

重型颅脑创伤并发颅内感染危险因素分析及列线图预测模型构建

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【摘要】 目的 筛查重型颅脑创伤患者并发颅内感染的危险因素,并基于危险因素构建风险预测列线图(Nomogram)模型。方法 纳入2021年1月至2022年6月山东第一医科大学第二附属医院收治的130例重型颅脑创伤患者,根据是否并发颅内感染分为颅内感染组(27例)和无颅内感染组(103例),单因素和多因素逐步法Logistic回归分析筛查重型颅脑创伤并发颅内感染的危险因素,并基于危险因素构建Nomogram模型,绘制受试者工作特征曲线(ROC曲线)和校准曲线并行Hosmer-Lemeshow拟合优度检验。结果 颅内感染组糖尿病($\chi^2 = 5.356, P = 0.021$)、开放性颅脑创伤($\chi^2 = 4.248, P = 0.039$)、合并脑脊液漏(校正 $\chi^2 = 4.731, P = 0.030$)、手术治疗($\chi^2 = 8.284, P = 0.004$)、并发重症感染(校正 $\chi^2 = 6.479, P = 0.011$)、气管插管($\chi^2 = 6.487, P = 0.011$)和气管切开($\chi^2 = 4.072, P = 0.044$)比例均高于无颅内感染组。Logistic回归分析显示,糖尿病($OR = 2.748, 95\%CI: 1.417 \sim 8.654; P = 0.047$)、合并脑脊液漏($OR = 4.483, 95\%CI: 1.852 \sim 8.341; P = 0.031$)、手术治疗($OR = 1.941, 95\%CI: 1.483 \sim 8.842; P = 0.031$)、并发重症感染($OR = 1.614, 95\%CI: 1.113 \sim 5.682; P = 0.041$)是重型颅脑创伤并发颅内感染的危险因素。基于这4项危险因素构建Nomogram模型,ROC曲线下面积为0.758(95%CI: 0.641 ~ 0.875, $P = 0.001$),该模型预测重型颅脑创伤并发颅内感染的最佳截断值为175分;校准曲线显示预测概率与实际概率之间具有良好的-一致性,Hosmer-Lemeshow拟合优度检验显示差异无统计学意义($\chi^2 = 4.613, P = 4.412$),表明该模型具有良好的区分度、校准度和稳定性。结论 糖尿病、合并脑脊液漏、手术治疗、并发重症感染的重型颅脑创伤患者更易并发颅内感染,据此构建的Nomogram模型可以较好地预测重型颅脑创伤并发颅内感染风险。

【关键词】 脑损伤; 创伤性; 感染; 危险因素; Logistic模型; 列线图

Analysis of risk factors of secondary intracranial infection in patients with severe traumatic brain injury and construction of a Nomogram prediction model

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【Abstract】 Objective To screen the risk factors of intracranial infection in patients with severe traumatic brain injury (sTBI) and establish a Nomogram model based on these risk factors. **Methods** A total of 130 patients with sTBI admitted to The Second Affiliated Hospital of Shandong First Medical University from January 2021 to June 2022 were enrolled. They were divided into a group with intracranial infection ($n = 27$) and a group without intracranial infection ($n = 103$) according to whether complicated with intracranial infection. To analyze the risk factors of intracranial infection in patients with sTBI by univariate and multivariate stepwise Logistic regression, and construct a Nomogram model based on the risk factors to draw receiver operating characteristic (ROC) curve and calibration curve of this model and perform Hosmer-Lemeshow goodness of fit test. **Results** The proportion of diabetes ($\chi^2 = 5.356, P = 0.021$), open traumatic brain injury ($\chi^2 = 4.248, P = 0.039$), cerebrospinal fluid (CSF) leakage (adjusted $\chi^2 = 4.731, P = 0.030$), surgical treatment ($\chi^2 = 8.284, P = 0.004$), severe infection (adjusted $\chi^2 = 6.479, P = 0.011$), tracheal intubation ($\chi^2 = 6.487, P = 0.011$) and tracheotomy ($\chi^2 = 4.072, P = 0.044$) in intracranial infection group were higher than those in non-intracranial infection group. Logistic regression analysis showed

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diabetes ($OR = 2.748$, 95%CI: 1.417–8.654; $P = 0.047$), CBF leakage ($OR = 4.483$, 95%CI: 1.852–8.341; $P = 0.031$), surgical treatment ($OR = 1.941$, 95%CI: 1.483–8.842; $P = 0.031$) and severe infection ($OR = 1.614$, 95%CI: 1.113–5.682; $P = 0.041$) were risk factors for sTBI complicated with intracranial infection. The area under the curve (AUC) of ROC curve was 0.758 (95%CI: 0.641–0.875, $P = 0.001$), and the optimal cut-off value for predicting sTBI complicated with intracranial infection was 175. The calibration curve showed good consistency between the predicted probability and the actual probability, while the Hosmer-Lemeshow goodness of fit test showed no statistically significant difference ($\chi^2 = 4.613$, $P = 4.412$), indicating the Nomogram model has good differentiation, calibration and stability. **Conclusions** Diabetes, CBF leakage, surgical treatment and severe infection can increase the risk of sTBI complicated with intracranial infection. The Nomogram model can better predict the risk of sTBI complicated with intracranial infection.

【Key words】 Brain injuries, traumatic; Infections; Risk factors; Logistic model; Nomograms

Conflicts of interest: none declared

颅脑创伤(TBI)系外力导致的短暂性或永久性脑损伤^[1],病残率及病死率较高,其中重型颅脑创伤(sTBI)患者脑损伤严重,通常伴意识障碍,需长期卧床,抵抗力较低,极易并发颅内感染。颅内感染是颅脑创伤的常见并发症,可延长住院时间,加重疾病负担,影响患者预后,严重者甚至危及生命^[2]。但颅内感染早期表现缺乏特异性,易被重型颅脑创伤的急危重症掩盖,因此,筛查其并发颅内感染的危险因素并及早采取针对性措施,对改善患者预后具有重要意义。本研究回顾分析山东第一医科大学第二附属医院诊断与治疗的130例重型颅脑创伤患者临床资料,筛查其并发颅内感染的危险因素并构建风险预测列线图(Nomogram)模型,以为临床早期预防重型颅脑创伤并发颅内感染提供理论依据。

对象与方法

一、研究对象

1. 纳入标准 (1)重型颅脑创伤的诊断符合广泛性颅骨骨折、脑挫裂伤、脑干损伤或颅内血肿,昏迷时间 > 12 h,意识障碍逐渐加重或出现再昏迷,有明显神经系统阳性体征,且体温、呼吸、心率、血压明显改变^[3]。(2)创伤至入院时间 < 24 h。(3)入院时 Glasgow 昏迷量表(GCS)^[3]评分为 3~8 分。(4)年龄 18~80 岁。(5)临床和随访资料完整。

2. 排除标准 (1)合并脑膜炎、脑炎、脑室炎等颅内感染性疾病。(2)合并心、肺、肝、肾等重要脏器功能障碍或严重损伤。(3)合并自身免疫性疾病。(4)凝血功能障碍。

二、研究方法

1. 临床资料采集 (1)社会人口学资料:性别、年龄、既往史(高血压、糖尿病)。(2)疾病相关资料:

颅脑创伤原因(交通事故伤、摔伤、打击伤、高空坠落伤)、颅脑创伤性质(开放性或闭合性)、入院时 GCS 和急性生理学和慢性健康状况评估 II (APACHE II)评分、合并脑脊液漏。(3)实验室检查:血清白蛋白、乳酸。(4)治疗相关资料:亚低温治疗、手术方式(开颅血肿清除术、神经内镜下血肿清除术、去骨瓣减压术)、脑室外引流术和腰大池引流术比例,以及并发重症感染(肺部感染、菌血症、脓毒血症、脓毒性休克)、气管插管、气管切开比例等。

2. 颅内感染诊断标准 参照《神经外科中枢神经系统感染诊治中国专家共识(2021版)》^[4]。(1)临床表现:意识及精神状态改变、体温异常(> 38 °C 或 < 36 °C)、心率和呼吸增快等全身炎症反应症状与体征。(2)血清学检查:血常规白细胞计数 > $10 \times 10^9/L$ 且中性粒细胞比例 > 80%。(3)腰椎穿刺脑脊液检查:急性期脑脊液浑浊,呈黄色或脓性;压力 > 200 mm H₂O (1 mm H₂O = 9.81×10^{-3} kPa);白细胞计数 > $10 \times 10^6/L$ 和(或)多核细胞比例 > 70%;蛋白定量 > 450 mg/L;葡萄糖 < 2.20 mmol/L。(4)影像学检查:头部 CT 或 MRI 不具特异性,可表现为弥漫性脑水肿、硬脑膜增厚强化、脑室系统扩张、脑室内液-液平面等。(5)脑脊液、手术切口分泌物、手术标本细菌培养阳性。其中,(5)为病原学诊断,病原学检测阳性即可确诊为颅内感染,但因抗生素的应用,细菌培养阳性率较低,故临床综合考虑具备(1)、(2)、(4)以及(3)中至少 1 项即可诊断为颅内感染。

3. 统计分析方法 采用 SPSS 26.0 统计软件进行数据处理与分析。计数资料以相对数构成比(%)或率(%)表示,采用 χ^2 检验。正态性检验采用 Kolmogorov-Smirnov 检验,呈正态分布的计量资料以均数 ± 标准差($\bar{x} \pm s$)表示,采用两独立样本的 t 检

表 1 颅内感染组与无颅内感染组患者临床资料的比较

Table 1. Comparison of clinical data between intracranial infection group and non-intracranial infection group

观察指标	无颅内感染组 (n=103)	颅内感染组 (n=27)	χ^2 或t值	P值	观察指标	无颅内感染组 (n=103)	颅内感染组 (n=27)	χ^2 或t值	P值
性别[例(%)]			0.021	0.885	入院时GCS($\bar{x} \pm s$, 评分)	5.20 ± 1.47	5.11 ± 1.60	0.286	0.097
男性	71(68.93)	19(70.37)			入院时APACHE II ($\bar{x} \pm s$, 评分)	18.66 ± 8.97	21.96 ± 5.67	1.816	0.072
女性	32(31.07)	8(29.63)			合并脑脊液漏[例(%)]	11(10.68)	8(29.63)	4.731*	0.030
年龄[例(%)]			0.044	0.834	血清白蛋白[例(%)]			0.069	0.793
≥65岁	21(20.39)	6(22.22)			<40 g/L	41(39.81)	10(37.04)		
<65岁	82(79.61)	21(77.78)			≥40 g/L	62(60.19)	17(62.96)		
高血压[例(%)]	42(40.78)	12(44.44)	0.119	0.731	血清乳酸[例(%)]			0.014	0.906
糖尿病[例(%)]	20(19.42)	11(40.74)	5.356	0.021	>2 mmol/L	24(23.30)	6(22.22)		
致伤原因[例(%)]			0.160	0.837	≤2 mmol/L	79(76.70)	21(77.78)		
交通事故伤	56(54.36)	15(55.56)			亚低温治疗[例(%)]	40(38.83)	10(37.04)	0.029	0.864
摔伤	34(33.01)	9(33.33)			手术治疗[例(%)]	37(35.92)	18(66.67)	8.284	0.004
打击伤	8(7.77)	2(7.41)			脑室外引流术[例(%)]	30(29.13)	10(37.03)	0.628	0.428
高空坠落伤	5(4.85)	1(3.70)			腰大池引流术[例(%)]	23(22.33)	6(22.22)	0.000	0.990
创伤性质[例(%)]			4.248	0.039	并发重症感染[例(%)]	9(8.74)	8(29.63)	6.479*	0.011
开放性	42(40.78)	17(62.96)			气管插管[例(%)]	24(23.30)	13(48.15)	6.487	0.011
闭合性	61(59.22)	10(37.04)			气管切开[例(%)]	7(6.80)	6(22.22)	4.072	0.044

*adjusted χ^2 value, 校正 χ^2 值。Two-independent-sample *t* test for comparison of GCS and APACHE II on admission, and χ^2 test for comparison of others, 入院时 GCS 和 APACHE II 评分的比较行两独立样本的 *t* 检验, 其余指标的比较行 χ^2 检验。GCS, Glasgow Coma Scale, Glasgow 昏迷量表; APACHE II, Acute Physiology and Chronic Health Evaluation II, 急性生理学和慢性健康状况评估 II

验。重型颅脑创伤并发颅内感染危险因素的筛查采用单因素和多因素逐步法 Logistic 回归分析($\alpha_{\text{入}} = 0.05, \alpha_{\text{出}} = 0.05$)。采用 R 软件将筛选出的危险因素构建 Nomogram 模型以预测重型颅脑创伤并发颅内感染的风险, 进一步绘制该模型的受试者工作特征曲线(ROC 曲线)并计算曲线下面积(AUC), 评价模型的区分度(曲线下面积 ≥ 90% 为区分度好、70% ~ 89% 为区分度较好、50% ~ 69% 为区分度一般、< 50% 为区分度较差); Hosmer-Lemeshow 拟合优度检验行内部验证($P > 0.05$ 提示稳定性良好); 绘制校准曲线, 评价模型校准度(模型预测概率与实际概率之间具有良好的一致性提示校准度良好)。以 $P \leq 0.05$ 为差异具有统计学意义。

结 果

根据上述纳入与排除标准, 选择 2021 年 1 月至 2022 年 6 月在我院神经重症监护病房住院治疗的重型颅脑创伤患者共 130 例, 男性 90 例, 女性 40 例; 年龄 18 ~ 80 岁, 平均(49.79 ± 15.72)岁, ≥ 65 岁 27 例(20.77%)、< 65 岁 103 例(79.23%); 既往合并高血压占 41.54%(54/130)、糖尿病占 23.85%(31/130)。致伤原因为交通事故伤 71 例(54.62%)、摔伤 43 例

(33.08%)、打击伤 10 例(7.69%)、高空坠落伤 6 例(4.62%); 开放性颅脑创伤 59 例(45.38%), 闭合性颅脑创伤 71 例(54.62%); 入院时 GCS 评分 3 ~ 8 分, 平均为(5.18 ± 1.49)分; 入院时 APACHE II 评分为 10 ~ 30 分, 平均(19.34 ± 8.48)分; 合并脑脊液漏 19 例(14.62%)。血清白蛋白 < 40 g/L 51 例(39.23%), ≥ 40 g/L 79 例(60.77%); 血清乳酸 > 2 mmol/L 者 30 例(23.08%), ≤ 2 mmol/L 者 100 例(76.92%)。予以亚低温治疗 50 例(38.46%); 行手术治疗 55 例(42.31%), 分别为开颅血肿清除术 30 例、去骨瓣减压术 15 例、神经内镜下血肿清除术 10 例; 40 例(30.77%)行脑室外引流术; 29 例(22.31%)行腰大池引流术。并发重症感染者 17 例(13.08%), 分别为肺部感染 11 例、菌血症 4 例、脓毒血症 1 例、脓毒性休克 1 例; 气管插管 37 例(28.46%); 气管切开 13 例(10%)。根据是否并发颅内感染分为颅内感染组(27 例)和无颅内感染组(103 例), 颅内感染组既往有糖尿病($P = 0.021$)、开放性颅脑创伤($P = 0.039$)、合并脑脊液漏($P = 0.013$)、手术治疗($P = 0.004$), 以及并发重症感染($P = 0.011$)、气管插管($P = 0.011$)、气管切开($P = 0.017$)比例均高于无颅内感染组, 其余指标组间差异无统计学意义(均 $P > 0.05$, 表 1)。

表 2 重型颅脑创伤并发颅内感染相关影响因素变量赋值表

Table 2. Variable assignment of related influencing factors of secondary intracranial infection in patients with sTBI

变量	赋值				变量	赋值			
	0	1	2	3		0	1	2	3
颅内感染	否	是			血清乳酸 (mmol/L)	≤ 2	> 2		
性别	女性	男性			亚低温治疗	否	是		
年龄 (岁)	< 65	≥ 65			手术治疗	否	是		
高血压	否	是			脑室外引流术	否	是		
糖尿病	否	是			腰大池引流术	否	是		
致伤原因	交通事故伤	摔伤	打击伤	高空坠落伤	并发重症感染	否	是		
创伤类型	闭合性	开放性			气管插管	否	是		
合并脑脊液漏	否	是			气管切开	否	是		
血清白蛋白 (g/L)	≥ 40	< 40							

表 3 重型颅脑创伤并发颅内感染相关影响因素的单因素 Logistic 回归分析

Table 3. Univariate Logistic regression analysis of influencing factors of secondary intracranial infection in patients with sTBI

变量	<i>b</i>	<i>SE</i>	Wald χ^2	<i>P</i> 值	<i>OR</i> 值	<i>OR</i> 95%CI	变量	<i>b</i>	<i>SE</i>	Wald χ^2	<i>P</i> 值	<i>OR</i> 值	<i>OR</i> 95%CI
男性	-0.629	4.875	5.124	0.087	1.236	0.754 ~ 1.436	合并脑脊液漏	0.126	0.017	236.556	0.000	1.954	1.537 ~ 2.675
年龄	2.792	2.549	2.751	0.162	1.591	1.036 ~ 3.147	血清白蛋白 < 40 g/L	0.796	1.483	4.357	0.549	1.726	0.914 ~ 2.164
高血压	-0.534	5.125	2.254	0.247	1.438	0.875 ~ 1.358	血清乳酸 > 2 mmol/L	0.876	2.971	3.425	0.301	2.314	0.854 ~ 2.751
糖尿病	0.917	0.028	854.391	0.000	2.542	1.864 ~ 2.904	亚低温治疗	-0.975	1.475	4.215	0.464	3.425	0.755 ~ 4.360
入院时 GCS 评分	1.081	4.855	4.621	0.398	1.362	0.751 ~ 2.667	手术治疗	0.229	0.025	149.638	0.000	2.014	1.572 ~ 2.684
入院时 APACHE II 评分	1.056	4.964	3.453	0.467	1.558	0.568 ~ 2.601	脑室外引流术	1.295	0.807	2.578	0.108	3.651	0.752 ~ 17.742
摔伤	0.759	1.326	3.694	0.411	2.046	0.744 ~ 2.964	腰大池引流术	-1.035	5.964	3.467	0.442	1.387	0.825 ~ 3.648
打击伤	1.657	6.324	5.330	0.628	3.125	0.884 ~ 5.369	并发重症感染	0.557	0.025	195.361	0.000	2.367	1.592 ~ 2.677
高空坠落	1.354	5.647	4.105	0.741	2.146	0.694 ~ 3.069	气管插管	0.357	0.037	203.665	0.000	1.552	1.157 ~ 2.221
开放性颅脑创伤	1.025	0.159	39.452	0.000	2.543	1.545 ~ 3.049	气管切开	0.240	0.029	167.517	0.000	1.687	1.304 ~ 1.892

表 4 重型颅脑创伤并发颅内感染相关影响因素的多因素逐步法 Logistic 回归分析

Table 4. Multivariate stepwise Logistic regression analysis of influencing factors of secondary intracranial infection in patients with sTBI

变量	<i>b</i>	<i>SE</i>	Wald χ^2	<i>P</i> 值	<i>OR</i> 值	<i>OR</i> 95%CI	变量	<i>b</i>	<i>SE</i>	Wald χ^2	<i>P</i> 值	<i>OR</i> 值	<i>OR</i> 95%CI
糖尿病	1.475	0.034	2.782	0.047	2.748	1.417 ~ 8.654	并发重症感染	1.238	0.038	2.432	0.041	1.614	1.113 ~ 5.682
合并脑脊液漏	1.839	0.042	4.543	0.031	4.483	1.852 ~ 8.341	常数项	-4.691	0.011	3.126	0.093		
手术治疗	2.741	0.016	1.764	0.031	1.941	1.483 ~ 8.842							

单因素 Logistic 回归分析显示,糖尿病 ($P = 0.000$)、开放性颅脑损伤 ($P = 0.000$)、合并脑脊液漏 ($P = 0.000$)、手术治疗 ($P = 0.000$)、并发重症感染 ($P = 0.000$)、气管插管 ($P = 0.000$)、气管切开 ($P = 0.000$) 是重型颅脑创伤并发颅内感染的危险因素 (表 2, 3); 将上述符合纳入与剔除标准的影响因素纳入多因素 Logistic 回归方程, 结果显示, 糖尿病 ($OR = 2.748, 95\%CI: 1.417 \sim 8.654; P = 0.047$)、合并脑脊液漏 ($OR = 4.483, 95\%CI: 1.852 \sim 8.341; P = 0.031$)、手术治疗 ($OR = 1.941, 95\%CI: 1.483 \sim 8.842;$

$P = 0.031$), 以及并发重症感染 ($OR = 1.614, 95\%CI: 1.113 \sim 5.682; P = 0.041$) 是重型颅脑创伤并发颅内感染的危险因素 (表 4)。

以 Logistic 回归分析筛查出的危险因素——糖尿病、合并脑脊液漏、手术治疗、并发重症感染作为预测因素, 以颅内感染为结局, 构建重型颅脑创伤并发颅内感染的 Nomogram 模型 (图 1), 每项因素的数值或分类特征对应至标尺为每项因素的分值 (糖尿病 84 分、手术治疗 100 分、合并脑脊液漏 87 分、并发重症感染 95 分), 各项分值之和为总分值, 总分值

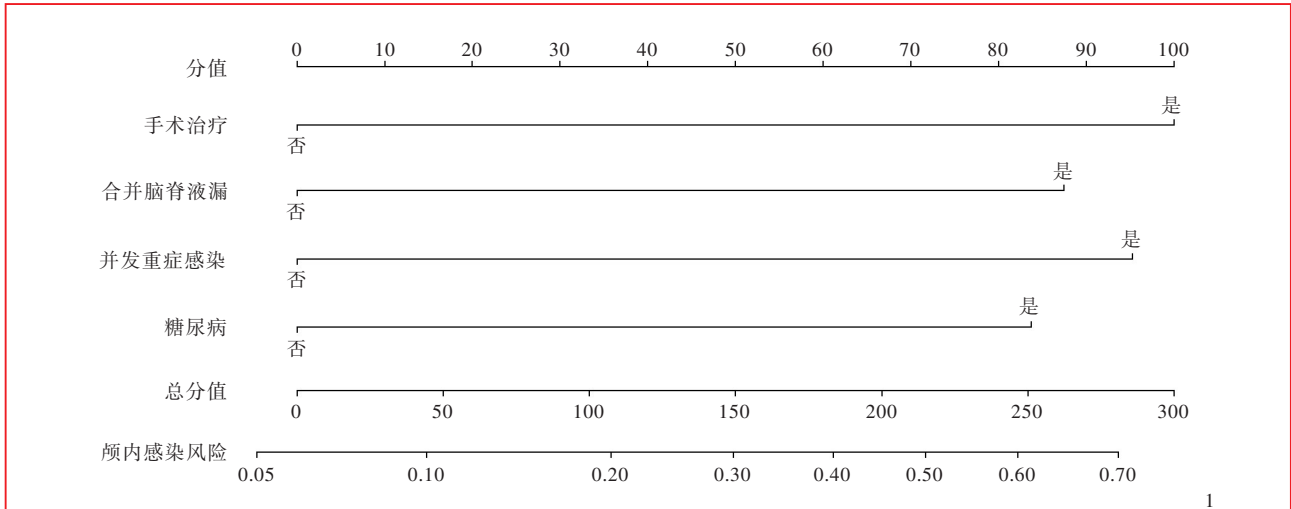


图 1 重型颅脑创伤并发颅内感染的 Nomogram 模型

Figure 1 Nomogram model of sTBI complicated with intracranial infection.

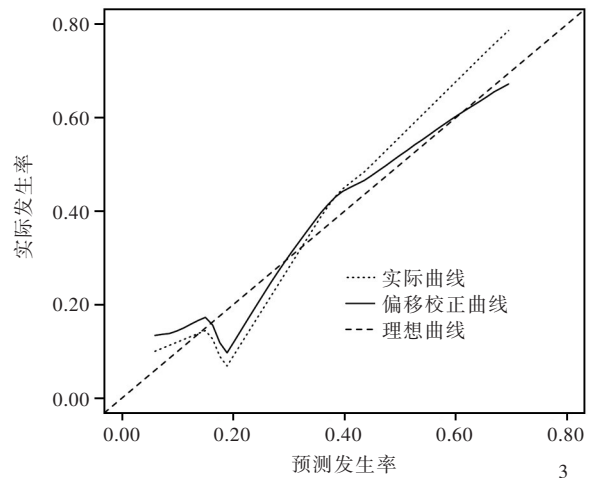
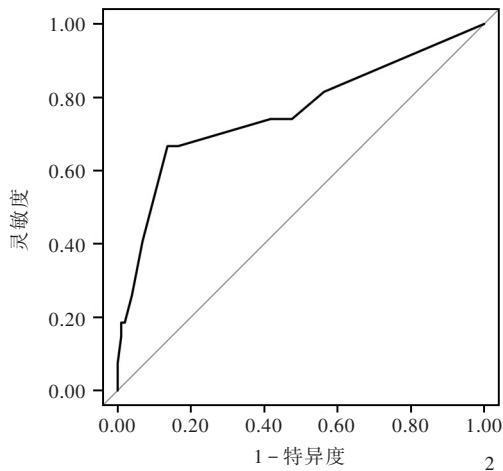


图 2 Nomogram 模型的 ROC 曲线显示, 曲线下面积为 0.758(95%CI: 0.641 ~ 0.875, P = 0.001), 提示该模型的预测效能较好

图 3 Nomogram 模型的校准曲线显示, 模型曲线与理想曲线的趋势较为一致, 提示该模型的准确度较好

Figure 2 The ROC curve of the Nomogram model showed the AUC was 0.758 (95%CI: 0.641-0.875, P = 0.001), indicating the Nomogram model had better prediction performance. Figure 3 The calibration curve of Nomogram model showed the trend of model curve was consistent with that of ideal curve, suggesting the Nomogram model had good prediction efficiency.

对应的预测值即为重型颅脑创伤并发颅内感染的风险。进一步绘制 ROC 曲线, Nomogram 模型的曲线下面积为 0.758(95%CI: 0.641 ~ 0.875, P = 0.001), 提示该模型的预测效能较好(图 2); 当 Youden 指数为 0.511 时, 其协助诊断的灵敏度为 0.667, 特异度为 0.844, 截断值为 175 分。绘制校准曲线显示, 经 Nomogram 模型获得的重型颅脑创伤并发颅内感染风险模型的预测概率与实际概率之间具有良好的一致性, 表明该模型的准确度良好(图 3), 且经 Hosmer-Lemeshow 拟合优度检验显示差异无统计学意义($\chi^2 = 4.613, P = 4.412$), 表明该模型的稳定性亦较好。

讨 论

全球每年约有超过 5000 万例颅脑创伤患者^[5]。国内一项流行病学研究共调查 31 个省、市、自治区计 583 370 名全年龄段人群, 2673 人曾发生过颅脑创伤, 加权患病率为 442.4/10 万, 且患病率随年龄增长逐渐增加^[6]。重型颅脑损伤患者因免疫系统损伤^[7-8], 极易并发颅内感染, 颅内感染发生率高达 10% ~ 30%^[9-10], 与颅脑创伤性质和严重程度、颅脑创伤治疗方案、颅内感染预防措施等多种因素密切相关。术后并发颅内感染可延长重型颅脑创伤患者住院时间, 遗留严重神经功能障碍甚至死亡, 预

后不良,因此,积极预防重型颅脑创伤并发颅内感染的危险因素,对改善患者预后具有重要意义。

研究显示,开颅手术是颅脑创伤并发颅内感染的重要危险因素($OR = 2.137, 95\%CI: 1.081 \sim 5.385; P = 0.025$)^[11],本研究也得出相同结论。究其原因,可能是由于开颅手术破坏头皮、颅骨和脑膜对脑组织的保护作用,使其与外界环境相通,细菌逆行进入脑室系统或深部脑组织,增加颅内感染风险,若术后并发切口感染可进一步增加颅内感染风险^[12]。因此,手术前后应严格遵循无菌操作规范。

颅脑创伤是脑脊液漏的最常见原因,约 50% 患者伤后 2 天内即发生脑脊液漏^[13],而重型颅脑创伤患者更易合并脑脊液漏。既往研究显示,合并脑脊液漏是重型颅脑创伤患者并发颅内感染的重要危险因素($OR = 15.059, 95\%CI: 3.636 \sim 40.665; P = 0.001$)^[14],本研究亦得出相同结论。正常情况下,颅内为无菌环境,重型颅脑创伤患者病情严重,常因颅骨骨折、硬脑膜和蛛网膜破坏,导致脑脊液自骨折缝裂经鼻腔、外耳道或开放伤口流出,形成漏口,漏口使颅内与外界相通,细菌沿脑脊液逆行进入颅内,导致颅内感染^[15],因此应保持鼻腔、外耳道清洁,适当抬高床头至 $20^\circ \sim 30^\circ$,避免用力排便、咳嗽、打喷嚏等可导致颅内压升高的动作,并预防性应用抗生素^[13]。除颅内感染外,重型颅脑创伤患者还可并发其他重症感染,主要包括肺部感染、血流感染、尿路感染、脓毒症或脓毒症休克^[16],此类患者可显著增加颅内感染的风险^[17]。由于重型颅脑损伤患者病情危重,通常伴意识障碍和吞咽障碍,需行气管插管、气管切开、持续留置导尿管及中心静脉导管等,卧床时间较长,抗生素应用时间较长,免疫功能低下,易发生侵袭性颅内感染,因此必要时可予强效抗生素治疗。

本研究还发现,糖尿病是重型颅脑创伤并发颅内感染的危险因素,与既往研究结果相一致^[18-19]。糖尿病患者长期处于高血糖状态,体内代谢紊乱、微循环障碍造成脑组织缺氧、缺血,损伤神经功能,使其对感染的反应性降低,增加颅内感染风险^[20-21];此外,部分糖尿病患者免疫功能低下,无法及时识别和消灭入侵的病原体,使得合并糖尿病的颅脑创伤患者更易发生感染^[22-23]。糖尿病患者还可因血管内皮细胞损伤或血管壁硬化,出现细菌和病毒防御能力降低,从而增加病原体侵入颅内的风险^[24-26]。因此,对于重型颅脑创伤患者应进行全程血糖管

理,将血糖水平控制在合理范围内,以降低颅内感染的风险。

综上所述,糖尿病、手术治疗、合并脑脊液漏、并发重症感染是重型颅脑创伤并发颅内感染的危险因素,并基于这 4 项危险因素构建 Nomogram 模型,绘制 ROC 曲线,经 Hosmer-Lemeshow 拟合优度检验和校准曲线证实该模型区分度、稳定性及校准度均良好,提示该模型在预测重型颅脑创伤并发颅内感染方面具有重要价值。然而,本研究仍存在一定的局限性:(1)为单中心研究,且样本量较小,可能存在选择偏倚。(2)纳入的影响因素较少,未完善相关实验室指标。(3)仅部分患者行开颅手术,未对具体术式进行分层分析。未来尚待扩大样本量,纳入多中心患者,增加实验室指标,延长随访时间,进一步验证本研究结论。

利益冲突 无

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