Original Research
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Prognostic value of hematological parameters

Influenza

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Abstract

Aim: Acute bacterial and viral infections are usually associated with elevations of the mean platelet volume. We correlated infection with influenza changes in mean platelet volume (MPV), neutrophil-to-lymphocyte ratio (NLR), and platelet-to-lymphocyte ratio (PLR), to determine whether these might be predictors for the duration of hospitalization or mortality. Material and Method: A total of 122 influenza patients (54 males and 68 females), including 87 children and 35 adults, and 42 age-gender-matched healthy individuals (18 males and 24 females) including 25 children and 17 adults were included in the study. Hematologic tests were conducted on the patients and controls. Linear regression analysis was used to determine independent predictors of hospitalization. Results: The MPV was significantly higher in influenza patients [10.7 (min/max 7.5-15) fL] than in the healthy control group [7.8(min/max 5.7-10.8)fL, p<0.001]. The NLR and PLR were similar in both groups. There was no correlation between MPV, NLR, or PLR and mortality. Predictors of hospitalization were determined to be neutrophil level (NL) and NLR and PLR ratios (p = 0.00, p = 0.035 and p = 0.041, respectively). Discussion: Neutrophil, MPV, NLR, and PLR were significantly higher in the influenza group. While the MPV was not determined to correlate with the length of stay and mortality in the patient group, the higher levels of NLR and PLR and increased neutrophil levels predicted the duration of hospitalization.

Keywords

Influenza; Mean Platelet Volume; Neutrophil-To-Lymphocyte Ratio; Platelet-To-Lymphocyte Ratio

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Introduction

Mean platelet volume (MPV) levels are higher than normal levels in severe infections such as acute septicemia and pneumonia [1,2,3]. It has been reported that MPV levels are high even in cases of bacterial septicemia without thrombocytopenia and it has been reported that these values decrease after treatment [4]. MPV is a well-known indicator of the presence of large platelets in young and peripheral blood. MPV may increase aggregates the levels of released substances by themselves and consequently obstructive arterial or venous diseases can easily occur. It has been reported that high MPV levels are associated with acute diseases such as myocardial infarction, venous thromboembolism, and stroke [5,6,7]. In fact, some studies suggest that MPV elevation may have prognostic value when the platelet count is low [1,2,3]. The mortality rate (46%) was higher in patients with increased MPV and decreased platelet count. Higher MPV levels were independently associated with high hospital mortality after admission to intensive care units [8].

There are many studies in which MPV values are investigated in viral infections [9,10,11,12,13,14,15,16]. In a previous study, some patients with respiratory syncytial virus (RSV) infections had relatively low MPVs. In a study that measured MPVs in a series of consecutive patients in various settings, RSV infections were found to have a strong correlation with a decrease in mean platelet volume [9]. Previous viral studies have supported the findings that MPV levels are elevated in some chronic viral diseases, such as chronic hepatitis B and C, whereas MPV levels decrease in some acute viral diseases, such as rotavirus gastroenteritis, HIV, and RSV. MPV levels were significantly lower in patients with acute hepatitis A as compared to the healthy control group. The study demonstrated that MPV may be a negative acute phase reactant for acute hepatitis A [10]. MPV is inversely correlated with platelet count. Therefore, MPV is usually increased in patients with thrombocytopenia caused by a viral infection [11, 13, 14, 15].

The neutrophil-to-lymphocyte ratio (NLR) and the platelet-to-lymphocyte ratio (PLR) are accepted as good predictors of systemic infection. Both NLR and PLR have been proven to be prognostic and predictive factors in a number of viral diseases [17, 18, 19]. In influenza, hemophagocytic lymphohistiocytosis occurs because of an increase in proinflammatory cytokines, which increase hemophagocytic macrophage proliferation and activation in the reticuloendothelial system. As a result, the numbers of leucocytes and platelets decrease rapidly [20, 21, 22].

In routine diagnostic laboratory examinations, there are significantly more leukopenia, neutropenia, and lymphopenia in cases of influenza when compared with control or other upper respiratory tract infections. However, rates of neutrophil/lymphocyte were significantly higher at the time of admission to the hospital [23]. The neutrophil/lymphocyte ratio is a practical systemic inflammation indicator and has been studied as a prognostic factor [17, 23].

To the best of our knowledge, MPV in patients with influenza infections has not been previously studied. This study evaluates changes in MPV levels, and NRL and PLR ratios in patients who have been diagnosed with influenza in order to determine whether these factors might be predictors for the duration of hospitalization or mortality.

Material and Method

Patients and controls

This study was performed according to the guidelines of the Helsinki Declaration and was approved by the local ethics committees of the Education and Research Hospital of Recep Tayyip Erdoğan University in Rize, Turkey. The study was conducted between 01 March 2016 and 30 May 2016 and was approved by the Institutional Board of the hospital. The included patients had been admitted to the chest diseases, infectious diseases, and pediatric clinics with flu symptoms and were hospitalized by virtue of having a probable H1N1 diagnosis. Nasal and nasopharyngeal swab samples of all participants were analyzed by real-time PCR for influenza A (H1N1), influenza A (H3N2), and influenza B pathogens, using the influenza surveillance test package in Turkey Public Health Institutions-Reference Microbiology Laboratories. Patient and control groups had more children than adults in the study. A total of 122 [54 (44.3%) male and 68 (55.7) female] patients aged between 1 and 70 years [87 (71.3%) children and 35 (28.7%) adults] were admitted to the study. A total of 42 [18 (42.9%) male and 24 (57.1%) female] similar age group ((controls aged between 1 and 70 years (25 children (59.5%) and 17 (40.5%) adults)) healthy individuals were included in the study. The subjects in the control group did not have flu symptoms and had no history of contact with any of the influenza patients. The study excluded patients and adult control subjects with a history of diabetes, hypertension, hyperlipidemia, coronary artery disease, chronic obstructive pulmonary disease, cirrhosis, portal hypertension, hematological disorders, and malignancies. All participants were non-smokers with no history of alcohol or substance use.

Hospitalization period

"First day" was when clinical diagnosis of the condition was made. "Recovery day" was the date in which all clinical symptoms disappeared and normal values were measured for each parameter. The length of the hospital stay was the period from admission to discharge.

Hematological tests

Tests for Hb, platelets, white blood cell counts (WBC), and MPV were performed using the Abbott Cell-Dyn® Ruby analyzer (Abbott Diagnostics, IL, USA).

Statistical analysis

The SPSS 17.0 program was used. Kruskal Wallis, Mann Whitney U test, Chi-square and Fisher's exact tests were used in the comparison. Spearman analysis was applied in the correlation analysis. Linear regression analysis was performed with predictors of hospital stay. $P<0.017$ in triple comparisons, and $p<0.05$ significance level in binary comparisons were considered statistically significant.

Results

In this study, laboratory analyses showed that lymphocyte and platelet levels were significantly lower ($p<0.05$) and neutrophil and MPV levels were significantly higher ($p<0.05$) (see Figure 1) in influenza patients when compared to the control group. In addition, the NLR and PLR ratios were found to be significantly

higher (p <0.001, p = 0.010, respectively). The MPV of the influenza patients group [10.7 (min/max 7.5-15) fL] was higher than that of the control group [7.8(min/max 5.7-10.8)fL, p<0.001], which was statistically significant. Platelet numbers [256 (min/max 71-444) x109/L] of the patients group were lower than those of the control group [318.5 (min/max 123-701) x109/L], (p =0.002). The WBC counts of the influenza patients group was [9.6 (min/max 2.5-18.7)x109/L] and was [10 (min/max 4.5-12.1) x109/L] in the control group; the difference was not statistically significant (p=0.097). The NLR of the influenza patient group was 2.1 (min/max 0-13.7) and was 1.1 (min/max 0.5-1.7) in the control group and the PLR of the influenza patient group was 10 (min/max 2.1-36.6) and was 8.1 (min/max 2.1-12.8) in the control group; both levels were statistically significant (p <0.001, p = 0.010, respectively) (see Table 1).

In this study, the pediatric population was more represented in the influenza patient group. A total of 122 [54 (44.3%) male and 68 (55.7) female] patients aged1 to 70 years [87 (71.3%) children and 35 (28.7%) adults] were admitted to the study group. A total of 42 healthy individuals [18 (42.9%) male and 24 (57.1%) female] aged 1 to 70 years [25 children (59.5%) and 17 (40.5%) adults)] were included in the control group. The ages, sex, and age groups of the influenza patient group and the control group were similar (p> 0.05, see Table 2).

In the influenza group (n = 122), significantly higher fever and cough symptoms in the child age group was found; dyspnoea symptoms were higher in the adult age group (p<0.001 for both); hospitalization and the duration of illness were similar to each other. Microbiological factors of the patients were: Influenza was identified as H1N1 47 (28.7%), influenza H3N2 39 (23.8%), and influenza B 36 (22.2%). In adults, influenza H3N2 17 (48.6%) was the most common causative agent and influenza B 33 (37.9%) was the most common causative agent in children. The mean duration of illness in the influenza patients was 8 days (min/max 4-21) and the mean duration of hospitalization was 5 days (min/max 1-11 days) (see Table 3).

WBC, lymphocyte, and platelet levels were found to be lower in the adult age group (p = 0.018, p = 0.037, p = 0.001, respectively) in the influenza patients (n = 122) according to age groups (see Table 4).

MPV values were not significantly different between the groups (p = 0.113), when compared between the adult and the pediatric age groups (although both groups showed an increase compared to the control group, see Table 1). Similarly, there was no significant difference in levels of NLR and PLR in the adult and children groups (p = 0.079 and p = 0.421, respectively). There was no correlation between MPV and the length of hospitalization (Spearman rho = 0.013, p = 0.885). The increase in neutrophil and NLR and PLR rates predicted the length of hospital stay (p = 0.00, p = 0.035 and p = 0.041, respectively) (see Table 5). In the patient group (n = 122), there were no differences in the three mortality types in terms of gender, virus type, duration of hospital stay, or duration of illness (p> 0.05 for all, see Table 6). There was no correlation between MPV and mortality (Spearman rho = 0.096, p = 0.291). Neutrophil level and NLR

Table 1. Comparison of lab variables of two groups

	Patient (n=122)	Control (n=42)	
	M (mn-mx)	M (mn-mx)	p
Laboratory			
WBC (x10^9/L)	9.6 (2.5-18.7)	10.0 (4.5-12.1)	0.097
Monocyte (%)	7.3 (0.5-76.7)	9.4 (6.6-10.3)	0.136
Neutrophil (%)	61.5 (0-536)	45.5 (30.3-55.6)	0.000
Lymphocyte (%)	28.7 (6.1-63.5)	39.7 (31.5-61.2)	0.000
PLT (x10^9/L)	256 (71-444)	318.5 (123-701)	0.002
MPV (fL)	10.7 (7.5-15)	7.8 (5.7-10.8)	0.000
NLR	2.1 (0-13.7)	1.1 (0.5-1.7)	0.000
PLR	10 (2.1-36.6)	8.1 (2.1-12.8)	0.010

M: median, mn: minimum, mx: maximum, WBC: white blood cells, PLT: platelets

Table 2. Similarity between the variables of the two groups in terms of age, sex and age groups

		Patient (n=122)	Control (n=42)		
	Total n (%)	M (mn-mx) or n (%)	M (mn-mx) or n (%)	x^2 or z	p
Age (years)		7 (1-70)	9.5 (1-70)	1.126	0.289
Age and group (%)					
Child (1-18)	112 (68.3)	87 (71.3)	25 (59.5)	2.005	0.157
Adult(19 ve +)	52 (31.7)	35 (28.7)	17(40.5)		
Age group (years)					
Child (1-18)	112 (68.3)	5 (1-17)	6 (1-17)		
Adult (19 ve +)	52 (31.7)	57 (21-70)	42 (23-70)		
Sex					
Male (M)	72 (43.9)	54 (44.3)	18 (42.9)	0.025	0.874
Female (F))	92 (56.1)	68 (55.7)	24 (57.1)		
Group and sex (%)		M/F	M/F		
Child (1-18)	112 (68.3)	40 (46.0)/47 (54.0)	9 (36.0)/16 (64.0)	0.785	0.375
Adult (19 ve +)	52 (31.7)	14 (40.0)/21 (60.0)	9 (52.9)/8 (47.1)	0.777	0.378

M: median, mn: minimum, mx: maximum

Table 3. Analysis in influenza group (n=122)

		Child (n=87)	Adult (n=35)		
	Total n (%)	M (mn-mx) or n (%)	M (mn-mx) or n (%)	x^2 or z	p
Symptoms					
Fever	80 (65.6)	79 (90.8)	10 (29)	85.517	0.000
Cough	78 (63.9)	69 (79.3)	9 (25.7)	31.093	0.000
Dyspnea	33 (27.0)	3 (3.4)	30 (85.7)	85.602	0.000
Myalgia	14 (16.1)	1 (2.9)	15 (12.3)		0.064*
Poor appetite	8 (6.6)	5 (5.7)	3 (8.6)		0.688*
Runny nose	7 (8.0)	0 (0.0)	7 (5.7)		0.190*
Virus type					
H1N1	47 (28.7)	32 (36.8)	15 (42.9)		
H3N2	39 (23.8)	22 (25.3)	17 (48.6)		
Influenza B	36 (22.2)	33 (37.9)	3 (8.6)		
Pregnancy	2 (1.4)	0	2 (1.6)		
Mortality	3 (2.5)	1 (1.1)	2 (5.7)		0.198*
Duration (days) Illness	8 (4-21)	8 (4-21)	9 (5-15)	-1.420	0.156
Hospitalization	5 (1-11)	5 (1-8)	5 (2-11)	-1.817	0.069

M: median, mn: minimum, mx: maximum
*: Fisher's exact test

Table 4. Analysis of laboratory variables according to age groups in the influenza group (n = 122)

	Total (n=122)	Child (n=87)	Adult (n=35)		
	M (mn-mx)	M (mn-mx)	M (mn-mx)	z	p
Laboratory					
WBC (x10^9/L)	9.6 (2.5-18.7)	10.6 (3.8-17.1)	8.3 (2.5-18.7)	-2.356	0.018
Monocyte (%)	7.3 (0.5-76.7)	7.6 (0.5-76.7)	8.9 (3.4-20.5)	-0.012	0.991
Neutrophil (%)	61.5 (0-536)	59.6 (0-91.6)	66.9 (3-536)	-1.161	0.246
Lymphocyte (%)	28.7 (6.1-63.5)	30.6 (6.1-63.5)	21.8 (9.9-53)	-2.084	0.037
PLT (x10^9/L)	256 (71-444)	311 (123-444)	220 (71-392)	-3.295	0.001
MPV (fL)	10.7 (7.5-15)	10.8 (7.5-15)	10.1 (8.7-13)	-1.585	0.113
NLR	2.1 (0-13.7)	1.9 (0-13.7)	3.3 (0.2-12.4)	-1.755	0.079
PLR	10.0 (2.1-36.6)	10.4 (2.7-36.6)	9.5 (2.1-35.9)	-0.804	0.421

M: median, mn: minimum, mx: maximum

Table 5. Analysis of variables predicting length of hospital stay

	OR (beta)	t	p	95%CI
Age	-0.166	-1.840	0.068	-0.023-0.001
WBC	-0.166	-1.810	0.073	-0.132-0.006
Lymphocyte	0.235	1.366	0.175	-0.013-0.068
Monocyte	-0.098	-1.145	0.254	-0.058-0.015
Neutrophil	0.541	4.026	0.000	0.009-0.026
Platelet	-0.256	-1.425	0.157	-0.009-0.001
MPV	-0.045	-0.515	0.608	-0.210-0.123
NLR	-0.457	-2.133	0.035	-0.508-0.019
PLR	0.448	2.067	0.041	0.004-0.193

Table 6. Factors affecting mortality (n = 3) in the patient group (n = 122)

	Total (n=122)	No Mortality (n=119)	Mortality (n=3)		
	n (%)	n (%)	n (%)	x^2	p
Gender					
Male	54 (44.3)	53 (44.5)	1 (33.3)	0.149	0.586*
Female	68 (55.7)	66 (55.5)	2 (66.7)		
Virus type					
H1N1	47 (38.5)	46 (38.7)	1 (33.3)	1.766	0.502*
H3N2	39 (32.0)	37 (31.1)	2 (66.7)		
Influenza B	36 (29.5)	36 (30.3)	0 (0.0)		
	M (mx-mn)	M (mx-mn)	M (mx-mn)	Z	p
Duration (days) Illness	8 (4-21)	8 (4-21)	8 (7-11)	-1.735	0.083
Hospitalization	5 (1-11)	5 (1-11)	3 (3-5)	-0.142	0.887

M: median, mn: minimum, mx: maximum
*: Fisher's exact test

were not correlated with PLR or mortality (p = 0.435, p = 0.651 and p = 0.527, respectively).

Discussion

In this study, MPV and neutrophil levels were significantly higher in the influenza study group and platelet and lymphocyte counts were significantly lower than in the control group. In addition, NLR and PLR rates were significantly higher. Neutrophil level and NLR and PLR ratios predicted the length of stay in the hospital. Interestingly, there was no correlation between duration of hospital stay and MPV. There was no correlation between MPV and mortality. Similarly, there was no correlation between neutrophil level, NLR, PLR and mortality.

Changes in the hematologic system have prognostic value in severe, fulminant, acute, subacute, or chronic forms of infectious diseases. The hemostatic system is often disturbed during sepsis. Coagulation and platelet activation / hyperaggregation may occur in sepsis and multiple organ failure (MOF). Previous and recent studies support the relationship between severity of sepsis and thrombocytopenia [1,2,4,24,25]. Similarly, platelet changes in routine blood tests may be useful in early differential diagnosis in acute bacterial infections such as meningitis, pneumonia, and tuberculosis [1, 2, 3, 4].

Infections with clinical predictors of thrombocytopenia are often associated with high MPV values [8, 9, 10, 12, 16]. According to the studies, MPV is inversely proportional to platelet count. Because of this, MPV is usually increased in patients with thrombocytopenia due to viral infection [11, 13, 14, 15]. In the case of other virus-related studies, it was considered significant that low level of MPV was detected. In a study by Renshaw et al. [9], respiratory viral infection (RSV) has been associated with low MPV <8.9 fL levels. In pediatric patients with pneumonia and airway obstruction, RSV was diagnosed by rapid testing and culture during bronchoscopy. In children with RSV, MPV was significantly lower than in non-RSV children.

In a recent study by Almış et al., MPV levels in outpatient children with acute hepatitis A were found to be significantly lower than in those in a healthy control group. It has been reported that MPV may be a negative acute phase reactant for acute hepatitis A. Since fulminant hepatitis patients were not included, the severity of the disease was not correlated with MPV [10]. In study of Akın et al. [11] MPV was found to be higher in children hospitalized with acute hepatitis A with severe nausea and vomiting. In patients, thrombocytopenia was not found to be significant compared to the control group, but aspartate transaminase (AST) and alanine transaminase (ALT) values were found to be quite high. The authors reported that increased proinflammatory cytokines and thrombopoietin contributed to MPV elevation in hepatitis A patients. Different outcomes in the MPV values in the same disease group may be associated with the presence of severe clinical symptoms that would be indicative of hospitalization. Mete et al. [12] found significantly lower MPV (fL) values in rotavirus-positive patients than in rotavirus-negative and healthy control group. They suggested that MPV could be used as an acute phase reactant and inflammatory marker. In another study, 234 HIV-infected and 134 non-HIV-infected women were enrolled in a study; the HIV-infected women were found to have lower MPV values than the uninfected women [16].

Other studies in viral infections have supported the finding that MPV levels are elevated in some chronic viral diseases such as chronic hepatitis B and C [13,14,15]. In a previous study, MPV levels were significantly higher in the inactive HBsAg carrier group than in the control group. This elevation indicated a relatively elevated platelet activation and an atherothrombotic risk in chronic hepatitis B patients with inactive and non-active cardiovascular risk factors/diseases [13]. It was explained that in this way platelet-related changes in liver fibrosing patients,

portal hypertension leading to hypersplenism in cirrhotic patients, the production of immunoglobulins with platelet antibodies, circulation through the platelet storage pool, and HBV virus affects bone marrow megakaryocytes and causes thrombocytopenia and, in addition, liver fibrosis affects the production of thrombopoietin [27].

MPV changes were studied in various viral diseases, but we did not find a study that evaluated MPV in patients with influenza infections in the literature. MPV was elevated in influenza patients in our study. MPV increases inversely with platelet count which results in the development of thrombocytopenia with activation of the reticuloendothelial system in the influenza.

NLR and PLR are good markers of systemic infection. These ratios have also been confirmed as prognostic and predictive factors in various viral diseases [17,18,19]. A study was conducted in patients with chronic hepatitis B (CHB) [18]. It investigated the associations between the PLR-NLR and disease severity in patients with chronic HBV infection-related liver disease (CHB). It was seen that PLR and NLR partially reflect the amounts of serum HBV DNA and serum HBeAg levels circulating in CHB patients. The NLR may be useful for follow-up in HBV-related-compensated-cirrhosis (HBV-CC) patients to predict disease progression. The PLR and NLR may provide additional information for the characterization of the phase of chronic HBV infection. Additionally, the NLR was significantly higher in HBV-related-decompensated-cirrhosis (HBV-DC) patients. It may be useful for follow-up in HBV-CC patients to predict disease progression. In summary, the PLR and NLR provided a supplementary means for effectively managing chronic HBV infection and disease. In a study, Meng X et al. [19] investigated the association of PLR and NLR with disease severity in patients with HCV-associated liver and virologic response in chronic hepatitis C (CHC) patients. The researchers claimed that PLR is closely related to disease severity in patients with HCV-associated liver disease and the virologic response in CHC patients. Better PLR than NLR shows a strong correlation with CHC patients. The PLR, superior to the NLR, correlates with the disease severity of HCV infection.

In the Akturk et al. [17] study of influenza and other respiratory viruses, neutrophilic leukocytosis, CRP, and procalcitonin were found to be higher in the hospitalized patients than outpatients, but leukocyte, neutrophil, lymphocyte, and CRP were found to be low in influenza compared to other respiratory viruses. Neutrophilic leukocytosis can be considered as a prognostic factor in hospitalization in this case [17]. Hemophagocytic lymphohistiocytosis in influenza is caused by an increase in proinflammatory cytokines, which increases hemophagocytic macrophage proliferation and activation in the reticuloendothelial system. As a result, the number of leukocytes and platelets decreases rapidly [20,21]. Lalueza et al. [21] studied the effects of severe hematological abnormalities in patients admitted to hospital for influenza virus infection; they pointed out that these hematological abnormalities are especially common at the onset of the disease and cause hospitalization and poor prognosis. In a study of hematological findings of influenza, when H1N1 infection was diagnosed, 8 (25.8%) patients had leukopenia and 6 patients (19.4%) had thrombocytopenia, It has been reported that H1N1 infection can lead to various hematological findings including cytopenia and hemophagocytosis [22]. de Jager et al. [23] studied the neutrophil / lymphocyte ratio and reported that it has been a prognostic factor as a practical systemic inflammatory marker in a study of community-acquired pineomonia with typical and atypical bacterial and influenza agents. The rates of neutrophil / lymphocyte were significantly higher at the time of admission to the hospital.

In this study, MPV levels, NRL, and PLR rates were predictive of hospitalization duration in patients with influenza virus infection and prognostic evaluation was performed. MPV and neutrophil NLR and PLR rates were significantly higher. It was seen that the increase in NLR and PLR rates predicted the length of stay in the hospital. There was no correlation between MPV and the duration of hospital stay. There was no relationship between MPV, neutrophil level and NLR, PLR, mortality.

Conclusions

We demonstrated increased MPV values in patients hospitalized with influenza for the first time in the literature. The number of leukocytes and platelets decreases in influenza due to the development of hemophagocytosis and the increase of proinflammatory cytokines, which increase activation in the reticuloendothelial system. The increase in MPV was in inverse proportion to the number of platelets. Initially neutropenia and lymphocytosis were expected with a rapid immune response in influenza-diagnosed patients; this result was not seen in patients with rapid onset of immunity. It was thought that these patients were hospitalized with increased neutrophil or normal range. Rapid onset of immunity is correlated with a long duration of hematologic abnormalities and an increase in the length of stay in the hospital. However, prospective studies with larger number of patients are needed to assess the mechanism of increased MPV, NLR, and PLR values in influenza.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and human rights statement

All procedures performed in this study 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. No animal or human studies were carried out by the authors for this article.

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Conflict of interest

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