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临床研究·论著

## 冠心病患者经皮冠状动脉介入术相关造影剂 急性肾损害的影响因素分析及KIM-1、 NGAL、NHE3的预测价值\*

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**摘要: 目的** 探究冠状动脉粥样硬化性心脏病(以下简称冠心病)患者经皮冠状动脉介入术(PCI)相关造影剂急性肾损害(CIAKI)的影响因素,并分析尿液中肾损伤分子-1(KIM-1)、中性粒细胞明胶酶相关脂质结合蛋白(NGAL)、钠/氢交换蛋白3(NHE3)预测CIAKI发生的价值。**方法** 回顾性分析2021年7月—2022年6月在齐齐哈尔医学院附属第一医院行PCI的142例冠心病患者的病历资料,根据患者术后是否发生CIAKI,分为CIAKI组和非CIAKI组。分析影响PCI术后发生CIAKI的因素,评估PCI前后KIM-1差值、NGAL差值及NHE3差值对PCI术后发生CIAKI的预测价值。**结果** 142例行PCI的冠心病患者中发生CIAKI 25例(17.61%)。CIAKI组糖尿病占比及造影剂使用剂量高于非CIAKI组( $P < 0.05$ ),术前GFR水平低于非CIAKI组( $P < 0.05$ )。CIAKI组手术前后尿KIM-1、NGAL及NHE3的差值均高于非CIAKI组( $P < 0.05$ )。多因素逐步Logistic回归分析结果显示:糖尿病[OR=3.350(95% CI:1.145, 9.802)]、造影剂使用剂量[OR=3.377(95% CI:1.154, 9.880)]、KIM-1差值[OR=4.958(95% CI:1.695, 14.506)]、NGAL差值[OR=4.446(95% CI:1.519, 13.008)]、NHE3差值[OR=4.446(95% CI:1.519, 3.008)]是冠心病患者PCI术后发生CIAKI的危险因素( $P < 0.05$ );GFR[OR=0.262(95% CI:0.089, 0.765)]是冠心病患者PCI术后发生CIAKI的保护因素( $P < 0.05$ )。受试者工作特征曲线分析结果表明,KIM-1差值、NGAL差值、NHE3差值单一及联合预测冠心病患者PCI术后发生CIAKI的敏感性为75.32%(95% CI:0.594, 0.831)、68.59%(95% CI:0.537, 0.762)、62.77%(95% CI:0.514, 0.735)、80.93%(95% CI:0.629, 0.924),特异性为74.01%(95% CI:0.583, 0.826)、83.16%(95% CI:0.652, 0.941)、78.92%(95% CI:0.603, 0.875)、81.15%(95% CI:0.638, 0.945),曲线下面积为0.743、0.748、0.762和0.837,联合诊断效能最高。**结论** 糖尿病、GFR、造影剂使用剂量和PCI前后KIM-1、NGAL、NHE3的变化影响CIAKI的发生,PCI前后KIM-1差值、NGAL差值及NHE3差值联合预测CIAKI的效能较好。

**关键词:** 冠状动脉粥样硬化性心脏病;经皮冠状动脉介入术;造影剂急性肾损害;肾损伤分子-1;中性粒细胞明胶酶相关脂质结合蛋白;钠/氢交换蛋白3

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## Factors affecting the occurrence of contrast-induced acute kidney injury related to PCI in patients with coronary heart disease and predictive values of KIM-1, NGAL and NHE3\*

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**Abstract: Objective** To explore the factors affecting the occurrence of contrast-induced acute kidney injury (CIAKI) related to percutaneous coronary intervention (PCI) in patients with coronary heart disease, and to analyze the predictive values of kidney injury molecule-1 (KIM-1), neutrophil gelatinase-associated lipocalin (NGAL), and sodium-hydrogen exchanger 3 (NHE3) in the urine for the occurrence of CIAKI. **Methods** A retrospective analysis was conducted on medical records of 142 patients with coronary heart disease who underwent PCI in the First Affiliated Hospital of Qiqihar Medical University from July 2021 to June 2022. The patients were divided into the CIAKI group and the non-CIAKI group based on whether they developed CIAKI after PCI. The factors influencing the occurrence of CIAKI after PCI were analyzed, and the predictive values of the differences of the levels of KIM-1, NGAL and NHE3 before and after PCI for the development of CIAKI following PCI were assessed. **Results** Among the 142 patients with coronary heart disease who underwent PCI, 25 cases (17.61%) developed CIAKI. The proportion of patients with concomitant diabetes mellitus and the dosage of contrast agents were higher in the CIAKI group compared to the non-CIAKI group ( $P < 0.05$ ). The preoperative GFR in the CIAKI group was lower than that in the non-CIAKI group ( $P < 0.05$ ). The differences of urine levels of KIM-1, NGAL and NHE3 before and after PCI in the CIAKI group were greater than those in the non-CIAKI group ( $P < 0.05$ ). The multivariable stepwise Logistic regression analysis (inclusion of variables with  $P$ -value  $< 0.05$  and exclusion of variables with  $P$ -value  $> 0.10$ ) revealed that presence of concomitant diabetes mellitus [ $\hat{OR} = 3.350$  (95% CI: 1.145, 9.802)], high dosage of contrast agents [ $\hat{OR} = 3.377$  (95% CI: 1.154, 9.880)], and great differences of levels of KIM-1 [ $\hat{OR} = 4.958$  (95% CI: 1.695, 14.506)], NGAL [ $\hat{OR} = 4.446$  (95% CI: 1.519, 13.008)], and NHE3 [ $\hat{OR} = 4.446$  (95% CI: 1.519, 3.008)] were identified as risk factors ( $P < 0.05$ ), and that low preoperative GFR [ $\hat{OR} = 0.262$  (95% CI: 0.089, 0.765)] was identified as a protective factor for CIAKI after PCI in patients with coronary heart disease ( $P < 0.05$ ). The receiver operating characteristic (ROC) curve analysis indicated that the sensitivities of the differences of levels of KIM-1, NGAL, and NHE3 alone and their combination for predicting CIAKI after PCI were 75.32% (95% CI: 0.594, 0.831), 68.59% (95% CI: 0.537, 0.762), 62.77% (95% CI: 0.514, 0.735), and 80.93% (95% CI: 0.629, 0.924), with the specificities being 74.01% (95% CI: 0.583, 0.826), 83.16% (95% CI: 0.652, 0.941), 78.92% (95% CI: 0.603, 0.875), and 81.15% (95% CI: 0.638, 0.945), and the areas under the ROC curves (AUC) being 0.743, 0.748, 0.762, and 0.837. The diagnostic efficacy of the combined detection was the highest. **Conclusions** Presence of diabetes mellitus, GFR, dosage of contrast agents, and changes in levels of KIM-1, NGAL and NHE3 before and after PCI affect the occurrence of CIAKI. The combination of the differences of levels of KIM-1, NGAL and NHE3 before and after PCI exhibits great predictive efficacy for CIAKI.

**Keywords:** coronary heart disease; percutaneous coronary intervention; contrast-induced acute kidney injury; kidney injury molecule-1; neutrophil gelatinase-associated lipocalin; sodium-hydrogen exchanger 3

冠状动脉粥样硬化性心脏病(以下简称冠心病)是中老年人群罹患风险较高的一类心血管疾病,病情进展可诱发急性心肌梗死,威胁患者的生命安全。经皮冠状动脉介入术(percutaneous coronary intervention, PCI)作为现阶段治疗冠心病的首选方案,借助导丝或导管直接作用于冠状动脉病灶,修复血管狭窄,促进血流灌注恢复,疗效确切<sup>[1-2]</sup>。然而,PCI术中造影剂的使用虽然增加了冠状动脉血管内狭窄、堵塞或血栓的辨识度,但同样存在肾损伤风险,可导致肾脏储备及代偿功能下降,诱发造影剂急性肾损伤(contrast-induced acute kidney injury, CIAKI),影响患者预后<sup>[3-4]</sup>。目

前,冠心病患者PCI术后发生CIAKI的诊断标准以欧洲泌尿生殖放射学会<sup>[5]</sup>提出的造影剂管理指南为主,即静脉注射造影剂后48~72h内监测到急性肾功能减退,血肌酐(serum creatinine, Scr) $\geq 25\%$ 术前基础值或升高 $> 44.2 \mu\text{mol/L}$ 。但对冠心病患者PCI术后发生CIAKI的预测尚无统一标准或共识。

Scr是目前辅助评估肾功能的生物学标志物,可准确反映肾脏滤过功能,常作为慢性肾脏病、急性肾损伤等肾疾病治疗反应性及药物代谢性肾损伤中药物剂量调整的参考<sup>[6]</sup>。但冠心病患者PCI术中使用造影剂后,Scr水平往往在术后24~48h升高,5~7d左右达峰值,而发生CIAKI的时间段在静脉

注射造影剂后48~72 h内,与Scr变化存在交叉重合区,因此参考Scr水平无法对CIAKI进行早期诊断,可能导致漏诊<sup>[7]</sup>。随着近几年基因及蛋白技术发展,有研究发现尿液中肾损伤分子-1(kidney injury molecule-1, KIM-1)、中性粒细胞明胶酶相关脂质结合蛋白(neutrophil gelatinase-associated lipocalin, NGAL)及钠/氢交换蛋白3(sodium-hydrogen exchanger 3, NHE3)在急性肾损伤早期具有更高的敏感性,可能成为预测冠心病患者PCI术后发生CIAKI的高敏性生物学标志物<sup>[8-10]</sup>。但目前针对冠心病患者PCI术后发生CIAKI的影响因素及与KIM-1、NGAL、NHE3相关性的报道较少。基于此,本研究采用回顾性分析对冠心病患者PCI术后发生CIAKI的影响因素及与KIM-1、NGAL、NHE3的关系进行探究,为冠心病患者PCI术后发生CIAKI的预防及治疗提供理论依据。

## 1 资料与方法

### 1.1 研究对象

回顾性分析2021年7月—2022年6月在齐齐哈尔医学院附属第一医院行PCI的142例冠心病患者的病历资料。本研究通过院内医学伦理会审批。纳入标准:①符合美国心脏病学会/美国心脏协会实践指南工作组<sup>[11]</sup>制订的冠心病诊断标准;②行PCI治疗;③疾病类型为稳定型心绞痛或非ST段抬高型急性冠脉综合征;④年龄>18岁;⑤PCI术前Scr水平正常;⑥使用碘化造影剂;⑦PCI术前及术后72 h内肾功能检测指标记录完整。排除标准:①慢性肾病;②PCI围手术期使用磺胺类(如磺胺乙氧恶唑)、氨基糖苷类(如万古霉素)等肾毒性药物;③恶性肿瘤;④活动性出血;⑤合并脑血管疾病;⑥心血管介入治疗史,或心肌梗死病史;⑦哺乳或妊娠期女性。

### 1.2 研究方法

**1.2.1 病历资料收集** 包括人口学资料(性别、年龄、体质量指数、糖尿病、高血压)、造影剂使用剂量、心肌功能指标[术前左室射血分数(left ventricular ejection fraction, LVEF)]、术前白细胞、血小板、红细胞、纤维蛋白原、总蛋白、Scr、肾小球滤过率(glomerular filtration rate, GFR),以及术前及术后24 h尿KIM-1、NGAL、NHE3。GFR=175×Scr-

1.234×年龄(岁)-0.179×0.79(女性)。

**1.2.2 酶联免疫吸附试验(enzyme linked immunosorbent assay, ELISA)检测尿KIM-1、NGAL、NHE3** 收集尿液样品,3 500 r/min离心12 min,离心半径13.5 cm,收集上清液。在ELISA微孔板中分别涂覆抗人KIM-1、NGAL、NHE3抗体,后将标准品和待测样品加入不同的孔中。37℃孔板孵育1~2 h,分别使KIM-1、NGAL、NHE3与捕获抗体结合。使用PBS洗涤孔板3 min/次,共5次,去除非特异性结合物质。加入酶标记的二抗(辣根过氧化物酶),使其与孔中残余的KIM-1、NGAL、NHE3结合,再次洗涤孔板3 min/次,共5次。将底物溶液加入酶标二抗结合的孔中,触发酶催化反应,产生可测量的颜色反应。反应5~15 min,待颜色稳定后加入相应反应停止溶液终止酶反应。使用酶标仪测量颜色反应强度,使用标准曲线检测待测样品KIM-1、NGAL、NHE3浓度。KIM-1试剂盒购自上海泽叶生物科技有限公司,NGAL试剂盒购自上海瑞番生物科技有限公司,NHE3试剂盒购自上海酶仪生物科技有限公司。

**1.2.3 分组** 参考欧洲泌尿生殖放射学会<sup>[5]</sup>制订的CIAKI标准:静脉注射造影剂后48~72 h内监测到急性肾功能减退,Scr≥25%术前基础值和/或升高>44.2 μmol/L,将入组患者分为CIAKI组和非CIAKI组。

### 1.3 统计学方法

数据分析采用SPSS 26.0统计软件。计量资料以均数±标准差( $\bar{x} \pm s$ )表示,比较用 $t$ 检验。计数资料以构成比或率(%)表示,比较用 $\chi^2$ 检验;影响因素的分析用多因素逐步Logistic回归模型;绘制受试者工作特征(receiver operating characteristic, ROC)曲线。 $P < 0.05$ 为差异有统计学意义。

## 2 结果

### 2.1 CIAKI发生率

142例行PCI的冠心病患者中发生CIAKI 25例(17.61%),包括单一Scr≥25%术前基础值20例,单一升高>44.2 μmol/L 2例,同时满足Scr≥25%术前基础值和升高>44.2 μmol/L 3例。

### 2.2 两组患者术前基线资料比较

两组患者年龄、体质量指数(body mass index,

BMI)及术前LVEF、白细胞、血小板、红细胞、纤维蛋白原、总蛋白、Scr比较,经 $t$ 检验,差异均无统计学意义( $P>0.05$ )。两组性别、高血压比较,经 $\chi^2$ 检验,差异均无统计学意义( $P>0.05$ )。两组患者糖尿病占比比较,经 $\chi^2$ 检验,差异有统计学意义( $\chi^2=9.544$ ,

$P=0.002$ ),CIAKI组高于非CIAKI组;两组患者造影剂使用剂量和术前GFR比较,经 $t$ 检验,差异均有统计学意义( $t=7.857, 3.341$ ,均 $P=0.001$ ),CIAKI组造影剂使用剂量高于非CIAKI组,术前GFR水平低于非CIAKI组。见表1。

表1 两组患者术前基线资料比较

组别	$n$	年龄/(岁, $\bar{x} \pm s$ )	男/女/ 例	BMI/(kg/m <sup>2</sup> , $\bar{x} \pm s$ )	糖尿病 例(%)	高血压 例(%)	造影剂使用剂量/ (mL, $\bar{x} \pm s$ )	LVEF/(%, $\bar{x} \pm s$ )
CIAKI组	25	62.51 ± 7.95	12/13	23.81 ± 1.15	10(40.00)	14(56.00)	179.01 ± 29.15	54.61 ± 10.49
非CIAKI组	117	60.34 ± 8.21	57/60	23.97 ± 0.82	16(13.68)	43(36.75)	129.75 ± 28.31	57.84 ± 12.96
$t/\chi^2$ 值		1.206	0.004	0.820	9.544	3.176	7.857	1.166
$P$ 值		0.229	0.948	0.413	0.002	0.075	0.001	0.246

组别	白细胞/( $\times 10^9$ , $\bar{x} \pm s$ )	血小板/( $\times 10^9$ , $\bar{x} \pm s$ )	红细胞/( $\times 10^9$ , $\bar{x} \pm s$ )	纤维蛋白原/(g/L, $\bar{x} \pm s$ )	总蛋白/(g/L, $\bar{x} \pm s$ )	Scr/( $\mu\text{mol/L}$ , $\bar{x} \pm s$ )	GFR/[mL/(min· 1.73 m <sup>2</sup> ), $\bar{x} \pm s$ ]
CIAKI组	8.42 ± 2.49	206.91 ± 32.58	4.01 ± 1.16	3.75 ± 0.97	62.35 ± 8.09	86.51 ± 12.75	70.45 ± 6.09
非CIAKI组	8.50 ± 2.03	210.45 ± 36.91	4.28 ± 1.37	3.74 ± 0.64	63.01 ± 10.48	83.09 ± 12.44	76.58 ± 8.72
$t/\chi^2$ 值	0.172	0.444	0.917	0.064	0.297	1.242	3.341
$P$ 值	0.864	0.658	0.361	0.949	0.767	0.216	0.001

### 2.3 两组患者手术前后尿KIM-1、NGAL、NHE3的变化

两组手术前后尿KIM-1、NGAL及NHE3的差值比较,经 $t$ 检验,差异均有统计学意义( $P<0.05$ ),CIAKI组手术前后尿KIM-1、NGAL及NHE3的差值均高于非CIAKI组。见表2。

表2 两组手术前后尿KIM-1、NGAL、NHE3的差值比较  
(ng/L,  $\bar{x} \pm s$ )

组别	$n$	KIM-1差值	NGAL差值	NHE3差值
CIAKI组	25	60.84 ± 15.69	129.63 ± 26.54	351.01 ± 42.08
非CIAKI组	117	46.21 ± 10.32	90.13 ± 11.26	237.69 ± 39.15
$t$ 值		5.814	11.241	12.965
$P$ 值		0.001	0.000	0.000

### 2.4 冠心病患者PCI术后发生CIAKI的影响因素

以发生CIAKI为因变量(否=0,是=1),糖尿病(否=0,是=1)、GFR、造影剂使用剂量及手术前后KIM-1差值、NGAL差值、NHE3差值(均赋值为实测值)为自变量,进行多因素逐步Logistic回归分析(引入水准为0.05,排除水准为0.10),结果显示:糖尿

病[ $\hat{OR}=3.350$ (95% CI: 1.145, 9.802)],造影剂使用剂量[ $\hat{OR}=3.377$ (95% CI: 1.154, 9.880)],KIM-1差值[ $\hat{OR}=4.958$ (95% CI: 1.695, 14.506)],NGAL差值[ $\hat{OR}=4.446$ (95% CI: 1.519, 13.008)],NHE3差值[ $\hat{OR}=4.446$ (95% CI: 1.519, 3.008)]是冠心病患者PCI术后发生CIAKI的危险因素( $P<0.05$ );GFR[ $\hat{OR}=0.262$ (95% CI: 0.089, 0.765)]是冠心病患者PCI术后发生CIAKI的保护因素( $P<0.05$ )。见表3。

### 2.5 KIM-1差值、NGAL差值及NHE3差值对冠心病患者PCI术后发生CIAKI的预测价值

ROC曲线分析结果表明,KIM-1差值、NGAL差值、NHE3差值单一及联合预测冠心病患者PCI术后发生CIAKI的敏感性为75.32%(95% CI: 0.594, 0.831)、68.59%(95% CI: 0.537, 0.762)、62.77%(95% CI: 0.514, 0.735)、80.93%(95% CI: 0.629, 0.924),特异性为74.01%(95% CI: 0.583, 0.826)、83.16%(95% CI: 0.652, 0.941)、78.92%(95% CI: 0.603, 0.875)、81.15%(95% CI: 0.638, 0.945),曲线下面积(area under curve, AUC)为0.743、0.748、0.762和0.837,联合诊断效能最高。见表4。

表3 冠心病患者PCI术后发生CIAKI的多因素逐步Logistic回归分析参数

自变量	b	S <sub>b</sub>	Wald $\chi^2$	P值	OR	95% CI	
						下限	上限
糖尿病	1.029	0.601	4.047	0.019	3.350	1.145	9.802
GFR	-1.341	0.684	3.844	0.021	0.262	0.089	0.765
造影剂使用剂量	1.217	0.592	4.226	0.018	3.377	1.154	9.880
KIM-1差值	1.601	0.792	4.086	0.019	4.958	1.695	14.506
NGAL差值	1.492	0.685	4.744	0.016	4.446	1.519	13.008
NHE3差值	1.531	0.693	4.881	0.016	4.623	1.580	13.525

表4 KIM-1差值、NGAL差值、NHE3差值单一及联合预测冠心病患者PCI术后发生CIAKI的效能分析

指标	截断值	敏感性/ %	95% CI		特异性/ %	95% CI		AUC	95% CI	
			下限	上限		下限	上限		下限	上限
KIM-1差值	53.52	75.32	0.594	0.831	74.01	0.583	0.826	0.742	0.619	0.835
NGAL差值	109.85	68.59	0.537	0.762	83.16	0.652	0.941	0.748	0.648	0.842
NHE3差值	292.35	62.77	0.514	0.735	78.92	0.603	0.875	0.762	0.667	0.856
3者联合	-	80.93	0.629	0.924	81.15	0.638	0.945	0.837	0.796	0.940

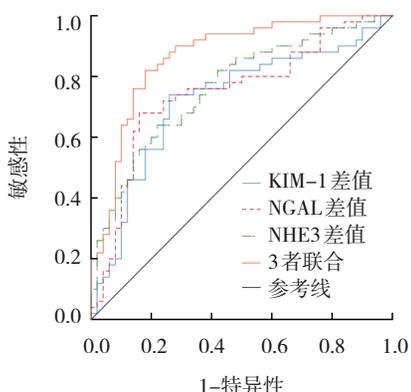


图1 KIM-1差值、NGAL差值及NHE3差值单一及联合预测冠心病患者PCI术后发生CIAKI的ROC曲线

### 3 讨论

近几年,随着介入诊疗技术在临床上应用逐渐成熟,我国在冠心病介入诊疗方面取得了一定突破,在医院接受造影检查及介入治疗的患者不断增加,但同时造影剂的应用同样随之增多,导致CIAKI发病率呈升高趋势。有研究报道,CIAKI已成为仅次于肾毒性药物及肾灌注不足所致的院内获得性肾损伤,对PCI治疗冠心病患者造成潜在威胁<sup>[12-13]</sup>。相关研究表明,造影剂通过扩张血管作用,增加冠状动脉血流量,改善血流灌注,促进造影剂更快地输送至病灶部位,以提高影像质量及诊断准确率<sup>[14]</sup>。

但造影剂代谢过程中经肾小球滤过后被肾脏清除,此过程同样可引起肾脏血流动力学改变,而肾脏自身具有调节血管收缩及舒张的能力,在造影剂刺激下可促进血管紧张素、儿茶酚胺等血管收缩活性物质的合成、释放,进而通过激活肾素-血管紧张素-醛固酮系统及交感神经系统等促使血管收缩,以维持正常的血流动力学平衡。但由于造影剂代谢后肾脏内血管收缩活性因子仍处于活跃状态,可导致肾髓质发生缺血、缺氧性损伤,引起肾脏代偿功能下降,诱导CIAKI的发生<sup>[14-15]</sup>。CARADU等<sup>[16]</sup>报道,与未发生CIAKI患者相比,发生CIAKI患者术后并发症发生率显著升高(57.1% vs 20.5%)。因此,筛查影响冠心病患者PCI术后发生CIAKI的高危因素,更有助于合理制订针对性预防及治疗方案,改善预后。

本研究结果显示,CIAKI组患者PCI前后KIM-1差值、NGAL差值及NHE3差值升高幅度更大,可见冠心病患者PCI前后KIM-1、NGAL及NHE3的变化可能与CIAKI发生有关。进一步行多因素逐步Logistic回归分析,结果显示KIM-1差值、NGAL差值、NHE3差值是冠心病患者PCI术后发生CIAKI的危险因素,表明随着冠心病患者PCI术后KIM-1、NGAL及NHE3表达水平升高,CIAKI发生风险更高。

造影检查或治疗后,短时间内可导致肾脏小动脉及微血管扩张,血流量增加,诱导肾脏生成血管紧张素,诱导肾血管发生缺血再灌注损伤。KIM-1作为肾脏缺血再灌注过程中合成的I型跨膜糖蛋白,属于T细胞免疫球蛋白和黏蛋白结构域家族蛋白,由免疫活性细胞和上皮细胞表达,de SILVA等<sup>[17]</sup>研究发现,在急性肾损伤患者中KIM-1、NGAL表达明显升高。因此冠心病患者PCI术后KIM-1升高幅度可直接反映肾血管损伤程度。MANDURINO-MIRIZZI等<sup>[18]</sup>研究表明,碘化造影剂可对肾小管上皮细胞产生直接的细胞毒性作用,且损伤程度取决于肾小管上皮细胞暴露于造影剂的持续时间。NGAL是一种由肾小管上皮细胞产生的蛋白质,在炎症及组织损伤等应激情况下表达升高。因此冠心病患者PCI术后NGAL升高提示CIAKI发病风险增加。PERROTTA等<sup>[19]</sup>研究报道,造影剂经肾脏代谢可导致肾血管出现水电解质紊乱,增加尿酸盐沉淀及Tamm-Horsfall蛋白积聚,降低肾小管代谢功能,损伤肾小管。NHE3是一种存在于肾小管上皮细胞和肠道上皮细胞中的膜蛋白,具有调节细胞内H<sup>+</sup>与尿液中Na<sup>+</sup>交换的作用,伴随钠尿酸盐沉积,NHE3合成信号被激活,因此冠心病患者PCI术后NHE3升高同样反映患者肾损伤程度与CIAKI发生密切相关。此外,本研究多因素逐步Logistic回归分析结果表明,合并糖尿病、造影剂使用剂量及术前GFR是冠心病患者PCI术后发生CIAKI的影响因素。有研究分析,糖尿病患者因处于高糖或高糖波动状态,可诱导广泛的血管内皮损伤,引起肾脏弥漫性基底膜病变,提高肾血管对造影剂的敏感性,增加CIAKI发病风险<sup>[20]</sup>。GFR是反映肾小球滤过功能的客观指标,术前GFR降低提示肾小球滤过率下降,肾功能基线水平更低,术后更易发生CIAKI<sup>[21]</sup>。造影剂使用剂量增加使肾脏暴露于更多的造影剂中,肾小管中造影剂浓度随之升高,损伤肾小管的代谢功能,增加CIAKI发生风险。本研究ROC曲线分析结果得出,KIM-1差值、NGAL差值、NHE3差值单一及联合预测冠心病患者PCI术后发生CIAKI的AUC为0.743、0.748、0.762、0.837。进一步证实冠心病患者PCI前后KIM-1、NGAL、NHE3的变化与CIAKI发生有关,且预测效能良好。

综上所述,糖尿病、GFR、造影剂使用剂量和

PCI前后KIM-1、NGAL、NHE3的变化影响CIAKI的发生,PCI前后KIM-1差值、NGAL差值及NHE3差值联合预测CIAKI的效能较好。

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