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ORIGINAL RESEARCH

Predictive Value of Monocyte to High-Density Lipoprotein Cholesterol Ratio for Target Lesion Revascularization in Patients With Drug-Eluting Stent Implantation

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Background: Severe in-stent restenosis (ISR) following the implantation of drug-eluting stent (DES) can lead to recurrent angina pectoris or even acute myocardial infarction, thereby necessitating target lesion revascularization (TLR). Prior studies have confirmed the correlation between the monocyte to high-density lipoprotein cholesterol ratio (MHR) and ISR after DES implantation. The potential of MHR to predict TLR following DES implantation remains an area of ongoing research and may have significant clinical implications.

Methods: A retrospective analysis was conducted on a consecutive series of 474 patients undergoing DES implantation and follow-up coronary angiography between December 1, 2014 and December 1, 2022. The patients were categorized into two distinct groups according to their exposure to TLR. To assess the predictive performance of the MHR with respect to TLR, we utilized multivariate logistic regression analysis and receiver operating characteristic (ROC) curve analysis.

Results: The study revealed a significant elevation in the MHR value within the TLR group compared to the non-TLR group (12.34 vs 8.97; $P < 0.001$). MHR was identified as an independent predictor of TLR (Odds Ratio [OR] = 1.162; 95% Confidence Interval [CI]: 1.102–1.225). The area under the curve (AUC) was found to be 0.712 (95% CI: 0.664–0.759). When the MHR exceeded 10.98, the specificity for predicting TLR was 75.8%, and the sensitivity was 58.0%. When the MHR was incorporated into the predictive model comprising established risk factors, there was a notable improvement in the AUC, from 0.689 to 0.749 ($P < 0.001$). Additionally, there was a significant categorical net reclassification improvement (NRI) of 0.183 ($P < 0.001$) and an integrated discrimination improvement (IDI) of 0.074 ($P < 0.001$).

Conclusion: The MHR functions as a predictor for TLR subsequent to DES implantation. Incorporating MHR into the predictive model improves the model's accuracy, indicating its potential value for clinical application.

Keywords: monocyte to high density lipoprotein cholesterol ratio, target lesion revascularization, biomarker, inflammatory factors, lipid metabolism, drug-eluting stent

Introduction

Coronary heart disease (CHD) constitutes a substantial factor contributing to the global mortality burden.[1] The implementation of drug-eluting stents (DESs) has enhanced the effectiveness of percutaneous coronary intervention (PCI) in the management of severe coronary heart disease.[2] However, in-stent restenosis (ISR) after the placement of DES continues to pose a considerable challenge, with incidence rates reported to vary between 3% and 20%.[3–5] An increase in clinical risks, encompassing recurrent angina pectoris and acute myocardial infarction, ultimately necessitates revascularization therapies, including plain old balloon angioplasty (POPA), drug-coated balloons (DCB) angioplasty, repeated DES applications, and coronary artery bypass grafting (CABG). Early risk stratification after DES implantation

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is considered an important means to improve prognosis. In addition to traditional risk factors, the identification of novel predictors for TLR may be of considerable importance in reducing the incidence of this condition.

Previous studies have increasingly emphasized the monocyte to high density lipoprotein cholesterol ratio (MHR) as an emerging and promising prognostic marker for cardiovascular events.[6–9] A study suggested that MHR was a predictive factor for ISR following DES implantation in patients with non-ST-segment elevation acute coronary syndrome (NSTE-ACS).[10] The predictive ability of the MHR for TLR in patients with DES remains ambiguous. The objective of the current research was to assess the efficacy of the MHR in predicting TLR subsequent to the implantation of DES.

Methods

Study Population

This retrospective, observational, case-control study presents an analysis of 622 consecutive patients who underwent successful primary DES implantation, followed by post-implantation coronary angiography at Tianjin Chest Hospital from December 1, 2014 to December 1, 2022. The research excluded participants who had a previous history of CABG, heart failure, hematological abnormalities, active infectious diseases, autoimmune disorders or chronic connective tissue diseases, severe hepatic pathology, thyroid dysfunction, malignancy, renal insufficiency (estimated glomerular filtration rate below 30 mL/min/1.73 m²). Ultimately, a total of 474 patients were enrolled in the study. Among them, 193 patients underwent TLR, with 25 undergoing POBA, 45 receiving DCB treatment, 96 receiving DES implantation, and 27 undergoing CABG. Figure 1 presents the flowchart depicting the study's design and progression.

Intervention Procedure

The interventional procedures were executed in full compliance with the interventional therapy guidelines that were followed at our medical institution.[11] Patients received antiplatelet therapy that consisted of an initial oral loading dose of 300 mg of aspirin, succeeded by a daily maintenance dose of 100 mg. Furthermore, patients were assigned to one of two antiplatelet regimens: either a loading dose of 300 mg of clopidogrel, followed by a maintenance dose of 75 mg per day, or a loading dose of 180 mg of ticagrelor, maintained at 90 mg administered twice daily. Throughout the course of the interventional procedures, anticoagulation therapy was provided using unfractionated heparin, with an initial bolus of 70–100 IU/kg and subsequent doses as required to maintain an activated clotting time exceeding 250 seconds. Coronary angiography was conducted using the Judkins technique on the Philips Allura Xper FD10 fixed X-ray system, after which digital imaging was obtained for further quantitative analysis. The operator was afforded discretion in selecting the type

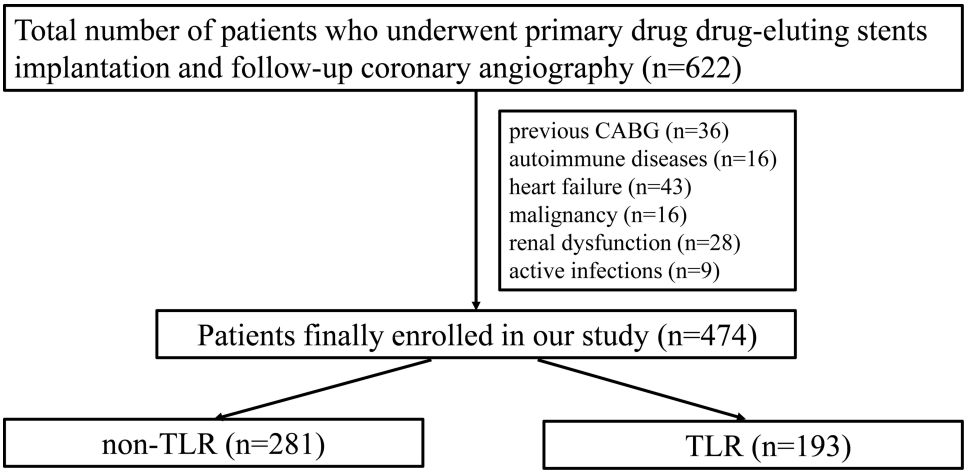

Figure 1 Study flow chart.
Abbreviations: TLR, Target Lesion Revascularization; CABG, Coronary Artery Bypass Grafting.

and size of DES, and making decisions regarding the utilization of glycoprotein IIb/IIIa receptor antagonists. Patients adhered to secondary prevention strategies in accordance with the most recent guidelines after PCI.

Data Collection and Definitions

Data were collected from patient information records by physicians who were adequately trained and blinded to the objectives of the study, including demographics characteristics (age, sex, hypertension, smoking, diabetes), echocardiography (left ventricular ejection fraction[LVEF]), data from coronary angiography, and prescribed medications. Prior to the implantation of the stent, blood samples from the peripheral veins were gathered and then put through an analysis. The subsequent laboratory results were recorded: fasting blood glucose (FBG), high-sensitivity C-reactive protein (hs-CRP), creatinine, uric acid, white blood cell (WBC) counts, total cholesterol (TC), low-density lipoprotein (LDL) cholesterol, triglyceride (TG) levels, and high-density lipoprotein (HDL) cholesterol. The MHR is determined utilizing the subsequent equation: $Monocyte\,count[/\mu l]/HDL[mg/dL]$. Hypertension is characterized by a systolic reading of 140 mmHg or more and/or a diastolic reading of 90 mmHg or above, as determined by at least three separate measurements conducted on different days, or the patient is undergoing antihypertensive treatment. Diabetes mellitus is identified when a person's fasting blood glucose reaches 7.0 mmol/L or higher, or by the utilization of hypoglycemic medications for management. TLR is characterized as any repeat PCI or CABG performed on the target lesion due to: 1) ischemic symptoms that are functionally confirmed and/or myocardial ischemia, accompanied by a luminal diameter stenosis of 50% or greater, as assessed quantitatively by angiography; or 2) any revascularization procedure required due to a luminal diameter stenosis of 70% or greater, confirmed quantitatively by angiography.[12,13]

Statistical Analysis

We employed the Kolmogorov–Smirnov test to evaluate the normality of the continuous variables. Following this assessment, the data were reported as follows: for variables conforming to a normal distribution, the mean ± standard deviation was utilized; for those not conforming to a normal distribution, the median with interquartile range was presented. Moreover, the categorical variables were presented in terms of their frequencies and percentages (%). For data that followed a normal distribution, we utilized independent sample *t*-tests to analyze the results, whereas Mann–Whitney *U*-tests were applied to data that deviated from normal distribution. We evaluated the categorical variables for their statistical significance by employing the chi-square test. A univariate logistic regression analysis was performed to ascertain the factors that were correlated with TLR. Variables that exhibited a P-value of less than 0.1 or were clinically relevant to TLR were subsequently incorporated into the multivariate logistic regression analysis model. MHR was analyzed as a continuous variable. To investigate the relationship between MHR and TLR, we conducted an analysis after excluding the impact of confounding factors. The predictive value of MHR for TLR was conducted through the application of the receiver operating characteristic (ROC) curve, followed by the calculation of the area under the curve (AUC) and determination of the optimal cut-off value. Two models were constructed to assess whether the incorporation of MHR among established risk factors would enhance predictive accuracy. We employed the DeLong test for comparing the areas under the curves (AUCs), and assessed the predictive value of MHR through the calculation of net reclassification improvement (NRI) and integrated discrimination improvement (IDI). The alpha level for all two-tailed tests was established at 0.05. Statistical analyses were performed using SPSS software (version 25.0) and R software (version 4.2.3).

Results

Baseline Characteristics of the Study Participants

The patient cohort had an average age of 60.4 ± 8.6 years, with 59.7% (n = 283) being male. The research participants were divided into two groups: the non-TLR group (281 patients) and the TLR group (193 patients). The baseline demographic and clinical characteristics of the study participants are summarized in Table 1.

The TLR and non-TLR groups exhibited comparable characteristics in respect to age, hypertension, smoking status, LVEF, interval between the two coronary angiographies, and the use of angiotensin-converting enzyme inhibitors

Table 1 Baseline Characteristics of the Study Participants

	Total (n = 474)	Non-TLR (n = 281)	TLR (n = 193)	P Value
Male, n (%)	283 (59.7%)	148 (52.7%)	135 (69.9%)	< 0.001
Age (years)	60.4 ± 8.6	60.6 ± 8.4	59.9 ± 8.9	0.375
Hypertension, n (%)	337 (71.1%)	191 (68.0%)	146 (75.6%)	0.070
Diabetes Mellitus, n (%)	134 (28.3%)	60 (21.4%)	74 (38.3%)	< 0.001
Smoke, n (%)	259 (54.6%)	149 (53.0%)	110 (57.0%)	0.394
LVEF (%)	60.9 ± 4.8	61.2 ± 4.8	60.5 ± 4.8	0.133
Target coronary artery, n (%)				0.015
LAD	273 (57.6%)	176 (62.6%)	97(50.3%)	
LCX	81 (17.1%)	46 (16.4%)	35 (18.1%)	
RCA	120 (25.3%)	59 (21.0%)	61 (31.6%)	
Number of stenosed coronary arteries, n(%)				< 0.001
1	139(29.3%)	101(35.9%)	38(19.7%)	
2	160(33.8%)	101(35.9%)	59(30.6%)	
3	175(36.9%)	79(28.1%)	96(49.7%)	
Interval between the two coronary angiographies (months)	43 (28, 60)	42 (28, 59)	46 (29, 67)	0.057
Total stent length (mm)	28 (18, 38)	25 (18, 36)	33 (20, 49)	0.003
Minimal Stent diameter (mm)	3.00 (2.75, 3.50)	3.00 (2.75, 3.50)	3.00 (2.63, 3.36)	0.002
ACEI/ARB, n (%)	276 (58.2%)	157 (55.9%)	119 (61.7%)	0.210
Beta blockers, n (%)	321 (67.7%)	184 (65.5%)	137 (71.0%)	0.208
FBG(mmol/L)	5.31 (4.74, 6.63)	5.21 (4.73, 5.94)	5.66 (4.79, 7.25)	< 0.001
TC (mmol/L)	4.56 ± 1.08	4.60 ± 1.06	4.59 ± 1.10	0.293
LDL (mmol/L)	2.96 ± 0.96	2.96 ± 0.96	2.95 ± 0.96	0.953
HDL (mmol/L)	1.08±0.25	1.12±0.25	1.02 ± 0.24	< 0.001
TG (mmol/L)	1.52 (1.11, 2.11)	1.47 (1.07, 2.03)	1.58 (1.18, 2.19)	0.077
Creatinine(μmol/L)	71.51 ± 15.67	69.90 ± 14.85	73.84 ± 16.53	0.007
Uric Acid(μmol/L)	318.69 ± 82.04	314.10 ± 78.61	325.86 ± 86.53	0.125
WBC (10^9/L)	6.86 ± 1.75	6.58 ± 1.61	7.26 ± 1.86	< 0.001
Neutrophil (10^9/L)	4.52 ± 1.45	4.31 ± 1.33	4.83 ± 1.57	< 0.001
Lymphocyte (10^9/L)	1.81 ± 0.63	1.80 ± 0.62	1.83 ± 0.64	0.559
Monocyte (10^9/L)	0.41 ± 0.15	0.37 ± 0.13	0.46 ± 0.16	< 0001
Hs-CRP (mg/L)	1.33 (0.71, 3.24)	1.20 (0.69, 2.63)	2.05 (0.78, 4.52)	0.001
MHR	10.34 ± 4.68	8.97 ± 3.70	12.34 ± 5.22	< 0.001

Abbreviations: TLR, Target Lesion Revascularization; DES, Drug-Eluting Stent; LVEF, Left Ventricular Ejection Fraction; LAD, Left Anterior Descending Artery; LCX, Left Circumflex Artery; RCA, Right Coronary Artery; ACEI, Angiotensin-Converting Enzyme Inhibitors; ARB, Angiotensin Receptor Blockers; FBG, Fasting Blood Glucose; TC, Total Cholesterol; LDL, Low-Density Lipoprotein; HDL, High-Density Lipoprotein; TG, Triglycerides; WBC, White Blood Cell; hs-CRP, High-Sensitivity C-Reactive Protein; MHR, Monocyte Count to High-Density Lipoprotein Cholesterol Ratio.

(ACEIs), angiotensin receptor blockers (ARBs), and β-blockers. Equivalent concentrations of lymphocyte counts, TC, LDL, TG, and uric acid were observed between the two groups. However, a greater proportion of males and diabetics were present in the TLR group, accompanied by a higher incidence of multivessel disease. The TLR group exhibited narrower minimum stent diameters and longer total stent lengths. Additionally, the TLR group demonstrated significantly higher levels of FBG, creatinine, and hs-CRP. When compared with the non-TLR group, there was a significant increase in the counts of WBCs, neutrophils, and monocytes, coupled with a notable decrease in HDL levels.

Comparison of the MHR

The statistical analysis revealed a notable elevation in MHR within the TLR group when compared to the non-TLR group with respective values of 12.34 and 8.97, as illustrated in Figure 2A. Based on the tertile distribution of MHR, patients were stratified into three groups, with a statistically significant upward trend observed in the proportion of patients undergoing TLR from the lowest tertile (T1) to the highest tertile (T3), as depicted in Figure 2B.

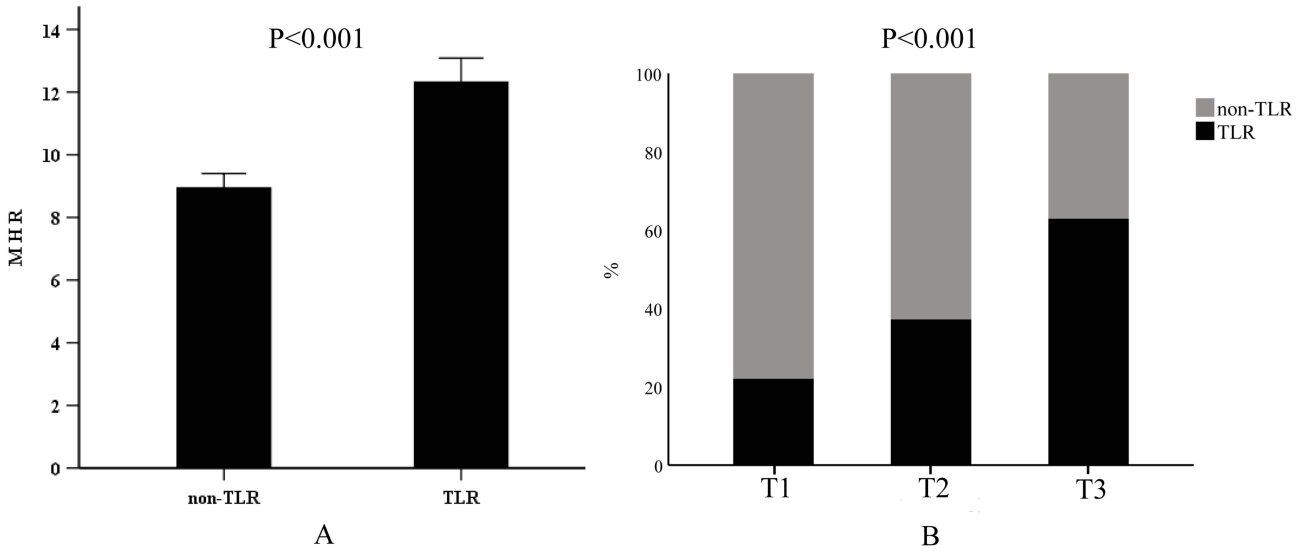

Figure 2 Comparison of the monocyte count to high-density lipoprotein cholesterol ratio (MHR) between the two groups (**A**); as well as the proportion of patients undergoing target lesion revascularization (TLR) by MHR tertiles (**B**).

Logistic Regression Analyses

Multivariate logistic regression analyses revealed associations between TLR and several factors, including the MHR, sex, diabetes mellitus, the target vessel, and the number of stenosed coronary arteries. Following adjustment for potential confounding variables, MHR was identified as an independent and significant predictor of TLR, exhibiting an odds ratio (OR) of 1.162 (95% confidence interval [CI]: 1.102–1.225), as presented in Table 2.

Receiver Operating Characteristic (ROC) Curve Analysis

Figure 3A illustrated the AUC for TLR, which was 0.712 (95% CI: 0.664–0.759). The optimal cut-off value was determined to be 10.98, with a resulting sensitivity of 58.0% and a specificity of 75.8%.

The incorporation of the MHR into a predictive model, which already included established risk factors such as male gender, diabetes, target coronary vessel, and the number of stenosed coronary arteries, resulted in an enhanced AUC from

Table 2 Logistic Regression Analyses of Predictors for Target Lesion Revascularization (TLR)

Variable	Univariate			Multivariate		
	B	OR (95% CI)	P Value	B	OR (95% CI)	P Value
Male	0.738	2.092 (1.421–3.079)	< 0.001	0.522	1.686 (1.095–2.595)	**0.018**
Diabetes Mellitus	0.829	2.290 (1.525–3.441)	< 0.001	0.547	1.728 (1.098–2.719)	**0.018**
Target coronary artery			0.016			0.127
LAD	Ref	Ref	Ref	Ref	Ref	Ref
LCX	0.322	1.381 (0.833–2.287)	0.210	0.116	1.123 (0.642–1.964)	0.684
RCA	0.629	1.876 (1.214–2.899)	0.005	0.505	1.656 (1.016–2.700)	**0.043**
Number of stenosed coronary arteries			< 0.001			**0.010**
1	Ref	Ref	Ref	Ref	Ref	Ref
2	0.440	1.553 (0.949–2.540)	0.080	0.216	1.242 (0.730–2.110)	0.424
3	1.172	3.230 (2.004–5.205)	< 0.001	0.762	2.143 (1.269–3.619)	**0.004**
MHR	0.182	1.200 (1.141–1.262)	< 0.001	0.150	1.162 (1.102–1.225)	**< 0.001**

Notes: Covariates controlled in the multivariate logistic regression model, MHR, sex, diabetes mellitus, the target vessel, and the number of stenosed coronary arteries. In the multivariate regression analysis, numerical results with P-values < 0.05 are highlighted in bold.
Abbreviations: MHR, Monocyte Count to High-Density Lipoprotein Cholesterol Ratio; OR, Odds Ratio; CI, Confidence Interval; Ref, Reference..

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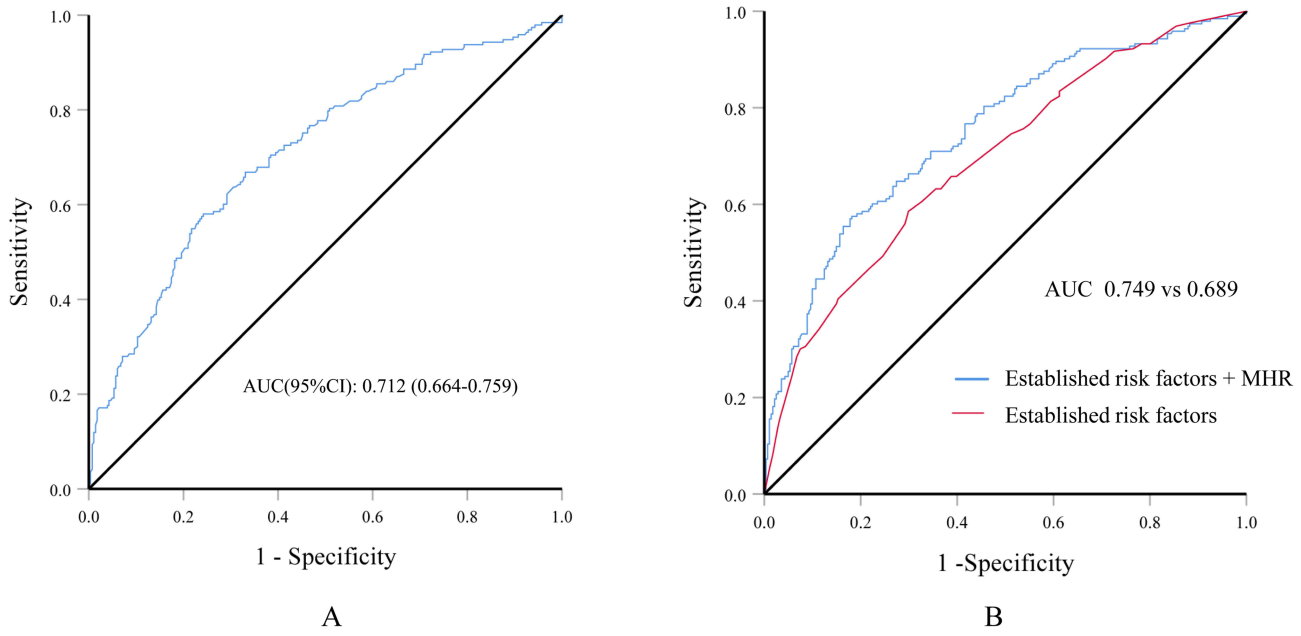

Figure 3 Receiver operating characteristic (ROC) curve analysis of the monocyte count to high-density lipoprotein cholesterol ratio (MHR) for predicting target lesion revascularization (TLR) (**A**), and area under curve (AUC) comparison between the models (**B**).

0.689 to 0.749 (P < 0.001), as illustrated in Figure 3B. Additionally, improvements were noted in the categorical NRI of 0.183 (P < 0.001) and the IDI of 0.074 (P < 0.001), as detailed in Table 3.

Discussion

The present study examined the correlation between MHR and TLR in patients undergoing DES implantation. An increase in MHR was correlated with a higher probability of TLR following DES implantation. Upon adjustment for potential confounding variables, MHR was identified as an independent predictor of TLR. Incorporating MHR into the mix of conventional risk factors could significantly improve the early assessment of risk for TLR.

Previous research has shown that in patients with ST-segment elevation myocardial infarction (STEMI), the MHR can predict the risk of stent thrombosis with a hazard ratio (HR) of 1.08 (95% CI: 1.02–1.17).[14] Analysis of data from multiple studies has demonstrated that the preprocedural MHR serves as an independent predictor of BMS-ISR. Specifically, the ORs and 95% CIs reported in these studies are as follows: OR = 1.45 (95% CI: 1.06–1.88),[15] OR = 1.29 (95% CI: 1.15–1.49),[16] and OR = 3.64 (95% CI: 2.45–4.84).[17] Nan et al performed a study involving 214 patients who were diagnosed with NSTE-ACS. Their findings indicated that the MHR independently predicted DES-ISR with an OR of 1.02 (95% CI: 1.01–1.03; P = 0.041).[10] Previous studies examining the relationship between MHR and ISR have piqued our interest in investigating the link between MHR and TLR. Our study differs from that of Nan et al in several respects. First, the study population in our research comprises individuals with unstable angina rather than those with NSTE-ACS; Second, the clinical outcomes investigated in our study differ. We included 31 patients in the non-TLR group who were diagnosed with ISR but did not undergo revascularization through repeat PCI or CABG, instead for medical therapy. Essentially, the target vessel revascularization rate reflects the incidence of severe in-stent restenosis,

Table 3 Assessment of the Predictive Efficacy of the Models Concerning Target Lesion Revascularization (TLR)

	AUC	P Value	P for Comparison	Categorical NRI	P Value	IDI	P Value
Established risk factors	0.689 (0.641–0.738)	P<0.001					
Established risk factors plus MHR	0.749 (0.704–0.794)	P<0.001	P<0.001	0.183 (0.088–0.278)	P<0.001	0.074 (0.049–0.098)	P<0.001

Abbreviations: AUC, Area Under the Curve; MHR, Monocyte Count to High-density Lipoprotein Cholesterol Ratio; NRI, Net Reclassification Improvement; IDI, Integrated Discrimination Improvement.

indicating more severe clinical outcomes. Nan et al confirmed the correlation between MHR and ISR, while we have demonstrated the connection between MHR and severe ISR.

The primary underlying factor contributing to TLR is the occurrence of excessive neointimal hyperplasia within the stented region.[18,19] Additionally, patients with DES exhibit an earlier and more prevalent occurrence of neoatherosclerosis compared to those with BMS. Inflammation is a crucial factor in the process of endothelial hyperplasia. Upon activation, monocytes are capable of releasing pro-inflammatory cytokines. These cytokines facilitate the proliferation and activation of vascular smooth muscle cells within the vascular wall.[20,21] A study conducted by Fukuda et al revealed that circulating monocytes contribute to the development of neointimal hyperplasia in the context of stent implantation.[22] Neoatherosclerosis is defined by the presence of lipid-rich foamy macrophages that accumulate in the neointimal layer. In this context, the critical processes involve the activity of monocytes and their differentiation into macrophages. Our study revealed a statistically significant increase in monocyte counts in the TLR group compared to the control group (0.46 vs 0.37, $P < 0.001$), indicating a positive correlation between the two variables.

HDL exhibits several properties that may confer anti-atherogenic potential. The inherent antioxidant and anti-inflammatory characteristics of HDL collectively enhance its anti-atherogenic effect, thereby mitigating atherogenic processes.[23] HDL exhibits a multifaceted array of protective effects, encompassing the inhibition of endothelial cell apoptosis, facilitation of re-endothelialization, augmentation of endothelial cell-derived prostacyclin synthesis, reduction of platelet aggregability, and regulation of endothelial function via enhanced endothelial nitric oxide production.[23–25] Moreover, HDL plays a pivotal role in maintaining cholesterol homeostasis by enabling the elimination of excess cholesterol from peripheral tissues via the reverse cholesterol transport pathway.[26] Nagano et al observed that a reduced ability of HDL to accommodate additional cholesterol could potentially result in future stent failure, mediated through the induction of atherogenic alterations within the neointima of stents.[27] Our study revealed a statistically significant decrease in HDL levels in the TLR group compared to the control group (1.02 vs 1.12, $P < 0.001$), indicating an inverse correlation between the two variables.

Moreover, existing literature has documented an interaction between HDL and monocytes, indicating that HDL possesses the ability to reduce the manifestation of adhesion molecules on endothelial cells. This reduction effectively hinders the migration of monocytes to the arterial wall.[28] HDL demonstrates a significant interaction with monocytes, which inhibits their activation and disrupts their differentiation process into macrophages. This interaction ultimately contributes to a decrease in the subsequent inflammatory response.[29] MHR, which serves as a biomarker reflecting the combined influence of monocytes and HDL, has been shown to exhibit an independent correlation with TLR. In our study, the MHR exhibited a predictive AUC of 0.712 for TLR, which demonstrates moderate predictive capability. The incorporation of the MHR into a predictive model resulted in an enhanced AUC from 0.689 to 0.749. Additionally, improvements were noted in the categorical NRI of 0.183 and the IDI of 0.074. Incorporating MHR into the risk stratification following stent implantation will facilitate the identification of high-risk individuals and guide clinicians in providing intensified pharmacotherapy, thereby reducing the rate of target vessel revascularization.

However, some limitations of our study must be acknowledged. Due to the inherent constraints of this retrospective, single-center, observational study design, a definitive causal relationship between MHR and TLR cannot be established. More prospective cohort studies are needed to validate the predictive value of MHR. To discern the causes of in-stent restenosis, additional research utilizing intracoronary imaging techniques is necessary, rather than relying solely on angiography. More research needs to be conducted in order to identify the underlying causes of in-stent restenosis to seek further explanations for relationship between MHR and TLR.

Conclusion

In conclusion, the MHR, serving as a biomarker, demonstrates an independent and positive association with the risk of TLR in patients undergoing DES implantation. Incorporating MHR into predictive models has the potential to enhance their predictive accuracy. Further validation of the predictive significance of MHR requires the conduct of multicenter, prospective studies.

Data Sharing Statement

The datasets underlying the conclusions of this study are presented within the article. Upon receipt of a reasonable request, the corresponding author will provide any supplementary data.

Ethical Approval and Consent to Participate

The current research was granted approval by the Ethics Committee of Tianjin Chest Hospital (IRB-SOP-016[F]-001-03), with strict adherence to the ethical guidelines delineated in the Declaration of Helsinki. The requirement for obtaining informed consent was waived by the Ethics Commission because of the retrospective design. All patient data have been anonymized and de-identified to the fullest extent possible, with all personal identifiers removed to ensure that individuals cannot be traced or identified from the information provided. Furthermore, we have implemented robust data security measures to safeguard the confidentiality and integrity of patient data, including encryption, secure storage, and restricted access to the data. The authors acknowledge their responsibility to maintain the highest standards of confidentiality and ethical conduct in all aspects of the research process.

Consent for Publication

This study excludes data pertaining to any individual persons; consequently, the requirement for consent for publication is not pertinent.

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Author Contributions

Each author has made substantial contributions to the reported work, encompassing conception, study design, execution, data acquisition, analysis, interpretation, and/or all these domains; participated in drafting, revising, and critically reviewing the manuscript; approved the final version for publication; concurred on the journal of submission; and accepts responsibility for all aspects of the work.

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Disclosure

The authors declare that they have no conflicts of interest in this work.

References

1. GBD 2016 Risk Factors Collaborators. Global, regional, and national disability-adjusted life-years (DALYs) for 333 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. *Lancet*. 2017;390(10100):1260–1344. doi:10.1016/S0140-6736(17)32130-X
2. Serruys PW, Kutryk MJ, Ong AT. Coronary-artery stents. *N Engl J Med*. 2006;354(5):483–495. doi:10.1056/NEJMra051091
3. Alfonso F, Byrne RA, Rivero F, Kastrati A. Current treatment of in-stent restenosis. *J Am Coll Cardiol*. 2014;63(24):2659–2673. doi:10.1016/j.jacc.2014.02.545
4. Byrne RA, Joner M, Kastrati A. Stent thrombosis and restenosis: what have we learned and where are we going? The Andreas Grüntzig Lecture ESC 2014. *Eur Heart J*. 2015;36(47):3320–3331. doi:10.1093/eurheartj/ehv511
5. Dangas GD, Claessen BE, Caixeta A, Sanidas EA, Mintz GS, Mehran R. In-stent restenosis in the drug-eluting stent era. *J Am Coll Cardiol*. 2010;56(23):1897–1907. doi:10.1016/j.jacc.2010.07.028
6. Kanbay M, Solak Y, Unal HU, et al. Vural A and others. Monocyte count/HDL cholesterol ratio and cardiovascular events in patients with chronic kidney disease. *Int Urol Nephrol*. 2014;46(8):1619–1625. doi:10.1007/s11255-014-0730-1
7. Akboga MK, Balci KG, Maden O, et al. Usefulness of monocyte to HDL-cholesterol ratio to predict high SYNTAX score in patients with stable coronary artery disease. *Biomarker Med*. 2016;10(4):375–383. doi:10.2217/bmm-2015-0050
8. Kundi H, Kiziltunc E, Cetin M, et al. Association of monocyte/HDL-C ratio with SYNTAX scores in patients with stable coronary artery disease. *Herz*. 2016;41(6):523–529. doi:10.1007/s00059-015-4393-1

9. Zhan X, Pan D, Wei X, Wen D, Yan C, Xiao J. Monocyte to high-density lipoprotein ratio and cardiovascular events in patients on peritoneal dialysis. *Nutr Metab Cardiovasc Dis*. 2020;30(7):1130–1136. doi:10.1016/j.numecd.2020.03.011
10. Nan J, Meng S, Hu H, et al. The Predictive Value of Monocyte Count to High-Density Lipoprotein Cholesterol Ratio in Restenosis After Drug-Eluting Stent Implantation. *Int J Gen Med*. 2020;13:1255–1263. doi:10.2147/IJGM.S275202
11. Neumann FJ, Sousa-Uva M, Ahlsson A, et al. ESC/EACTS Guidelines on myocardial revascularization. *Eur Heart J*. 2019;40(2):87–165. doi:10.1093/eurheartj/ehy394
12. Garcia-Garcia HM, McFadden EP, Farb A, et al. Standardized End Point Definitions for Coronary Intervention Trials: the Academic Research Consortium-2 Consensus Document. *Eur Heart J*. 2018;39(23):2192–2207. doi:10.1093/eurheartj/ehy223
13. Kandzari DE, Koolen JJ, Doros G, et al. Ultrathin Bioresorbable-Polymer Sirolimus-Eluting Stents Versus Thin Durable-Polymer Everolimus-Eluting Stents for Coronary Revascularization: 3-Year Outcomes From the Randomized BIOFLOW V Trial. *JACC: Cardiovasc Interv*. 2020;13(11):1343–1353. doi:10.1016/j.jcin.2020.02.019
14. Cetin EH, Cetin MS, Canpolat U, et al. Monocyte/HDL-cholesterol ratio predicts the definite stent thrombosis after primary percutaneous coronary intervention for ST-segment elevation myocardial infarction. *Biomarker Med*. 2015;9(10):967–977. doi:10.2217/bmm.15.74
15. Tok D, Turak O, Yayla Ç, Ozcan F, Tok D, Çağlı K. Monocyte to HDL ratio in prediction of BMS restenosis in subjects with stable and unstable angina pectoris. *Biomarker Med*. 2016;10(8):853–860. doi:10.2217/bmm-2016-0071
16. Yilmaz S, Akboga MK, Sen F, et al. Usefulness of the monocyte-to-high-density lipoprotein cholesterol ratio to predict bare metal stent restenosis. *Biomarker Med*. 2016;10(9):959–966. doi:10.2217/bmm-2016-0069
17. Ucar FM. A potential marker of bare metal stent restenosis: monocyte count - to- HDL cholesterol ratio. *BMC Cardiovasc Disord*. 2016;16(1):186. doi:10.1186/s12872-016-0367-3
18. Hoffmann R, Mintz GS, Dussaillant GR, et al. Patterns and mechanisms of in-stent restenosis. A serial intravascular ultrasound study. *Circulation*. 1996;94(6):1247–1254. doi:10.1161/01.CIR.94.6.1247
19. Grewe PH, Deneke T, Machraoui A, Barmeyer J, Müller KM. Acute and chronic tissue response to coronary stent implantation: pathologic findings in human specimen. *J Am Coll Cardiol*. 2000;35(1):157–163. doi:10.1016/S0735-1097(99)00486-6
20. Liu Y, Imanishi T, Ikejima H, et al. Ino Y and others. Association between circulating monocyte subsets and in-stent restenosis after coronary stent implantation in patients with ST-elevation myocardial infarction. *Circ J*. 2010;74(12):2585–2591. doi:10.1253/circj.CJ-10-0544
21. Welt FG, Rogers C. Inflammation and restenosis in the stent era. *Arterioscler Thromb Vasc Biol*. 2002;22(11):1769–1776. doi:10.1161/01.ATV.0000037100.44766.5B
22. Fukuda D, Shimada K, Tanaka A, Kawarabayashi T, Yoshiyama M, Yoshikawa J. Circulating monocytes and in-stent neointima after coronary stent implantation. *J Am Coll Cardiol*. 2004;43(1):18–23. doi:10.1016/j.jacc.2003.08.026
23. Barter PJ, Nicholls S, Rye KA, Anantharamaiah GM, Navab M, Fogelman AM. Antiinflammatory properties of HDL. *Circ Res*. 2004;95(8):764–772. doi:10.1161/01.RES.0000146094.59640.13
24. Seetharam D, Mineo C, Gormley AK, et al. High-density lipoprotein promotes endothelial cell migration and reendothelialization via scavenger receptor-B type I. *Circ Res*. 2006;98(1):63–72. doi:10.1161/01.RES.0000199272.59432.5b
25. Zeiher AM, Schächinger V. Coronary endothelial vasodilator dysfunction: clinical relevance and therapeutic implications. *Z Kardiol*. 1994;83(4):7–14.
26. Barter P, Kastelein J, Nunn A, Hobbs R. High density lipoproteins (HDLs) and atherosclerosis; the unanswered questions. *Atherosclerosis*. 2003;168(2):195–211. doi:10.1016/S0021-9150(03)00006-6
27. Nagano Y, Otake H, Toba T, et al. Nagasawa A and others. Impaired Cholesterol-Uptake Capacity of HDL Might Promote Target-Lesion Revascularization by Inducing Neoatherosclerosis After Stent Implantation. *J Am Heart Assoc*. 2019;8(9):e011975. doi:10.1161/JAHA.119.011975
28. Cockerill GW, Rye KA, Gamble JR, Vadas MA, Barter PJ. High-density lipoproteins inhibit cytokine-induced expression of endothelial cell adhesion molecules. *Arterioscler Thromb Vasc Biol*. 1995;15(11):1987–1994. doi:10.1161/01.ATV.15.11.1987
29. Murphy AJ, Woollard KJ, Hoang A, et al. High-density lipoprotein reduces the human monocyte inflammatory response. *Arterioscler Thromb Vasc Biol*. 2008;28(11):2071–2077. doi:10.1161/ATVBAHA.108.168690