Journal of Clinical and Nursing Research, 2024, Volume 8, Issue 8
http://ojs.bbwpublisher.com/index.php/JCNR
Online ISSN: 2208-3693
Print ISSN: 2208-3685

The Predictive Value of NLR, IL-6, CRP, and PCT in Mycoplasmal Pneumonia with Complicated Myocardial Injury

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Abstract: *Objective:* To evaluate the dynamic changes in neutrophil-to-lymphocyte ratio (NLR), interleukin-6 (IL-6), C-reactive protein (CRP), and procalcitonin (PCT) levels in children with *Mycoplasma pneumoniae* pneumonia (MPP) complicated by myocardial injury and to determine their predictive value both individually and in combination. *Methods:* 150 children diagnosed with MPP at Jiujiang Maternal and Child Health Hospital between June 2023 and June 2024 were selected. Patients were divided into the myocardial damage group (MD group, n = 65) and the non-myocardial damage group (non-MD group, n = 85), based on the presence of myocardial injury. Ninety hospitalized children without MPP served as the control group (Con group). Myocardial enzyme profile indicators, including lactate dehydrogenase (LDH), α-hydroxybutyrate dehydrogenase (α-HBDH), aspartate aminotransferase (AST), high-sensitivity cardiac troponin I (hs-cTnI), creatine kinase (CK), and creatine kinase-MB (CK-MB), were measured using a chemiluminescent immunoassay analyzer. Serum NLR, IL-6, CRP, and PCT levels were determined using appropriate analyzers. The correlation between these markers and myocardial enzyme indicators was analyzed using Spearman correlation analysis. Multivariate logistic regression was applied to identify risk factors for myocardial injury in MPP patients. *Results:* Serum levels of NLR, IL-6, CRP, and PCT in the MD and non-MD groups were significantly higher than in the Con group ($P < 0.05$), with the MD group showing higher levels than the non-MD group ($P < 0.05$). These markers were positively correlated with myocardial enzyme indicators. Logistic regression identified elevated NLR, IL-6, CRP, PCT, LDH, α-HBDH, AST, hs-cTnI, CK, and CK-MB as risk factors for myocardial injury in MPP patients ($P < 0.05$). *Conclusion:* Elevated levels of NLR, IL-6, CRP, PCT, and myocardial enzymes are significant risk factors for myocardial injury in children with MPP, offering valuable insights for prevention and prognosis.

Keywords: NLR; IL-6; CRP; PCT; *Mycoplasma pneumoniae* pneumonia (MPP); Myocardial injury

Online publication: September 7, 2024

1. Introduction

Mycoplasma pneumoniae (MP) is one of the primary pathogens causing pneumonia in children, accounting for 10% to 20% of pediatric pneumonia cases. In recent years, with the in-depth research on MP infection,

it has been found that MP not only causes damage to the respiratory system but also may lead to damage to extrapulmonary organs, particularly myocardial damage (MD). As a common complication of MP infection, the mechanism and risk factors of MD are not yet fully understood [1]. Currently, treatment measures for MD are limited, emphasizing prevention. If MD can be prevented by detecting common laboratory indicators, it would be highly beneficial. However, early detection of MP complicated with MD and determining the prognosis of patients through a single indicator remain challenging, requiring a combination of other objective examinations and clinical assessments [2]. This study selected 150 cases of *Mycoplasma pneumoniae* pneumonia (MPP) children admitted to Jiujiang Maternal and Child Health Hospital from March 2023 to March 2024 to observe the dynamic changes in neutrophil-to-lymphocyte ratio (NLR), interleukin-6 (IL-6), C-reactive protein (CRP), and procalcitonin (PCT) levels in children with different disease severities and with/without MD, to clarify the correlation between individual and combined detection of these indicators with the severity of MPP and their predictive value for MD in children with MPP. NLR, IL-6, CRP, and PCT, as simple and objective laboratory data, can predict the occurrence of myocardial damage in children with mycoplasma pneumonia, facilitate early diagnosis and treatment, improve patient prognosis, and provide more objective and direct results, which have significant guiding value for clinical practice.

2. Materials and methods

2.1. Study subjects

A total of 150 children with MPP admitted to Jiujiang Maternal and Child Health Hospital from June 2023 to June 2024 were selected as study subjects. The MPP group was divided into the myocardial damage group (MD group, $n = 65$) and the non-myocardial damage group (non-MD group, $n = 85$) based on the presence of myocardial damage. The MD group included 38 males and 27 females, with an average age of 5.72 ± 1.18 years and an average weight of 22.38 ± 1.32 kg. The non-MD group included 49 males and 36 females, with an average age of 5.62 ± 1.28 years and an average weight of 22.42 ± 1.29 kg. Additionally, 90 non-MPP children hospitalized during the same period were selected as the control group (Con group), including 53 males and 37 females, with an average age of 5.33 ± 1.25 years and an average weight of 22.29 ± 1.41 kg. The basic data of the three groups were comparable ($P > 0.05$), and the study was approved by the hospital ethics committee.

2.2. Inclusion and exclusion criteria

Inclusion criteria: (1) Age between 3 and 16 years; (2) Meet the diagnostic criteria for MPP in Western medicine; (3) The MD group children meet the criteria for myocardial damage; (4) Able to cooperate with the collection of physical signs and related examination data; (5) Informed consent signed by the children's guardians.

Exclusion criteria: (1) MPP combined with primary respiratory, circulatory, central nervous, digestive, hematopoietic, and psychiatric system diseases or other organ damage; (2) Severe primary diseases of the nervous, circulatory, or digestive systems; (3) Allergic to treatment drugs; (4) Unable to adhere to regular blood routine re-examinations and venous blood draws; (5) Participating in other clinical trials.

2.3. Research methods

(1) Grouping method: According to the severe pneumonia standards in the "Guidelines for the Diagnosis and Treatment of Mycoplasma Pneumonia in Children" (2023 edition), 150 children with MPP were divided into the MD group and non-MD group, and 90 non-MPP children hospitalized during the same

period were selected as the Con group. A unified clinical research form was developed to collect and summarize the clinical data of the subjects, including gender, age, ethnicity, body mass index (BMI), and course of the disease.

(2) Detection methods: Fasting blood was drawn from the children the morning after admission, left at room temperature for 20 minutes, and then centrifuged at 3,000 r/min for 30 minutes. The supernatant serum was stored at -80°C for later use.

2.4. Observation indicators

(1) Myocardial enzyme spectrum indicators: The myocardial enzyme spectrum indicators of the children in each group, including lactate dehydrogenase (LDH), α-hydroxybutyrate dehydrogenase (α-HBDH), aspartate transaminase (AST), hs-cTnI, creatine kinase (CK), and CK-MB, were detected using a chemiluminescence immunoassay analyzer [IMMULITE 2000, Siemens Healthcare Diagnostics Inc., NMPA Import Device Certificate No. 2008-3403500 (Rev)].

(2) NLR, IL-6, CRP, and PCT levels: Serum NLR and CRP levels were measured using a fully automated blood cell analyzer (Shenzhen Mindray, BC-5390 CRP, NMPA Certificate No. 20182400017), serum IL-6 was measured using a chemiluminescence immunoassay analyzer (IMMULITE 2000), and PCT levels were measured using a fluorescence immunoassay analyzer (Getein Biotech, Getein 1600, NMPA Certificate No. 20142220013). The serum levels of NLR, IL-6, CRP, and PCT in each group and subgroup were statistically analyzed.

(3) Correlation of serum NLR, IL-6, CRP, and PCT levels with myocardial enzyme spectrum indicators: The correlation between serum NLR, IL-6, CRP, and PCT levels and myocardial enzyme spectrum indicators was analyzed using Spearman correlation analysis.

(4) Predictive value of serum NLR, IL-6, CRP, and PCT levels for myocardial damage in children with MPP: The related factors of myocardial damage in children with mycoplasma pneumonia were analyzed using multivariate logistic regression analysis.

2.5. Statistical analysis

Statistical analysis was performed using SPSS 23.0. Count data were expressed as [*n* (%)], and the chi-squared (χ^2) test was used; measurement data were expressed as mean ± standard deviation (SD). One-way analysis of variance (ANOVA) was used for comparing quantitative data among the three groups, the SNK-Q test was used for pairwise comparisons among the three groups, and the *t*-test was used for comparing quantitative data between two groups. The correlation between serum NLR, IL-6, CRP, and PCT levels and the severity of MPP was analyzed using the Spearman method. Multivariate logistic regression analysis was used to analyze the related factors of MD in children with MPP. A P-value < 0.05 was considered statistically significant.

3. Results

3.1. Comparison of serum NLR, IL-6, CRP, and PCT levels among the three groups

The serum levels of NLR, IL-6, CRP, and PCT in children from the MD group and the non-MD group were significantly higher than those in the Con group ($P < 0.05$). Moreover, compared to the non-MD group, the MD group showed significantly higher levels of serum NLR, IL-6, CRP, and PCT ($P < 0.05$). See **Table 1**.

Table 1. Comparison of serum NLR, IL-6, CRP, and PCT levels among the three groups (mean ± SD)

Groups	*n*	NLR	IL-6 (pg/mL)	CRP (mg/L)	PCT (ng/L)
MD Group	65	2.97 ± 0.74	85.18 ± 6.49	16.14 ± 3.27	0.62 ± 0.18
Non-MD group	85	1.45 ± 0.52	40.57 ± 4.13	7.84 ± 1.26	0.36 ± 0.12
Con group	90	0.92 ± 0.26	7.83 ± 1.21	2.29 ± 0.11	0.12 ± 0.05
F-value		13.689	20.965	18.039	10.214
P-value		< 0.001	< 0.001	< 0.001	< 0.001

3.2. Comparison of myocardial enzyme spectrum-related indicators among the three groups

The levels of myocardial enzyme spectrum-related indicators (LDH, α-HBDH, AST, hs-cTnI, CK, CK-MB) in children from the MD group and the non-MD group were significantly higher than those in the Con group ($P < 0.05$). Additionally, the levels of LDH, α-HBDH, AST, hs-cTnI, CK, and CK-MB in the MD group were significantly higher than those in the non-MD group ($P < 0.05$). See **Table 2**.

Table 2. Comparison of myocardial enzyme spectrum-related indicators among the three groups (mean ± SD)

Groups	*n*	LDH (U/L)	α-HBDH (U/L)	AST (U/L)	hs-cTnI (μg/L)	CK (U/L)	CK-MB (U/L)
MD Group	65	335.47 ± 50.15	255.38 ± 33.56	31.74 ± 5.16	0.25 ± 0.07	352.38 ± 53.17	32.68 ± 5.62
Non-MD group	85	218.25 ± 39.36	167.35 ± 20.79	22.65 ± 4.29	0.07 ± 0.04	154.57 ± 36.29	18.35 ± 3.86
Con group	90	163.43 ± 34.27	105.46 ± 17.53	14.59 ± 2.42	0.03 ± 0.01	103.01 ± 24.46	12.38 ± 2.71
F-value		28.116	25.975	14.028	11.496	35.674	16.827
P-value		0.000	0.000	< 0.001	< 0.001	0.000	< 0.001

3.3. Correlation analysis between serum NLR, IL-6, CRP, and PCT levels and myocardial enzyme spectrum-related indicators

According to Spearman correlation analysis, serum NLR, IL-6, CRP, and PCT levels were positively correlated ($P < 0.05$). Serum NLR, IL-6, CRP, and PCT levels were positively correlated with myocardial enzyme spectrum-related indicators (LDH, α-HBDH, AST, hs-cTnI, CK, CK-MB) ($P < 0.05$). See **Table 3**.

Table 3. Correlation between serum NLR, IL-6, CRP, and PCT levels and myocardial enzyme spectrum-related indicators

Indicator	NLR		IL-6		CRP		PCT	
	r-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value	*r*-value	*P*-value
LDH	0.425	< 0.001	0.693	< 0.001	0.527	< 0.001	0.511	< 0.001
α-HBDH	0.504	< 0.001	0.542	< 0.001	0.533	< 0.001	0.405	< 0.001
AST	0.487	< 0.001	0.558	< 0.001	0.569	< 0.001	0.623	< 0.001
hs-cTnI	0.559	< 0.001	0.562	< 0.001	0.468	< 0.001	0.579	< 0.001
CK	0.582	< 0.001	0.504	< 0.001	0.455	< 0.001	0.536	< 0.001
CK-MB	0.614	< 0.001	0.496	< 0.001	0.612	< 0.001	0.473	< 0.001

3.4. Multivariate logistic regression analysis of factors related to MD in children with MPP

Taking the occurrence of mycoplasma pneumonia combined with myocardial damage as the dependent variable (yes = 1, no = 0), and NLR, IL-6, CRP, PCT, LDH, α-HBDH, AST, hs-cTnI, CK, and CK-MB as independent variables, with each variable assigned as a continuous variable, and no multicollinearity among the indicators. According to logistic regression analysis, it was found that elevated levels of NLR, IL-6, CRP, PCT, LDH, α-HBDH, AST, hs-cTnI, CK, and CK-MB were risk factors for MD in children with MPP ($P < 0.05$), as shown in **Table 4**.

Table 4. Multivariate logistic regression analysis of factors related to MD in children with MPP

Indicator	β	SE	Wald χ^2	P	OR	95% CI
NLR	0.995	0.215	20.132	< 0.001	2.764	1.696–4.015
IL-6	1.132	0.245	19.286	< 0.001	3.063	1.975–5.742
CRP	1.673	0.308	11.285	< 0.001	4.284	2.067–8.516
PCT	0.682	0.145	12.573	< 0.001	1.729	1.264–3.252
LDH	1.824	0.412	14.096	0.000	5.914	2.235–11.509
α-HBDH	1.935	0.557	17.823	0.000	6.156	2.448–15.803
AST	0.876	0.192	15.241	< 0.001	2.167	1.458–3.892
hs-cTnI	1.174	0.269	18.136	< 0.001	3.668	1.998–6.803
CK	1.485	0.582	19.392	0.000	6.028	2.361–13.328
CK-MB	1.108	0.259	13.186	< 0.001	2.965	1.924–5.443

4. Discussion

Mycoplasma pneumoniae infection can cause myocardial damage, which may be related to immune damage and direct invasion. The MP antigen shares common antigens with various human tissues, and infection can produce autoantibodies that cause tissue and organ damage [3,4]. Additionally, the high fever and sustained inflammatory response in the early stages of MP infection can lead to a mismatch between myocardial oxygen consumption and supply, further exacerbating myocardial damage.

When exploring the risk factors for myocardial damage in children with mycoplasma pneumonia, biomarkers such as neutrophil-to-lymphocyte ratio (NLR), interleukin-6 (IL-6), C-reactive protein (CRP), and procalcitonin (PCT) play crucial roles. These indicators not only reflect the degree of the body's inflammatory response but are also closely related to the occurrence and development of myocardial damage [5,6]. NLR, as a simple and easily obtainable inflammatory marker, has shown predictive value in various diseases in recent years. In children with MPP, an elevated NLR may indicate a more intense inflammatory response, which could lead to myocardial damage through multiple pathways [7].

IL-6 is a significant inflammatory factor widely involved in the body's immune and inflammatory responses. Studies have shown that IL-6 can promote apoptosis and fibrosis of myocardial cells through various pathways, leading to myocardial damage. Therefore, the level of IL-6 can serve as an important indicator for assessing the risk of myocardial damage in children with MPP [8].

CRP is an acute-phase protein that significantly increases during an inflammatory response. In children with MPP, elevated CRP levels similarly reflect the degree of the body's inflammatory response. High levels of CRP often indicate more severe inflammation and tissue damage, including myocardial damage [9]. PCT is a

protein secreted by thyroid C cells, but its level significantly increases during bacterial infection. Although the diagnostic value of PCT in MPP is somewhat controversial, some studies suggest that elevated PCT levels may be associated with the severity of the disease and the occurrence of complications [10]. Regarding myocardial damage, an increase in PCT may indicate a more severe bacterial infection and systemic inflammatory response, thereby increasing the risk of myocardial damage.

The results of this study show that, according to Spearman correlation analysis, serum NLR, IL-6, CRP, and PCT levels are positively correlated. Serum NLR, IL-6, CRP, and PCT levels are positively correlated with myocardial enzyme spectrum-related indicators. According to Logistic regression analysis, elevated NLR, IL-6, CRP, PCT, LDH, α-HBDH, AST, hs-cTnI, CK, and CK-MB are risk factors for myocardial damage in children with MPP. This study can provide clinical doctors with supplementary information for the early identification and prevention of myocardial damage in children with MPP, facilitate the optimization and improvement of treatment plans, and provide relevant evaluation indicators for prognosis assessment. This promotes comprehensive treatment and rapid recovery for children with MPP, reduces their suffering and treatment costs, and alleviates the economic burden on their families and society. This study provides clinical experience and guidance for the future prevention and prognosis evaluation of myocardial damage in children with MPP.

In summary, clinical practice should closely monitor changes in these indicators to detect and intervene in myocardial damage promptly. Further research should explore the specific mechanisms between these biomarkers and myocardial damage, providing more precise bases for clinical diagnosis and treatment.

Disclosure statement

The authors declare no conflict of interest.

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