; A-spo2: average pulse hemoglobin saturation.

FIGURE 1 The scatter plot of AHI and hematocrit in OSA patients

FIGURE 2 The scatter plot of AHI and lymphocyte in OSA patients

Cho's results.²⁸ One possible explanation was that hypoxemia could stimulate erythropoietin (EPO) production, resulting in increased hematocrit.²⁹ In addition, in Amir's study³⁰ with 101 OSA patients who were older than 65 and no anemia of aging (AOA), AOA was observed after one year of CPAP therapy. This might be interpreted as the irritation of hypoxemia in erythrocyte formation was relieved by CPAP therapy. However, no statistical correlation between OSA and hematocrit was reported in Christopher's research.³¹ Specific subjects might explain the difference. The patients with renal disease

were included in the former study. And renal diseases have been shown to result in anemia.³²

4.3 | Platelet parameters

Larger platelets tend to develop thrombosis. Therefore, MPV and PDW were closely related to the activity of platelets.³³ A few studies revealed that MPV was an independent predictor in patients with OSA.³⁴ In another study, PDW was correlated with AHI, but no

FIGURE 3 The scatter plot of AHI and neutrophil in OSA patients

statistical significance was found in MPV among different groups.³⁵ However, our study showed that MPV and PDW were significantly higher in severe OSA patients compared to the control group.

4.4 | N/L and P/L ratio

Both N/L and P/L ratios were newly identified inflammatory markers. There were reports which have demonstrated that P/L and N/L ratios were significantly associated with the severity of OSA.^{36,37} However, our present study found no significant difference in regard to these two ratios. Consistent with our conclusions, Tulay's research³⁸ also yielded no significant difference.

As far as we know, our study was the first to analyze the whole blood profile of OSA patients in a large sample. Blood routine is a simple, inexpensive, and rapid laboratory test. Our data showed that neutrophils, lymphocytes, and hematocrit were independently associated with the severity of OSA based on AHI, and may be of guiding significance in the diagnosis of OSA disease. However, our study had some limitations. Because this study is a retrospective study, we failed to explore the mechanism of blood routine abnormality in OSA patients. Secondly, we failed to evaluate the presence of asthma in OSA patients. Thirdly, we did not investigate the influence of CPAP therapy on blood profile. In order to further understand the relationship between OSA and blood profile, further studies are needed.

ETHICAL APPROVAL

All procedures performed in the studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, formal consent is not required.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR'S CONTRIBUTION

Taoping Li and Zeqin Fan designed the experiment and wrote the manuscript. Zeqin Fan collected and analyzed the data. Xiaoxia Lu helped with data analysis and revised the manuscript. Hong Long and Yanhong Zhang contributed to revise the manuscript.

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REFERENCES

- Olson EJ, Park JG, Morgenthaler TI. Obstructive sleep apnea-hypopnea syndrome. *Prim Care*. 2005;32:329-359.
- Fusetti M, Fioretti AB, Valenti M, Masedu F, Lauriello M, Pagliarella M. Cardiovascular and metabolic comorbidities in patients with obstructive sleep apnoea syndrome. *Acta Otorhinolaryngol Ital*. 2012;32:320-325.
- Nagayoshi M, Punjabi NM, Selvin E, et al. Obstructive sleep apnea and incident type 2 diabetes. *Sleep Med*. 2016;25:156-161.
- Jelic S, Padeletti M, Kawut SM, et al. Inflammation, oxidative stress, and repair capacity of the vascular endothelium in obstructive sleep apnea. *Circulation*. 2008;117:2270-2278.
- Lopez-Jimenez F, Sert Kuniyoshi FH, Gami A, Somers VK. Obstructive sleep apnea. *Chest*. 2008;133:793-804.
- Mills PJ, Dimsdale JE. Sleep apnea: a model for studying cytokines, sleep, and sleep disruption. *BrainBehav Immun*. 2004;18:298-303.
- Mehra R, Redline S. Sleep apnea: A proinflammatory disorder that co-aggregates with obesity. *J Allergy Clin Immunol*. 2008;121:1096-1102.
- Atan D, Sazak KF, Ozcan KM, Dere H. The relationship between platelet count and mean platelet volume with obstructive sleep apnea syndrome. *Kulak Burun Bogaz Ihtis Derg*. 2015;25:289-294.
- Ozsu S, Abul Y, Gulsoy A, Bulbul Y, Yaman S, Ozlu T. Red cell distribution width in patients with obstructive sleep apnea syndrome. *Lung*. 2012;190:319-326.
- Freire AX, Kadaria D, Avecillas JF, Murillo LC, Yataco JC. Obstructive sleep apnea and immunity: relationship of lymphocyte count and apnea hypopnea index. *South Med J*. 2010;103:771-774.
- Tamaki S, Yamauchi M, Fukuoka A, et al. Nocturnal hypoxic stress activates invasive ability of monocytes in patients with obstructive sleep apnoea syndrome. *Respirology*. 2009;14:689-694.
- Altunayoglu Cakmak V, Ozsu S, Gulsoy A, Akpınar R, Bulbul Y. The significance of the relative lymphocyte count as an independent predictor of cardiovascular disease in patients with obstructive sleep apnea syndrome. *Med Prin Pract*. 2016;25:455-460.
- Soehnlein O. Multiple roles for neutrophils in atherosclerosis. *Circ Res*. 2012;110:875-888.
- Dyugovskaya L, Polyakov A, Lavie P, Lavie L. Delayed neutrophil apoptosis in patients with sleep apnea. *Am J Resp Crit Care*. 2008;177:544-554.
- Geovanini GR, Wang R, Weng J, et al. Elevations in neutrophils with obstructive sleep apnea: The multi-ethnic study of atherosclerosis (MESA). *Int J Cardiol*. 2018;257:318-323.
- Lintermans LL, Stegeman CA, Heeringa P, Abdulahad WH. T cells in vascular inflammatory diseases. *Front Immunol*. 2014;5:504.
- Lange T, Dimitrov S, Born J. Effects of sleep and circadian rhythm on the human immune system. *Ann NY Acad Sci*. 2010;1193:48-59.
- Steiropoulos P, Kotsianidis I, Nena E, et al. Long-term effect of continuous positive airway pressure therapy on inflammation markers of patients with obstructive sleep apnea syndrome. *Sleep*. 2009;32:537-543.
- Nunez J, Minana G, Bodi V, et al. Low lymphocyte count and cardiovascular diseases. *Curr Med Chem*. 2011;18:3226-3233.
- Irwin MR, Wang M, Campomayor CO, Collado-Hidalgo A, Cole S. Sleep deprivation and activation of morning levels of cellular and genomic markers of inflammation. *Arch Intern Med*. 2006;166:1756-1762.
- Shi C, Pamer EG. Monocyte recruitment during infection and inflammation. *Nat Rev Immunol*. 2011;11:762-774.
- Faraut B, Boudjeltia KZ, Vanhamme L, Kerkhofs M. Immune, inflammatory and cardiovascular consequences of sleep restriction and recovery. *Sleep Med Rev*. 2012;16:137-149.
- Dinges DF, Douglas SD, Zaugg L, et al. Leukocytosis and natural killer cell function parallel neurobehavioral fatigue induced by 64 hours of sleep deprivation. *J Clin Invest*. 1994;93:1930-1939.
- Abdul RM, Chirakalwasan N. Obstructive sleep apnea and asthma. *Asian Pac J Allergy Immunol*. 2016;34:265-271.
- Ali Z, Ulrik CS. Obesity and asthma: A coincidence or a causal relationship? A systematic review. *Resp Med*. 2013;107:1287-1300.

26. Nadif R, Zerimech F, Bouzigon E, Matran R. The role of eosinophils and basophils in allergic diseases considering genetic findings. *Curr Opin Allergy Clin.* 2013;13:507-513.
27. Gibson PG, Dolovich J, Girgis-Gabardo A, et al. The inflammatory response in asthma exacerbation: changes in circulating eosinophils, basophils and their progenitors. *CLIN EXP ALLERGY.* 1990;20:661-668.
28. Choi JB, Loreda JS, Norman D, et al. Does obstructive sleep apnea increase hematocrit? *Sleep Breath.* 2006;10:155-160.
29. Guenard H, Vargas E, Villena M, Carras PM. Hpoxemia and the hematocrit in pathologic polycythemia due to altitude. *Bull Eur Physiopathol Respir.* 1984;20:319-324.
30. Khan AM, Ashizawa S, Hlebowicz V, Appel DW. Anemia of aging and obstructive sleep apnea. *Sleep Breath.* 2011;15:29-34.
31. Nguyen CD, Holty JC. Does untreated obstructive sleep apnea cause secondary erythrocytosis? *Resp Med.* 2017;130:27-34.
32. Stauffer ME, Fan T. Prevalence of anemia in chronic kidney disease in the United States. *PLOS ONE.* 2014;9:e84943.
33. Tsiara S, Elisaf M, Jagroop IA, Mikhailidis DP. Platelets as predictors of vascular risk: is there a practical index of platelet activity? *Clin Appl Thromb Hemost.* 2003;9:177-190.
34. Akyol S, Cortuk M, Baykan AO, et al. Mean platelet volume is associated with disease severity in patients with obstructive sleep apnea syndrome. *Clinics (Sao Paulo).* 2015;70:481-485.
35. Kurt OK, Yildiz N. The importance of laboratory parameters in patients with obstructive sleep apnea syndrome. *BloodCoagul Fibrinolysis.* 2013;24:371-374.
36. Koseoglu HI, Altunkas F, Kanbay A, Doruk S, Etikan I. Platelet-lymphocyte ratio is an independent predictor for cardiovascular disease in obstructive sleep apnea syndrome. *J Thromb Thrombolysis.* 2015;39:179-185.
37. Altintas N, Cetinoglu E, Yuceege M, et al. Neutrophil-to-lymphocyte ratio in obstructive sleep apnea; a multi center, retrospective study. *Eur Rev Med Pharmacol Sci.* 2015;19:3234-3240.
38. Kivanc T, Kulaksizoglu S, Lakadamyali H, Eyuboglu F. Importance of laboratory parameters in patients with obstructive sleep apnea and their relationship with cardiovascular diseases. *J Clin Lab Anal.* 2018;32:e22199.

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