İstanbul Med J 2014; 15: 216-20
DOI: 10.5152/imj.2014.75046

Can Neutrophil-to-Lymphocyte Ratio Serve as an Inflammatory Marker in Obesity?

Nötrofil Lenfosit Oranı Obezitede İnflamatuar Bir Belirteç Olarak Kullanılabilir mi?

Hanife Usta Atmaca[1], Feray Akbaş[1], İlker Nihat Ökten[1], Eda Nuhoğlu[1], Berrin Belçik İnal[2]

Abstract / Özet

Objective: Obesity is a disease that is known to stimulate low-grade inflammation. N/L ratio has been started to be used as an indicator of systemic inflammation. This study aims to examine the relationship between obesity and N/L ratio over anthropometric measurements, obesity grade, and some biochemical parameters.

Methods: A total of 96 obese patients (mild-moderate and severe) who were being monitored in an obesity outpatient clinic, who had no concomitant disease and no history of smoking and drug use and 20 patients of normal weight with the same characteristics, as the control group, were included in the study. Anthropometric measurements were recorded, and BMI was calculated. Biochemical tests and total blood counts were performed. N/L ratio was obtained by dividing the neutrophil count by lymphocyte count. The results were evaluated using the SPSS statistical analysis program.

Results: A significant increase was present in the neutrophil and lymphocyte counts of the morbid obese group compared to the control groups. Due to the increased neutrophil and lymphocyte counts, even though the L/N ratio increased, it was not statistically significant. The increase in total leukocyte count of morbid obese cases was statistically significant compared to mild obese cases. While N/L ratio demonstrated a strongly positive correlation with total leukocyte count and neutrophil count, it demonstrated a weakly positive correlation with waist circumference and with hip circumference.

Conclusion: N/L ratio increases by obesity grade and reveals that the concomitant inflammatory response increases. A high count of circulating neutrophils in obese patients might be considered an acute inflammatory response to a chronic inflammatory state. Therefore, N/L ratio might be used as an inflammatory marker in obese patients and might be helpful in the prediction of cardiovascular and metabolic risks for the patient.

Keywords: Obesity, neutrophil to lymphocyte ratio, inflammation

Amaç: Obezite düşük dereceli inflamasyonu uyaran bir hastalık olarak bilinmektedir. Nötrofil lenfosit (N/L) oranı da sistemik inflamasyon belirteci olarak kullanılmaya başlanmıştır. Bu çalışmada; N/L oranı obezite ilişkisinin antropometrik ölçümler, obezite derecesi ve biyokimyasal parametreler üzerinden araştırılması amaçlanmıştır.

Yöntemler: Obezite polikliniğinde izlenen, ek hastalığı, sigara ve ilaç kullanımı olmayan 96 obez hasta (hafif-orta ve ağır) ve aynı özelliklerde 20 sağlıklı normal kilolu hasta çalışmaya dahil edildi. Antropometrik ölçümler yapıldı ve VKİ hesaplandı. Biyokimyasal testler ve hemogram bakılarak N/L oranı nötrofil oranının lenfosit oranına bölünmesiyle hesaplandı. Sonuçlar SPSS istatistiksel analiz programıyla değerlendirildi.

Bulgular: Kontrol grubuyla karşılaştırılınca morbid obez grupta hem nötrofil, hem lenfosit oranında anlamlı artış mevcuttu. Ancak her iki grup da arttığından N/L oranı artmasına rağmen, sonuç istatistiksel olarak anlamlı değildi. Morbid obezlerdeki total lökosit artış oranı hafif obezlere göre istatistiksel olarak anlamlı şekilde yüksekti. N/L oranı total lökosit ve nötrofil sayımı ile güçlü pozitif korelasyon gösterirken, bel ve kalça çevresiyle zayıf korelasyon göstermekteydi.

Sonuç: N/L oranı obezite oranıyla artar ve eşlik eden inflamatuar yanıtın da arttığına işaret eder. Obez hastalarda görülen yüksek nötrofil oranı kronik inflamatuar durum üzerine eklenmiş akut inflamatuar cevap olarak kabul edilebilir. Bu nedenle; N/L oranı obez hastalarda inflamatuar bir belirteç olarak kullanılabilir ve hastanın kardiyovasküler ve metabolik riskini belirlemede yardımcı olabilir.

Anahtar Kelimeler: Obezite, nötrofil lenfosit oranı, inflamasyon

Introduction

Obesity and obesity-associated diseases increase gradually worldwide, primarily in developed countries. As this situation is similar in our country, according to the latest data, the obesity rate has reached 30.3%, and the morbid obesity rate has reached 2.9% in our country (1).

Obesity is a condition, constantly stimulating low-grade inflammation. In recent years, it has been revealed that adipose tissue is an important source of cytokines containing pro-inflammatory mediators. TNF-alpha, IL-6, IL-1, IL-8, and adipokines (leptin, resistin, and visfatin) are some of these cytokines. Cytokines, especially IL-6, are mediators, stimulating CRP formation (2-5). Intense macrophage stimulation has been demonstrated in fat tissue of severely obese patients (6). Macrophage activation and accumulation in adipose tissue play a significant role in the development of insulin resistance, impaired glucose intolerance, and diabetes (7, 8).

In studies performed in recent years, it has been revealed that a constant state of inflammation also plays an important role in the development of cardiovascular disease (9). The state of inflammation occurring in obesity plays a role in the etiopathogenesis of many developing diseases (diabetes, atherosclerosis). Immune dysfunction (cellular failure) caused by an inflammatory state plays a role in the development of diseases, such as cancer and scar infection.

We may use a wide variety of markers to demonstrate systemic inflammation. Recently, N/L ratio has been started to be used as a marker, since it is both easily accessible and cheap and since it

This orginal article was presented as the National Congress of Internal Medicine. National Congress of Internal Medicine 2014, Antalya, Türkiye.

[1]Department of Internal Medicine, İstanbul Training and Research Hospital, İstanbul, Türkiye
[2]Department of Biochemistry, İstanbul Training and Research Hospital, İstanbul, Türkiye

Address for Correspondence
Yazışma Adresi:
Hanife Usta Atmaca, Department of Internal Medicine, İstanbul Training and Research Hospital, İstanbul, Türkiye
Phone.: +90 530 312 29 73
E-mail: hanifeusta@yahoo.com

Received/Geliş Tarihi:
02.08.2014

Accepted/Kabul Tarihi:
07.08.2014

Table 1. Clinical and laboratory characteristics of the study population

	Healthy subjects (n=20)	Fat, obese patients (n=51)	Morbid obese patients (n=45)	p-value
Gender (F/M)	17/3	44/7	40/5	=0.8*
Age (year)	40.5±13.5	40.4±11	42.3±11.9	=0.721**
BMI (kg/m^2)		35 (32-38)	43 (41-46)	**<0.0001**
Ratio	1.63 (1.18-2.20) [a,b]	1.6 (1.5-1.91)[c]	1.95 (1.56-2.42)	=0.013***
Neutrophil	3.14 (2.93-4.10)[d,e]	3.97 (3.07-4.53)[f]	4.9 (3.8-6.6)	<0.0001***
Lymphocytes	2.16±0.76[g]	2.35±0.50	2.63±0.68	=0.015**$^{\delta}$
Leukocyte	7.01±1.01	7.09±1.55	8.73±2.37	<0.0001
Glucose		94±14	107±26	=0.006
LDL		114±34	112±24	=0.791
HDL		51±8	50±8	=0.614
Triglycerides		113 (83-166)	134 (98-199)	=0.140
Insulin		16.98±7.42	23.39±16.19	=0.152
Waist circumference		112±8.8	126.5±14,3	<0.0001
Hip circumference		122±9	133.5±11	<0.0001

Non-parametric tests were shown as median (25th-75th); parametric tests were shown as mean±SD.
*p value was calculated using chi-square test.
** p value was calculated using one-way ANOVA. δ Post hoc Tukey HSD test was used.
*** p value was calculated using Kruskal-Wallis test.
[a]p=0.74 versus obese
[b]p=0.059 versus morbid obese
[c]p=0.005 versus morbid obese
[d]p=0.147 versus obese
[e]p=0.0001 versus morbid obese
[f]p<0.0001 versus morbid obese
[g]p=0.019 versus morbid obese

Table 2. Correlations of variables studied

Variable pairs	Correlation coefficient	P
Ratio-neutrophil	0.66	<0.0001
Ratio-lymphocyte	-0.3	<0.001
Ratio-leukocyte	0.49	<0.0001
Ratio-waist circumference	0.33	=0.032
Ratio-hip circumference	0.37	=0.015
Ratio-HDL	-0.34	=0.032
Ratio-age	-0.21	=0.025

is also an indicator of the prognosis and systemic inflammation in various patient groups (10-15). N/L ratio has been demonstrated as a mortality determinant in cardiovascular studies and has been correlated to other inflammatory markers in patients with chronic renal failure (10-15).

This study has been designed to examine the relationship between obesity and N/L ratio, which has an increasing prevalence day by day and which is demonstrated to be closely related to many systemic diseases and chronic inflammation, over anthropometric measurements, obesity grade, and some biochemical parameters.

Methods

51 (44 females, 7 males) mild-moderate obese (Body mass index: BMI 30-40) and 45 (40 males, 5 females) severely obese patients (BMI≥ 40) who were being monitored in an obesity outpatient clinic and had no concomitant disease or history of smoking and drug use and 20 (17 females, 3 males) patients of normal weight, as the control group, with the same characteristics from an internal medicine outpatient clinic were included in the study. At baseline, anthropometric measurements (age, height, weight, and waist and hip ratio) were recorded, and body mass index (BMI) was calculated by dividing body weight by the square of the height. Blood samples were collected at rest in the morning and after 12 hours of fasting from the antecubital vein, and bio-chemical tests were performed. Total blood counts were performed by using the volume conductivity scatter method with a Coulter LH 780 (Beckman Coulter Inc., Miami, Fl, USA). N/L ratio was obtained by dividing neutrophil count by lymphocyte count.

Statistical Analysis

The parameters that were used for bio-statistical analysis of the study data included the mean, standard deviation, frequency, and percentage. For the comparison of frequency and percentage between the groups, the chi-square test was used. For the comparison of more than two group means, one-way ANOVA was used. For significant differences by ANOVA, the subgroup differences were analyzed using post hoc Tukey's HSD tests for the pairwise comparisons. When required (depending on the homogeneity test), non-parametric Kruskal-Wallis one-way variance analysis and post hoc Mann-Whitney U-test were used as appropriate. Pearson correlation analyses (r) were used to determine the mathematical correlations between the variables. The significance was set at $p \leq 0.05$. The SPSS (version 11.5) software package was used for the statistical analyses. Microsoft Excel (2007 version) was used for the regression analysis.

Results

The clinical and laboratory characteristics of the study population are shown in Table 1.

In the study, a significant increase was present in neutrophil count of the morbid obese group compared to the obese and control groups ($p<0.0001$). Lymphocyte count was also significantly high in the morbid obese group compared to the control group ($p=0.015$). Due to the increased neutrophil and lymphocyte counts, even though the N/L ratio increased, it was not statistically significant. The increase in total leukocyte count of morbid obese cases was statistically significant compared to mild obese cases ($p<0.0001$).

While the N/L ratio demonstrated a strongly positive correlation with total leukocyte count and neutrophil count ($p<0.0001$), it demonstrated a weakly positive correlation with waist circumference ($p=0.032$) and with hip circumference ($p=0.015$). Similarly, it demonstrated a weakly negative correlation with age and HDL cholesterol level (Table 2, Figure 1).

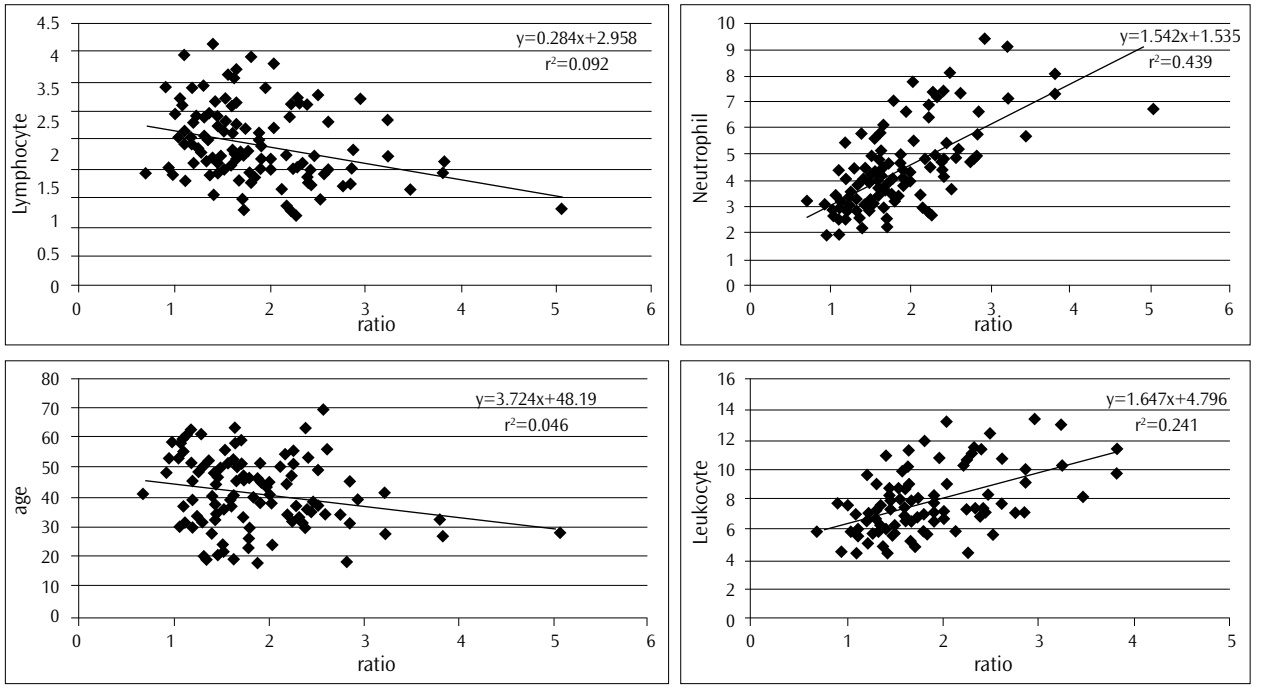

Figure 1. Scatterplot figures for positive and negative correlations of N/L ratio.

Discussion

Leukocytes play a role in the formation and progression of obesity and many obesity-associated diseases. They also play roles in the formation and development of micro- and macro-vascular complications of type 2 diabetes (16). In the meantime, they are associated with atherosclerotic diseases and are considered a risk factor for cardiovascular diseases (9, 17, 18). Leukocytes contribute to endothelial damage due to their adhesiveness on the blood vessel wall, which varies under stress. These characteristics have led to research on diseases or conditions stimulating increased leukocyte count.

Obesity is a condition stimulating reactive leukocytosis. In severely obese individuals, macrophage accumulation in fatty tissue and cortisol and insulin levels increase in parallel to increased fat tissue, and leukocytosis increases via leptin secretion from adipocytes (19). Leukocytes are a part of inflammation, and active leukocytes lead to changes in blood viscosity, acceleration of atherosclerosis, endothelial dysfunction, stimulation of plaque rupture, and thrombus formation by causing the secretion of abnormal cytokines (20, 21). Leukocytosis in obesity plays a role in the development of glucose intolerance, type 2 diabetes, and cardiovascular disease. Increased levels of insulin have been detected in our study, as well-mostly in severely obese individuals. This level has correlated positively with leukocyte count. This demonstrates the tendency toward metabolic syndrome of the patients.

Neutrophils are a part of the immune system and demonstrate phagocytic and anti-microbial activity by the proteins contained in their granules. When neutrophils of obese individuals are compared to normal individuals, it has been demonstrated that glucose oxidation (22) and bactericidal capacity decreased (23, 24) and chemotactic ability is weakened, and these characteristics are correlated with BMI. It has been observed that the maturation ability of monocytes in obese patients decreased and that oxidative burst increased.

Lymphocytes have also been accepted as the single prognostic factor in several diseases. In a study performed by Omen SR et al., it has been demonstrated that peripheral lymphocyte counts were inversely proportional with atherosclerosis in type 2 diabetes patients and that 5-year survival in coronary artery disease was better in patients with high lymphocyte counts compared to patients with low lymphocyte counts (25). The cause of decreased lymphocyte count in cardiovascular disease is not exactly understood. Again, lymphocyte count has been stated to be an inversely prognostic factor in patients with cardiac failure (26). On the other hand, in obese individuals, as detected in our study, as well, increased lymphocyte count has been demonstrated, contrary to this situation. More comprehensive studies with lymphocyte subgroups, their counts, and their roles are required for clarifying the reasons of this situation.

Obesity is a condition that increases leukocyte count. In early-phase studies, it has been demonstrated that neutrophil count did not change, and nevertheless, adhesion molecules on the neutrophil surface changed in severely obese patients (27, 28). In other studies, it has been observed that neutrophils were not activated, and circulating neutrophil count increased in severely obese patients (29, 30). In severely obese patients, it has been reported that leptin and TNF-alpha were possible mechanisms in neutrophil activation (31) and that leptin stimulated myeloid differentiation of progenitor cells in bone marrow (32). In our study, no change was observed in total leukocyte count of mild obese individuals. This situation may be attributed to the limited number of patients and to the leukocyte sub-groups not studied. We think that since the leukocyte ratio increased in direct proportion to adipose tissue, the higher ratio of mild overweight patients in the group also might have limited the increase in leukocyte count. In this study,

while an increase in neutrophil count was demonstrated in all obese groups, there was a more marked and statistically significant increase in neutrophil count of severely obese patients. Similarly, lymphocyte counts also increased as BMI increased. This situation paralleled the neutrophil count; this ratio increased in severely obese patients, and the neutrophil-lymphocyte ratio was also higher in severely obese patients. This situation supports the opinion that as obesity level increases, inflammation also increases.

Fatty tissue leukocyte counts change by age and total fat tissue. While BMI and total fat tissue increase, leukocyte, neutrophil, and lymphocyte counts increase; they are inversely proportional to age (30). Similarly, in our study, N/L ratio and age were detected to be negatively correlated.

It has been accepted that anthropometric measurements are closely associated with inflammatory state, and BMI and waist circumference are potent indicators of inflammation (33). These parameters are also a part of the metabolic syndrome. In several studies, it has been demonstrated that waist circumference and BMI were closely associated with inflammation, especially with leukocyte count. This association has been found to be more potent in women (33). Again, in a study conducted in obese adolescent women, it has been demonstrated that leukocyte count positively correlated with body mass index and total fat tissue. Similarly, in our findings, it has been demonstrated that absolute neutrophil and absolute lymphocyte counts correlated positively with body mass index. This increase was observed to be more apparent, especially in morbid obese individuals. Waist-hip ratio might be accepted as a new indicator of inflammation in visceral obesity (33).

Significant weight loss in obese individuals ensures that leukocytosis and acute phase reactants return to normal gradually. In obese individuals who have been followed for 2 years after bariatric surgery and who have lost a significant amount of weight by surgery (29.3±16.2 kg), significant decreases up - 12.2% in leukocytes and significant decreases in neutrophil (11.7%) and lymphocyte (6.9%) ratios have been observed (30). Similarly, inflammatory markers have regressed in the long term at post-surgery weight loss (34, 35). A decrease in oxidative stress markers has been also demonstrated within 3 weeks at patients losing weight by a strict diet and exercise program (36). While Cottam et al. (27) did not observe a significant change in neutrophil and total monocyte counts of patients who lost weight by surgery at their follow-ups up to Month 12, they observed decreases in CD14+/CD16+ monocyte counts and in monocyte CD62L ratio, which have inflammatory roles.

Limitation of the study: Lack of measurement of other inflammatory markers is our limitation of the study.

Conclusion

N/L ratio increases by obesity grade and, therefore, by increased fat tissue and reveals that the concomitant inflammatory response increases. A high count of circulating neutrophils in obese patients might be considered an acute inflammatory response to a chronic inflammatory state. Therefore, N/L ratio might be used as an inflammatory marker in obese patients and might be helpful in the prediction of cardiovascular and metabolic risks for the patient, and the contribution of the treatment in the prevention of obesity-associated diseases might be monitored with a simple method by the follow-up of the ratio along with treatments for weight loss.

Ethics Committee Approval: Ethics committee approval was received for this study.

Informed Consent: Written informed consent was not obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept - H.U.A., F.A.; Design - H.U.A., F.A.; Supervision - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Funding - H.U.A., F.A.; Materials - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Data Collection and/or Processing - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Analysis and/or Interpretation - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Literature Review - H.U.A., F.A.; Writer - H.U.A., F.A.; Critical Review - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: The authors declared that this study has received no financial support.

Etik Kurul Onayı: Bu çalışma için etik komite onayı alınmıştır.

Hasta Onamı: Yazılı hasta onamı bu çalışmaya katılan hastalardan alınmıştır.

Hakem Değerlendirmesi: Dış bağımsız.

Yazar Katkıları: Fikir - H.U.A., F.A.; Tasarım - H.U.A., F.A.; Denetleme - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Kaynaklar - H.U.A., F.A.; Malzemeler - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Veri Toplanması ve/veya işlemesi - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Analiz ve/veya Yorum - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.; Literatür taraması - H.U.A., F.A.; Yazıyı Yazan - H.U.A., F.A.; Eleştirel İnceleme - H.U.A., F.A., İ.N.Ö., E.N., B.B.İ.

Çıkar Çatışması: Yazarlar çıkar çatışması bildirmemişlerdir.

Finansal Destek: Yazarlar bu çalışma için finansal destek almadıklarını beyan etmişlerdir.

References

1. Türkiye Beslenme ve Sağlık Araştırması-2010 ön çalışma raporu. S.B. Türkiye Halk Sağlığı Kurumu Verileri 2010.
2. Hotamisligil GS, Shargill NS, Spiegelman BM. Adipose expression of tumor necrosis factor-alpha: direct role in obesity-linked insulin resistance. Science 1993; 259: 87-91. [CrossRef]
3. Fried SK, Bunkin DA, Greenberg AS. Omental and subcutaneous adipose tissues of obese subjects release interleukin-6: depot difference and regulation by glucocorticoid. J Clin Endocrinol Metab 1998; 83: 847-50. [CrossRef]
4. Bastard JP, Maachi M, Tran Van Nhieu J, Jardel C, Bruckert E, Grimaldi A, et al. Adipose tissue IL-6 content correlates with resistance to insulin activation of glucose uptake both in vivo and in vitro. J Clin Endocrinol Metab 2002; 87: 2084-9. [CrossRef]
5. Samad F, Yamamoto K, Pandey M, Loskutoff DJ. Elevated expression of transforming growth factor-beta in adipose tissue from obese mice. Mol Med 1997; 3: 37-48.
6. Weisberg SP, McCann D, Desai M, Rosenbaum M, Leibel RL, Ferrante AW et al. Obesity is associated with macrophage accumulation in adipose tissue. J Clin Invest 2003; 112: 1796-808. [CrossRef]
7. Bastard JP, Maachi M, Lagathu C, Kim MJ, Caron M, Vidal H, et al. Recent advances in the relationship between obesity, inflammation, and insulin resistance. Eur Cytokine Netw 2006; 17: 4-12.

8. Patel PS, Buras ED, Balasubramanyam A. The role of the immune system in obesity and insulin resistance. J Obes 2013; 2013: 616193. [CrossRef]
9. Danesh J, Whincup P, Walker M, Lennon L, Thomson A, Appleby P, et al. Low grade inflammation and coronary heart disease:prospective study and opdated meta-analyses. BMJ 2000; 321: 199-204. [CrossRef]
10. Ohno Y, Nakashima J, Ohori M, Hatano T, Tachibana M. Pretreatment neutrophil-to-lymphocyte ratio as an independent predictor of recurrence in patients with nonmetastatic renal cell carcinoma. J Urol 2010; 184: 873-8. [CrossRef]
11. Bhatti I, Peacock O, Lloyd G, Larvin M, Hall RI. Preoperative hematologic markers as independent predictors of prognosis in resected pancreatic ductal adenocarcinoma: neutrophil-lymphocyte versus platelet-lymphocyte ratio. Am J Surg 2010; 200: 197-203. [CrossRef]
12. Lee YY, Choi CH, Kim HJ, Kim TJ, Lee JW, Lee JH, Bae DS, Kim BG. Pretreatment neutrophil: lymphocyte ratio as a prognostic factor in cervical carcinoma. Anticancer Res 2012; 32: 1555-61.
13. Gibson PH, Cuthbertson BH, Croal BL, Rae D, El-Shafei H, Gibson G, et al. Usefulness of neutrophil/lymphocyte ratio as predictor of new-onset atrial fibrillation after coronary artery bypass grafting. Am J Cardiol 2010; 105: 186-91. [CrossRef]
14. Azab B, Zaher M, Weiserbs KF, Torbey E, Lacossiere K, Gaddam S, et al. Usefulness of neutrophil to lymphocyte ratio in predicting short- and long-term mortality after non-ST-elevation myocardial infarction. Am J Cardiol 2010; 106: 470-6. [CrossRef]
15. Uthamalingam S, Patvardhan EA, Subramanian S, Ahmed W, Martin W, Daley M, et al. Utility of the neutrophil to lymphocyte ratio in predicting long-term outcomes in acute decompensated heart failure. Am J Cardiol 2011; 107: 433-8. [CrossRef]
16. Tong PC, Lee KF, So WY, MBCHB, Margaret HN, Chan WB, et al. White blood cell count is associated with macro-and microvascular complications in chinese patients with type 2 diabetes. Diabetes Care 2004; 27: 216-22. [CrossRef]
17. Ernst E, Hammerschmidrt DE, Bagge U, Matrai A, Dormandy JA. Leukocytes aand the the risk of ischemic diseases. JAMA 1987; 257: 2318-24. [CrossRef]
18. Dannesh J, Collins R, Appleby P, Peto R. Association of fibrinogen, C-reactive protein, albümin,or leukocyte count with coronary heart disease:meta-analyses of prospective studies. JAMA 1998; 279: 1477-82. [CrossRef]
19. Wabitsch M, Jensen PB, Blum WF, Christoffersen CT, Englaro P, Heinze E, et al. Insulin and cortisol promote leptin production in cultured human fat cells. Diabetes 1996; 45: 1435-8. [CrossRef]
20. Hofmann MA, Schiekofer S, Kanitz M, Klevesath MS, Joswig M, Lee V, et al. Insufficient glycemic control increases nuclear factor-kappa B binding activity in peripheral blood mononuclear cells isolated from patients with type 1 diabetes. Diabetes Care 1998; 21: 1310-6. [CrossRef]
21. Shanmugam N, Reddy MA, Guha M, Natarajan R. High glucose-induced expression of proinflammatory cytokine and chemokine genes in monocytic cells. Diabetes 2003; 52: 1256-64. [CrossRef]
22. Kjösen B, Bassöe HH, Myking O. The glucose oxidation in isolated leukocytes from female patients suffering from overweight or anorexia nervosa. Scand Clin Lab Invest 1975; 35: 447-54. [CrossRef]
23. Palmblad J, Hallberg D,Engstedt L. Polymorphonuclear function after small intestinal shunt operation for morbid obesity. Br J Haematol 1980; 44: 101-8. [CrossRef]
24. Palmblad J, Rossner S. Granulocyte functions during treatment of obesity. Int J Obes 1979, 3: 119-22.
25. Ommen SR, Gibbons RJ, Hodge DO, Thomson SP. Usefulness of the lymphocyte concentration as a prognostic marker in coronary artery disease. Am J Cardiol 1997 Mar 15; 79: 812-4. [CrossRef]
26. Ommen SR, Hodge DO, Rodeheffer RJ, McGregor CG,Thompson SP, Gibbons RJ. Predictive power of the relative lymphocyte concentration in patients with advances heart failure. Circulation 1998; 97: 19-22. [CrossRef]
27. Cottam DR, Schaefer PA, Shaftan GW, L Velcu L, Angus LD. Effect of surgically-induced weight loss on leukocyte indicators of chronic inflammation in morbid obesity. Obesity Surgery 2002; 12: 335-42. [CrossRef]
28. Nijhuis J, Rensen SS, Slaats Y, van Dielen FM, Buurman WA, Greve JW. Neutrophil activation in morbid obesity, chronic activation of acute inflammation. Obesity (Silver Spring) 2009; 17: 2014-8. [CrossRef]
29. Pratley RE, Wilson C, Bogardus C.Relation of the White blood cell counts to obesity and insulin resistance; effect of race and gender. Obes Res 1995; 3: 563-71. [CrossRef]
30. Dixon JB, O' Brien PE. Obesity and the White Blood Cell Count: Changes with Sustained Weight Loss. Obes Surg. 2006; 16: 251-7. [CrossRef]
31. Zarkesh-Esfahani H, Pockley AG, Wu Z, Hellewell PG, Weetman AP, Ross RJM. Leptin indirectly activates human neutrophils via induction of TNF-α. J Immunol 2004; 172: 1809-14. [CrossRef]
32. Laharrague P, Oppert JM, Brausset P, Charlet JP, Campfield A, Fontanilles AM et al. High concentration of leptin stimulates myeloid differentiation from human bone marrow CD34+ progenitors: potential involvement in leukocytosis of obese subject. Int J Obes Relat Metab Disord 2000; 24: 1212-6. [CrossRef]
33. Arbel Y, Birati EY, Shapira I, Finn T, Berliner S, Rogowski O .Comparison of different anthropometric measurements and inflammatory biomarkers. Int J Inflam 2012; 2012: 124693. [CrossRef]
34. Van Dielen FM, Buurman WA, Hadfoune M, Nijhuis J, Greve JW. Macrophage inhibitory factor, plasminogen activator inhibitor-1, other acute phase proteins, and inflammatory mediators normalize as a result of weight loss in morbidly obese subjects treated with gastric restrictive surgery. J Clin Endocrinol Metab 2004; 89: 4062-8. [CrossRef]
35. Vázquez LA, Pazos F, Berrazueta JR, Fernández-Escalante C, García-Unzueta MT, Freijanes J et al. Effects of changes in body weight and insulin resistance on inflammation and endothelial function in morbid obesity after bariatric surgery. J Clin Endocrinol Metab 2005; 90: 316-22. [CrossRef]
36. Roberts CK, Won D, Pruthi S, Kurtovic S, Sindhu RK, Vaziri ND, et al. Effect of a short-term diet and exercise intervention on oxidative stress, inflammation, MMP-9, and monocyte chemotactic activity in men with metabolic syndrome factors. J Appl Physiol 2006; 100: 1657-65. [CrossRef]