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Research Progress on Early Diagnostic Markers of Urinary Tract Infection Complications after Percutaneous Nephrolithotomy

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Abstract

Urinary calculi are a common and frequently occurring disease in urology. For patients with kidney stones, especially large, multiple or staghorn stones, percutaneous nephrolithotomy (PCNL) is a preferred treatment method. Infection-related complications after percutaneous nephrolithotomy include transient fever, systemic inflammatory response syndrome, and urinary sepsis, especially urinary sepsis, which are considered to be common causes of death after percutaneous nephrolithotomy. Therefore, early identification and timely intervention of biomarkers can reduce the incidence and mortality of postoperative sepsis, as well as the length of hospital stay and hospitalization costs. This article reviews the biomarkers for early identification of urinary tract infection after PCNL, such as traditional inflammatory indicators, new inflammatory indicators, and composite inflammatory indicators.

Keywords

Percutaneous Nephrolithotripsy, Urinary Sepsis, Biomarkers, Composite Index

1. Introduction

Urinary calculi are a common and frequent disease in urology. In the past three decades, with the changes in diet and lifestyle, the incidence of calculi has increased at home and abroad, with 8.8% in the United States and 5.8% in China [1]. The treatment of urinary calculi has developed from traditional open surgery to endovascular minimally invasive urological surgery. Percutaneous nephrolithotomy (PCNL) is the preferred treatment for patients with large upper urinary tract calculi (diameter > 2 cm) and complex renal calculi [2], but the incidence of

postoperative complications (such as bleeding, infection, etc.) is high. Infection-related complications after PCNL were divided into transient fever, systemic inflammatory response syndrome (SIRS) and urinary sepsis according to the severity. SIRS is a systemic inflammatory response caused by a variety of factors, which is a common complication after PCNL. SIRS is an uncontrolled, self-destructive, self-sustaining, and amplified systemic inflammatory response triggered by severe injury, infection, trauma, surgery, ischemia, and other factors [3]. Even if antibiotics are used before operation, the incidence is still high, about 9.8% - 43% [4]. Sepsis is considered one of the most common causes of perioperative mortality in percutaneous nephrolithotomy [5], with a mortality rate ranging from 20% - 42% [6]. SIRS is the first step of the sepsis cascade and is closely related to it [7]. This article will review the traditional, new and compound biomarkers for early identification of urinary tract infection after PCNL.

2. Procalcitonin (PCT)

Procalcitonin is a protein containing 116 amino acids, which is a polypeptide precursor of calcitonin. It is mainly synthesized by thyroid C cells, and neuroendocrine tissues of organs such as lung and gastrointestinal tract can also be synthesized [8]. Under normal circumstances, the level of PCT in serum is extremely low (<0.02 ng/ml) [9]. During inflammation, PCT is produced through a direct pathway induced by lipopolysaccharide or microbial toxic metabolites, as well as an indirect pathway induced by inflammatory mediators [10]. At this time, PCT cannot be converted into calcitonin and directly enters the circulatory system, resulting in an increase in PCT concentration in the peripheral circulation.

PCT, as one of the most widely used biomarkers in sepsis, can effectively predict the occurrence, treatment efficacy, and prognosis of sepsis after PCNL [11] [12]. Zheng *et al.* [12] found that when PCT is greater than 0.3 ng/ml, the sensitivity for predicting sepsis after PCNL reaches 90.3%, and the specificity reaches 94.3%. Similarly, research [6] shows that PCT and C-reactive protein (CRP) are independent risk factors for SIRS after PCNL, with good predictive effects, and 88.2% of SIRS patients occur within 24 hours after surgery. Gao Xianglin *et al.* [13] showed that PCT at 2 hours after PCNL was more effective than CRP and white blood cells in predicting SIRS after PCNL. When PCT > 3.7 ng/L at 2 hours after PCNL, the diagnostic specificity of SIRS was 87.6% and the sensitivity was 75.4%. PCT at 2 hours after operation can predict the occurrence of SIRS after PCNL, but as a single index, the sensitivity is not good when predicting SIRS after operation. It is necessary to combine with CRP and other indicators to improve the sensitivity, so as to more accurately identify SIRS after operation. In addition, dynamic monitoring of PCT can evaluate the severity of postoperative infection, guide treatment and prevent drug resistance caused by antibiotic abuse.

3. C-Reactive Protein (CRP)

C-reactive protein is an acute phase protein produced by the liver, and its level

increases during infection or inflammation. CRP is currently widely used in various diseases, especially in cancer [14], while there are few studies predicting the occurrence of SIRS after PCNL. The increase of CRP is related to the occurrence of SIRS and sepsis after PCNL. Preoperative CRP level can be used as an independent risk factor for SIRS after PCNL, which is helpful to predict postoperative infection complications [15]. However, CRP is less effective than procalcitonin (PCT) in predicting SIRS and sepsis after PCNL, which may be due to the fact that CRP is affected by many factors and its specificity is not as good as PCT [13]. Studies have shown that the optimal critical value of preoperative CRP is 0.65 mg/dL the specificity was 69.4%, and the sensitivity was 51.4% [15], which was consistent with the study of Wang *et al.* [6]. but further research is needed to determine a more accurate prediction model and critical value, so that CRP can be used more effectively in clinical practice to predict postoperative infection complications after PCNL.

4. Interleukin-6

Interleukin-6 (IL-6) is a cytokine with multiple biological activities, exhibiting both pro-inflammatory and anti-inflammatory properties, depending on the immune response environment [16]. IL-6 is primarily produced by monocytes, neutrophils, T lymphocytes, B lymphocytes, and NK cells, and participates in systemic infections, autoimmune diseases, and the occurrence and development of tumors through immune regulation [17]. It can stimulate the production of CRP and fibrinogen. There are bacteria and endotoxin in the stones (especially infectious stones) of patients with renal calculi, which will be released during PCNL, and the flushing fluid may cause bacteria and endotoxin to enter the blood, resulting in postoperative systemic severe response syndrome and even urinary sepsis [17]. Qi *et al.* [18] showed that IL-6 at 2 hours after operation could diagnose urinary sepsis after PCNL earlier and more valuable than PCT, and the area under ROC curve was 1.0. Tang *et al.* [19] found that the area under the ROC curve (AUC) of serum IL-6 in the diagnosis of urinary sepsis after PCNL was 0.856 (95% CI: 0.7990.913), the sensitivity was 73.44%, and the specificity was 78.13%, which were higher than the PCT level (AUC: 0.819; 95% CI: 0.7260.911; sensitivity: 64.06%; specificity: 69.53%) and CRP level (AUC: 0.738; 95% CI: 0.6340.841; sensitivity: 60.94%; specificity: 62.50%); however, it was slightly lower than the combined detection level of the three indicators (AUC: 0.865; 95% CI: 0.7880.942; sensitivity: 81.22%; specificity: 84.94%). In conclusion, IL-6 at 2 hours after operation is the earliest and valuable, but the diagnostic value of PCT, CRP and IL-6 in predicting infection after PCNL is limited, and the combined diagnosis is more accurate.

5. Neutrophil CD64

CD64 exists on the surface of neutrophils and is a high affinity receptor for the Fc portion of IgG. Under normal conditions, the expression of CD64 on the surface of peripheral blood neutrophils is low. However, when the body is in an infected

state, the body will produce a large number of cytokines, such as interferon-*y*, IL6, TNF-a and granulocyte colony-stimulating factor. These cytokines will stimulate neutrophils to express a large amount of CD64, and its expression will peak within 4 to 6 hours, and remain stable for a certain period of time, until these cytokines return to normal and return to the basic expression after 7 days [20]. Cong *et al.* [9] compared the value of CD64, PCT and IL-6 in the diagnosis of sepsis through meta-analysis, and found that CD64 had the highest diagnostic value for sepsis, with a specificity of 88%, a sensitivity of 88%, and an area under the ROC curve of 0.94. Given its stability and high diagnostic value for sepsis, CD64 can be used as a biomarker to predict infection. There are not many studies about CD64 predicting SIRS after endourological lithotripsy, almost all of which focus on the occurrence of SIRS after ureteroscopic lithotripsy. Compared with PCT and CRP, CD64 has a higher diagnostic value for SIRS after endoscopic lithotripsy, especially after ureteroscopic lithotripsy. Although the effectiveness of CD64 in the prediction of SIRS after PCNL still needs to be verified, its expression level after 2 hours and 6 hours has shown the potential as an early predictor of SIRS [21] [22]. The incompatibility of different measurement units may affect clinical application, so these factors need to be considered when using CD64 to predict SIRS or sepsis.

6. Monocyte HLA-DR

HLA-DR is a glycosylated transmembrane protein expressed in antigen-presenting cells and belongs to class II antigen. HLA-DR on monocytes can present pathogenic microbial peptides to T cells to initiate an immune response. Reduced HLA-DR expression is a diagnostic and prognostic marker for immunosuppression or sepsis in critically ill patients [23]. Patients with a lower-than-normal level of 30% have a low survival rate and a 30-fold higher risk of death [24]. Hou *et al.* [25] also found that HLA-DR can predict sepsis after PCNL (critical value 56.19%, specificity 81.8%, sensitivity 89.7%). However, due to the difference between SIRS and sepsis, the results can not be used to predict SIRS after PCNL.A large sample clinical trial is needed to verify the role of HLA-DR in predicting SIRS after PCNL.

7. Neutrophil-Lymphocyte Ratio (NLR)

NLR is a commonly used comprehensive inflammatory index, which was proposed by Goodman *et al.* in the diagnostic study of appendicitis in 1995. With the deepening of the understanding of the relationship between tumor and inflammation, it is found that NLR is related to the diagnosis and prognosis of various urinary system tumors, and is also closely related to the prediction of infection after minimally invasive treatment of urinary calculi [5]. The presence of kidney stones leads to the release of inflammatory mediators such as IL-6, IL-7, IL-8 and TNF-a, which in turn leads to an increase in the number of neutrophils, and the inflammatory response reduces the cytolytic activity of lymphocytes, T cells and natural killer cells, thereby inhibiting the immune response. Therefore, the

increase of NLR may indicate that the inflammatory response persists. Wang Lin *et al.* [26] found that compared with PCT, NLR can better predict SIRS after PCNL. The area under the ROC curve of NLR is higher than that of PCT, and the specificity is as high as 97%. Kriplani *et al.* [5] found that compared with white blood cell count, NLR can predict sepsis after PCNL, and Kriplani *et al.* found that the critical value of SIRS after PCNL was 2.03. NLR is a simple and feasible marker for predicting SIRS or sepsis after PCNL, but the optimal cutoff value lacks consensus, and a large sample prospective multicenter study is needed to improve the evidence and standardize it.

8. Lymphocyte-Monocyte Ratio (LMR)

LMR is a common indicator of compound inflammation and has important value in the diagnosis and prognosis evaluation of various diseases [27]. Winkler *et al.* [28] observed that the number of monocytes increased in sepsis, while the number of circulating blood lymphocytes decreased in SIRS or sepsis. Therefore, lower LMR may reflect the inflammatory state. The earliest prediction of SIRS after PCNL by LMR was found in the study of Tang *et al.* [29], but its predictive ability was not as good as NLR. Consistent with foreign studies [5], they also calculated that the optimal cut-off value of LMR for predicting SIRS was 3.23, the sensitivity was 83.9%, the specificity was 42%, and the area was 0.649; the optimal critical value for predicting sepsis was 2.88, the sensitivity was 87.5%, the specificity was 55%, and the area was 0.726. Through multivariate logistic regression analysis, they found that LMR was an independent risk factor for SIRS after PCNL. This is consistent with the study of Xu *et al.* [30], and their optimal critical value is 3.4. On the other hand, the optimal cut-off values of a large number of related studies were less than the average LMR of Chinese healthy population (male: 5.14; female: 5.50) [5] [25] [31]. Therefore, LMR is a biomarker that can predict SIRS or sepsis. Therefore, LMR is a biomarker that can predict SIRS or sepsis, but its specificity is low, and it needs to be combined with other indicators to further improve the diagnostic effect, that is, to reduce the rate of misdiagnosis.

9. Platelet-Lymphocyte Ratio (PLR)

PLR is a new composite inflammatory marker, which can predict a variety of diseases. Platelets are involved in the pathophysiological process of sepsis and play a key role in organ dysfunction [32]. Lymphopenia is a common marker of immunosuppression induced by sepsis, so PLR may be a biomarker of systemic infection [33]. Yang Min *et al.* [34] found that PLR had a high predictive efficiency (OR = 5.217, 95% CI 1.212 - 13.283, P = 0.02). A retrospective analysis of 517 patients after PCNL found that [5] preoperative PLR was an independent risk factor for SIRS after PCNL. When preoperative PLR > 110.62, the specificity and sensitivity of predicting SIRS were 50.5% and 80.2%, respectively. The sensitivity was lower than NLR and LMR. This is similar to the results of Cetinkaya *et al.* [7]. They believe that when preoperative PLR > 114.1, the patient's vital signs should be

closely monitored and the occurrence of postoperative SIRS should be alerted. However, Tang *et al.* [29] found through a retrospective study that although there was a statistical difference in PLR between the non-SIRS group and the SIRS group, through multivariate logistic analysis, PLR was not an independent risk factor for predicting the occurrence of SIRS after PCNL, which may be due to the inherent limitations of the retrospective study type. Therefore, large sample prospective studies should be carried out in the future to determine the incidence of SIRS after PCNL. Due to the limitations of retrospective studies, a large sample prospective study is needed to determine the incidence of SIRS after PCNL in the future.

10. Systemic Immune Inflammation Index (SII)

SII was first proposed by Hu *et al.*, which is a new inflammation index derived from platelet × NLR [35]. At present, SII is mainly used in the prognosis of cardiovascular diseases and tumors [36] [37], while there are few studies on predicting postoperative complications, especially SIRS or sepsis. At present, there are few domestic and foreign studies on the prediction of SIRS after PCNL by SII [3]. In a retrospective analysis of 365 patients [3], it was found that SII was an independent risk factor for SIRS after PCNL, and had higher predictive value than NLR, LMR and PLR (sensitivity 79.63%, specificity 73.93%). This may be because these predictors become unstable when only one or two parameters are involved, and are usually susceptible to other confounding factors [38]. In contrast, SII contains three parameters that are more stable and objective in reflecting the balance between host inflammation and immune status [39]. Therefore, SII is expected to be a biological indicator that predicts the occurrence of SIRS after PCNL. However, their research lacks the best critical value to directly guide clinical practice, so the specific clinical application of SII, such as predictive diagnosis and guiding treatment, needs further study in the future.

11. Conclusion

Table 1. Biomarkers.

Biomarkers	PCNL/URL	Sepsis/SIRS	Cut-off	Sensitivity (%)	Specificity (%)	OR	AUC	Use time	References
PCT	PCNL and URL	SIRS	-	-	-	1.093 (1.005 - 1.187)	-	Within 24 h after surgery	Wang *et al.* [6]
	PCNL and URL	Sepsis	-	-	-	1.017 (1.006 - 1.029)	-	Within 24 h after surgery	Wang *et al.* [6]
	PCNL	Sepsis	0.3 ng/ml	90.3	94.3	-	0.960	Postoperative	Zheng *et al.* [12]
	PCNL	SIRS	3.7 ng/L	75.4	87.6	-	0.852	2 h postoperative	Gao *et al.* [13]

Continued

CRP	PCNL and URL	SIRS	-	-	-	1.017 (1.009 - 1.024)	-	Within 24 h after surgery	Wang *et al.* [6]
	PCNL and URL	Sepsis	-	-	-	1.080 (1.042 - 1.120)	-	Within 24 h after surgery	Wang *et al.* [6]
	PCNL	SIRS	0.65 mg/dL	51.4	69.4	1.59 (1.07 - 2.37)	0.63	Postoperative	Vishnu *et al.* [15]
IL-6	PCNL	Sepsis	-	-	-	-	1.000	2 h postoperative	Qi *et al.* [18]
	PCNL	Sepsis	146.79 pg/mL	73.44	78.13	-	0.856	12 h postoperative	Tang *et al.* [19]
nCD64	URL	SIRS	-	-	-	-	1.000	6 h postoperative	Wu *et al.* [21]
	URL	SIRS	-	-	-	-	0.999	6 h postoperative	Fang *et al.* [22]
mHLA-DR	URL	SIRS	-	-	-	-	1.000	6 h postoperative	Wu *et al.* [21]
	PCNL	Sepsis	56.19%	89.7	81.8		0.934	1d postoperative	Hou *et al.* [25]
NLR	PCNL	SIRS	2.03	82	31	-	0.596	Preoperative	Kriplani *et al.* [5]
	PCNL	Sepsis	2.45	87	31	-	0.639	Preoperative	Kriplani *et al.* [5]
	PCNL	SIRS	3.49	54.1	97	4.336 (1.630 - 11.534)	0.807	Preoperative	Wang *et al.* [26]
LMR	PCNL	SIRS	3.23	83.9	42	-	0.831	Preoperative	Kriplani *et al.* [5]
	PCNL	Sepsis	2.88	87.5	55	-	0.726	Preoperative	Kriplani *et al.* [5]
	PCNL	SIRS	-	-	-	-	0.723	Preoperative	Tang *et al.* [29]
	PCNL	Sepsis	3.4	-	-	-	0.633	Preoperative	Xu *et al.* [30]
PLR	PCNL	SIRS	110.62	80.2	50.5	-	0.663	Postoperative	Kriplani *et al.* [5]
	PCNL	Sepsis	120.25	87.5	53.2	-	0.627	Postoperative	Kriplani *et al.* [5]

Continued

	PCNL	SIRS	114.1	80.4	60.2	1.01 (1.002 - 1.022)	0.731	Postoperative	Cetinkaya *et al.* [7]
	PCNL	SIRS	-	-	-	-	0.685	Postoperative	Tang *et al.* [29]
SII	PCNL	SIRS	480.37	79.63	73.93	2.951 (1.370 - 6.355)	0.786	Postoperative	Peng *et al.* [3]

PCT, Procalcitonin; CRP, C-reactive protein; IL-6, Interleukin-6; nCD64, Neutrophil CD64; mHLA-DR, Monocyte HLA-DR; NLR, neutrophil-lymphocyte ratio; LMR, lymphocyte-monocyte ratio; PLR, platelet-lymphocyte ratio; SII, systemic immune inflammation index; PCNL, percutaneous nephrolithotomy; URL, Ureteroscope Lithotripsy; SIRS, systemic inflammatory response syndrome; OR, odd ratio. -, Unavailable.

Sepsis is one of the main causes of severe complications and death after PCNL, and more than half of them are caused by SIRS. Traditional (PCT, CRP and IL-6), new (neutrophil CD64 and monocyte HLA-DR) and compound inflammatory markers (NLR, LMR, PLR and SII) play an important role in the early prediction of postoperative SIRS (Table 1), but their effectiveness after PCNL needs to be verified. A large sample study is needed to determine the critical value, and multiple indicators should be combined to reduce the risk of postoperative sepsis.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Zeng, G.H., Ma, Z.L., Xia, S.J., *et al.* (2015) A Cross-Sectional Survey of the Prevalence of Urolithiasis in Chinese Adults. *Chinese Journal of Urology*, **36**, 528-532.

[2] Türk, C., Petřík, A., Sarica, K., Seitz, C., Skolarikos, A., Straub, M., *et al.* (2016) EAU Guidelines on Diagnosis and Conservative Management of Urolithiasis. *European Urology*, **69**, 468-474. https://doi.org/10.1016/j.eururo.2015.07.040

[3] Peng, C., Li, J., Xu, G., Jin, J., Chen, J. and Pan, S. (2021) Significance of Preoperative Systemic Immune-Inflammation (SII) in Predicting Postoperative Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Urolithiasis*, **49**, 513-519. https://doi.org/10.1007/s00240-021-01266-2

[4] Tan, F., Gan, X., Deng, Y., Li, X., Guo, N., Hei, Z., *et al.* (2018) Intraoperative Dexmedetomidine Attenuates Postoperative Systemic Inflammatory Response Syndrome in Patients Who Underwent Percutaneous Nephrolithotomy: A Retrospective Cohort Study. *Therapeutics and Clinical Risk Management*, **14**, 287-293. https://doi.org/10.2147/tcrm.s157320

[5] Kriplani, A., Pandit, S., Chawla, A., de la Rosette, J.J.M.C.H., Laguna, P., Jayadeva Reddy, S., *et al.* (2022) Neutrophil-Lymphocyte Ratio (NLR), Platelet-Lymphocyte Ratio (PLR) and Lymphocyte-Monocyte Ratio (LMR) in Predicting Systemic Inflammatory Response Syndrome (SIRS) and Sepsis after Percutaneous Nephrolithotomy (PNL). *Urolithiasis*, **50**, 341-348. https://doi.org/10.1007/s00240-022-01319-0

[6] Wang, C., Xu, R., Zhang, Y., Wu, Y., Zhang, T., Dong, X., *et al.* (2022) Nomograms for Predicting the Risk of SIRS and Urosepsis after Uroscopic Minimally Invasive

Lithotripsy. *BioMed Research International*, **2022**, Article ID: 6808239. https://doi.org/10.1155/2022/6808239

[7] Cetinkaya, M., Buldu, I., Kurt, O., *et al.* (2017) Platelet-to-Lymphocyte Ratio: A New Factor for Predicting Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Urology Journal*, **14**, 4089-4093.

[8] Sartelli, M., Ansaloni, L., Bartoletti, M., Catena, F., Cardi, M., Cortese, F., *et al.* (2021) The Role of Procalcitonin in Reducing Antibiotics across the Surgical Pathway. *World Journal of Emergency Surgery*, **16**, Article No. 15. https://doi.org/10.1186/s13017-021-00357-0

[9] Cong, S., Ma, T., Di, X., Tian, C., Zhao, M. and Wang, K. (2021) Diagnostic Value of Neutrophil CD64, Procalcitonin, and Interleukin-6 in Sepsis: A Meta-Analysis. *BMC Infectious Diseases*, **21**, Article No. 384. https://doi.org/10.1186/s12879-021-06064-0

[10] Vijayan, A.L., Vanimaya, Ravindran, S., Saikant, R., Lakshmi, S., Kartik, R., *et al.* (2017) Procalcitonin: A Promising Diagnostic Marker for Sepsis and Antibiotic Therapy. *Journal of Intensive Care*, **5**, Article No. 51. https://doi.org/10.1186/s40560-017-0246-8

[11] Tan, M., Lu, Y., Jiang, H. and Zhang, L. (2018) The Diagnostic Accuracy of Procalcitonin and C-Reactive Protein for Sepsis: A Systematic Review and Meta-Analysis. *Journal of Cellular Biochemistry*, **120**, 5852-5859. https://doi.org/10.1002/jcb.27870

[12] Zheng, J., Li, Q., Fu, W., Ren, J., Song, S., Deng, G., *et al.* (2014) Procalcitonin as an Early Diagnostic and Monitoring Tool in Urosepsis Following Percutaneous Nephrolithotomy. *Urolithiasis*, **43**, 41-47. https://doi.org/10.1007/s00240-014-0716-6

[13] Gao, X.L., Wu, Z.S., He, Y.H., *et al.* (2020) The Value of Procalcitonin in the Early Diagnosis of Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Journal of Clinical Urology*, **35**, 14-16.

[14] Zhu, M., Ma, Z., Zhang, X., Hang, D., Yin, R., Feng, J., *et al.* (2022) C-reactive Protein and Cancer Risk: A Pan-Cancer Study of Prospective Cohort and Mendelian Randomization Analysis. *BMC Medicine*, **20**, Article No. 301. https://doi.org/10.1186/s12916-022-02506-x

[15] Ganesan, V., Brown, R.D., Jiménez, J.A., De, S. and Monga, M. (2017) C-Reactive Protein and Erythrocyte Sedimentation Rate Predict Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Journal of Endourology*, **31**, 638-644. https://doi.org/10.1089/end.2016.0884

[16] Aliyu, M., Zohora, F.T., Anka, A.U., Ali, K., Maleknia, S., Saffarioun, M., *et al.* (2022) Interleukin-6 Cytokine: An Overview of the Immune Regulation, Immune Dysregulation, and Therapeutic Approach. *International Immunopharmacology*, **111**, Article ID: 109130. https://doi.org/10.1016/j.intimp.2022.109130

[17] Omar, M., Noble, M., Sivalingam, S., El Mahdy, A., Gamal, A., Farag, M., *et al.* (2016) Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy: A Randomized Single-Blind Clinical Trial Evaluating the Impact of Irrigation Pressure. *Journal of Urology*, **196**, 109-114. https://doi.org/10.1016/j.juro.2016.01.104

[18] Qi, T.G., Qi, X., Chen, J., *et al.* (2022) The Value of IL-6 Detection 2 h after Percutaneous Nephrolithotomy in the Diagnosis and Treatment of Urinary Sepsis and the Improvement of Prognosis. *Chinese Journal of Urology*, **43**, 730-733.

[19] Tang, Y.C., Fu, H., Guo, T., *et al.* (2018) Significance of Serum IL-6 Combined with Procalcitonin and C-Reactive Protein in the Diagnosis of Urinary Sepsis after Percutaneous Nephrolithotomy. *Practical Medical Journal*, **34**, 2198-2203.

[20] Agarwal, V., *et al.* (2020) Neutrophil CD64 a Diagnostic and Prognostic Marker of

Sepsis in Adult Critically Ill Patients: A Brief Review. *Indian Journal of Critical Care Medicine*, **24**, 1242-1250. https://doi.org/10.5005/jp-journals-10071-23558

[21] Wu, H.L., Zhang, L.Q., Liu, Q., *et al.* (2020) Neutrophil CD64, Monocyte HLA-DR, Serum Procalcitonin in the Ureter. Diagnostic Value of Early Monitoring of Systemic Inflammatory Response Syndrome after Flexible Ureteroscopic Holmium Laser Lithotripsy. *Chinese Journal of Experimental Surgery*, **37**, 1449-1451.

[22] Fang, Y.Q., Chen, Z.Q. and Mao, Y.F. (2021) Changes of Neutrophil CD64 Level in Peripheral Blood of Patients with SIRS after Holmium Laser Lithotripsy. *Zhejiang Trauma Surgery*, **26**, 630-632.

[23] Xu, J., Li, J., Xiao, K., Zou, S., Yan, P., Xie, X., *et al.* (2019) Dynamic Changes in Human HLA-DRA Gene Expression and Th Cell Subsets in Sepsis: Indications of Immunosuppression and Associated Outcomes. *Scandinavian Journal of Immunology*, **91**, e12813. https://doi.org/10.1111/sji.12813

[24] Chen, Y., *et al.* (2017) Dynamic Monitoring of Monocyte HLA-DR Expression for the Diagnosis Prognosis and Prediction of Sepsis. *Frontiers in Bioscience*, **22**, 1344-1354. https://doi.org/10.2741/4547

[25] Hou, H.F., Liu, Y., Zhang, X., Han, Z. and Chen, T. (2022) The Value of Postoperative HLA-DR Expression and High Mobility Group Box 1 Level in Predictive Diagnosis of Sepsis in Percutaneous Nephrolithotomy Surgery. *Renal Failure*, **44**, 1339-1345. https://doi.org/10.1080/0886022x.2022.2107541

[26] Wang, L., Wang, Y., Li, L., *et al.* (2021) The Predictive Value of CHR and NLR for Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Anhui Medicine*, **42**, 202-206.

[27] Brodska, H., Valenta, J., Pelinkova, K., Stach, Z., Sachl, R., Balik, M., *et al.* (2017) Diagnostic and Prognostic Value of Presepsin vs. Established Biomarkers in Critically Ill Patients with Sepsis or Systemic Inflammatory Response Syndrome. *Clinical Chemistry and Laboratory Medicine* (*CCLM*), **56**, 658-668. https://doi.org/10.1515/cclm-2017-0839

[28] Winkler, M.S., Rissiek, A., Priefler, M., Schwedhelm, E., Robbe, L., Bauer, A., *et al.* (2017) Human Leucocyte Antigen (HLA-DR) Gene Expression Is Reduced in Sepsis and Correlates with Impaired Tnfα Response: A Diagnostic Tool for Immunosuppression? *PLOS ONE*, **12**, e0182427. https://doi.org/10.1371/journal.pone.0182427

[29] Tang, K., Liu, H., Jiang, K., Ye, T., Yan, L., Liu, P., *et al.* (2017) Predictive Value of Preoperative Inflammatory Response Biomarkers for Metabolic Syndrome and Post-PCNL Systemic Inflammatory Response Syndrome in Patients with Nephrolithiasis. *Oncotarget*, **8**, 85612-85627. https://doi.org/10.18632/oncotarget.20344

[30] Xu, H., Hu, L., Wei, X., Niu, J., Gao, Y., He, J., *et al.* (2019) The Predictive Value of Preoperative High-Sensitive C-Reactive Protein/albumin Ratio in Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Journal of Endourology*, **33**, 1-8. https://doi.org/10.1089/end.2018.0632

[31] Wang, J., Zhang, F., Jiang, F., Hu, L., Chen, J. and Wang, Y. (2021) Distribution and Reference Interval Establishment of Neutral-to-Lymphocyte Ratio (NLR), Lymphocyte-to-Monocyte Ratio (LMR), and Platelet-to-Lymphocyte Ratio (PLR) in Chinese Healthy Adults. *Journal of Clinical Laboratory Analysis*, **35**, e23935. https://doi.org/10.1002/jcla.23935

[32] Liu, Y., Wang, X., Wang, L., Chen, W., Liu, W., Ye, T., *et al.* (2022) Platelet-to-Lymphocyte Ratio Predicts the Presence of Diabetic Neurogenic Bladder. *Diabetes, Metabolic Syndrome and Obesity: Targets and Therapy*, **15**, 7-13. https://doi.org/10.2147/dmso.s335957

[33] Wang, X.Q., Zhang, B., Zhang, Q., *et al.* (2024) Based on Single Cell Sequencing, the Changes of Platelet Count and Function in the Early Stage of Sepsis Were Analyzed. *Practical Medical Journal*, **40**, 1218-1224.

[34] Yang, M., Wang, X.R., Chen, W., *et al.* (2023) Risk Factors Analysis of Systemic Inflammatory Response Syndrome after Percutaneous Nephrolithotomy. *Labeled Immune Analysis and Clinical*, **30**, 97-100.

[35] Hu, B., Yang, X., Xu, Y., Sun, Y., Sun, C., Guo, W., *et al.* (2014) Systemic Immune-Inflammation Index Predicts Prognosis of Patients after Curative Resection for Hepatocellular Carcinoma. *Clinical Cancer Research*, **20**, 6212-6222. https://doi.org/10.1158/1078-0432.ccr-14-0442

[36] Xiang, J., He, L., Li, D., Wei, S. and Wu, Z. (2022) Value of the Systemic Immune-Inflammation Index in Predicting Poor Postoperative Outcomes and the Short-Term Prognosis of Heart Valve Diseases: A Retrospective Cohort Study. *BMJ Open*, **12**, e064171. https://doi.org/10.1136/bmjopen-2022-064171

[37] Li, J., Cao, D., Huang, Y., Xiong, Q., Tan, D., Liu, L., *et al.* (2022) The Prognostic and Clinicopathological Significance of Systemic Immune-Inflammation Index in Bladder Cancer. *Frontiers in Immunology*, **13**, Article ID: 865643. https://doi.org/10.3389/fimmu.2022.865643

[38] Bedel, C., Korkut, M. and Armağan, H.H. (2021) NLR, D-NLR and PLR Can Be Affected by Many Factors. *International Immunopharmacology*, **90**, Article ID: 107154. https://doi.org/10.1016/j.intimp.2020.107154

[39] Zhao, R., Shan, J., Nie, L., Yang, X., Yuan, Z., Xu, H., *et al.* (2021) The Predictive Value of the Ratio of the Product of Neutrophils and Hemoglobin to Lymphocytes in Non-Muscular Invasive Bladder Cancer Patients with Postoperative Recurrence. *Journal of Clinical Laboratory Analysis*, **35**, e23883. https://doi.org/10.1002/jcla.23883