



脑卒中患者医院感染的病原菌分布特征及危险因素分析*

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【摘要】 **目的** 探讨脑卒中患者发生医院感染的危险因素,并分析其病原菌分布及感染部位的相关特征。**方法** 采用回顾性队列研究设计,纳入2024年1月-2025年7月首都医科大学附属北京天坛医院住院的脑卒中患者393例,其中感染组184例,未感染组209例。采用多因素logistic回归分析筛选感染危险因素,并构建列线图模型。**结果** 多因素logistic回归分析显示,脑梗死[比值比(odds ratio, OR)=25.09, 95%置信区间(confidence interval, CI): 5.38~117.10]、无饮酒史(OR=4.47, 95%CI: 1.51~13.18)、无脑血管病史(OR=5.04, 95%CI: 1.35~18.76)、中性粒细胞计数升高(OR=1.29, 95%CI: 1.08~1.55)、C反应蛋白升高(OR=1.03, 95%CI: 1.01~1.06)为卒中患者医院感染的独立危险因素;未行鼻饲(OR=0.09, 95%CI: 0.03~0.31)、未留置导尿管(OR=0.21, 95%CI: 0.06~0.77)及无术后昏迷(OR=0.07, 95%CI: 0.01~0.36)为保护因素。列线图模型在训练集与验证集中的曲线下面积分别为0.96(95%CI: 0.94~0.98)和0.94(95%CI: 0.90~0.99),校准度良好。感染病原菌以革兰阴性菌为主(70.2%),感染部位以呼吸道最为常见(92.9%)。气管插管、意识障碍等为肺部及革兰阴性菌感染的共同危险因素。**结论** 本研究明确了脑卒中患者发生医院感染的独立危险因素,构建了预测效能良好的列线图模型,并初步揭示了不同感染类型和部位的风险特征,为临床早期识别高危患者及制定针对性防控策略提供参考依据。

【关键词】 脑卒中 医院感染 危险因素 预测模型

Pathogen Profile and Risk Factors for Hospital-Acquired Infection in Stroke Patients

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【Abstract】 **Objective** To investigate the risk factors for hospital-acquired infection in patients with stroke and to analyze the distribution of pathogens and characteristics of infection sites. **Methods** A retrospective cohort study was conducted, enrolling 393 patients with stroke hospitalized at Beijing Tiantan Hospital, Capital Medical University, from January 2024 to July 2025. Among them, 184 patients were assigned to the infection group and 209 to the non-infection group. Multivariable logistic regression analysis was used to identify risk factors for hospital-acquired infection, and a nomogram prediction model was constructed. **Results** Multivariable logistic regression analysis identified cerebral infarction (odds ratio = 25.09, 95% confidence interval: 5.38-117.10), no history of alcohol consumption (odds ratio = 4.47, 95% confidence interval: 1.51-13.18), no history of cerebrovascular disease (odds ratio = 5.04, 95% confidence interval: 1.35-18.76), elevated neutrophil count (odds ratio = 1.29, 95% confidence interval: 1.08-1.55), and elevated C-reactive protein (odds ratio = 1.03, 95% confidence interval: 1.01-1.06) as independent risk factors for hospital-acquired infection in patients with stroke. Absence of nasogastric tube feeding (odds ratio = 0.09, 95% confidence interval: 0.03-0.31), no indwelling urinary catheterization (odds ratio = 0.21, 95% confidence interval: 0.06-0.77), and absence of postoperative coma (odds ratio = 0.07, 95% confidence interval: 0.01-0.36) were identified as protective factors. The nomogram model achieved an area under the curve of 0.96 (95% confidence interval: 0.94-0.98) in the training set and 0.94 (95% confidence interval: 0.90-0.99) in the validation set, with good calibration. Gram-negative bacteria were the predominant pathogens (70.2%), and the respiratory tract was the most common infection site (92.9%). Endotracheal intubation and impaired consciousness were identified as common risk factors for both pulmonary and Gram-negative bacterial infections. **Conclusion** This study identified independent risk factors for hospital-acquired infection in patients with stroke, developed a nomogram model with good predictive performance, and preliminarily characterized the

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risk profiles associated with different infection types and sites. These findings provide a reference for early identification of high-risk patients and the formulation of targeted prevention and control strategies.

[Key words] Stroke Hospital-acquired infection Risk factors Predictive model

卒中是我国成年人致残和致死的主要原因之一。患者常因神经功能缺损、意识障碍及免疫功能低下等原因成为医院感染的易感人群^[1-3]。医院感染显著延长患者住院时间,增加医疗费用,并导致不良预后,是影响卒中患者康复进程的重要并发症^[3-6]。在卒中后医院感染中,肺部感染占据主导地位,其发生可能与误吸、长期卧床及侵入性操作密切相关^[7-8];而在病原菌分布方面,革兰阴性菌(Gram-negative, G⁻)感染尤为常见,且多药耐药现象日益严重,进一步加剧治疗难度与疾病负担^[3,9-11]。目前,国内外研究虽已探讨了卒中后感染的相关因素,但多集中于单一病源或部位的分析,对肺部感染与G⁻菌感染的特异性危险因素研究尚不充分,且缺乏能够用于临床个体化风险评估的有效工具^[2,5,12-14]。因此,系统性地分析卒中患者医院感染的多种影响因素,特别是聚焦于肺部感染与G⁻菌感染的特异性风险模式,并构建精准、直观的感染风险预测模型,对于早期识别高危患者、指导临床进行前置性干预、合理配置医疗资源以及最终改善患者预后具有重要的现实意义。本研究旨在通过回顾性分析,明确卒中后医院感染的独立危险因素,在此基础上开发并验证基于列线图的个体化预测模型,并进一步探讨肺部感染与G⁻菌感染的预测因子,以期为临床实践提供量化依据。

1 资料与方法

1.1 研究对象

采用回顾性队列研究设计,连续选取2024年1月-2025年7月于首都医科大学附属北京天坛医院神经内科/卒中中心住院的脑卒中患者作为研究对象。纳入标准:①符合中华医学会神经病学分会制定的脑卒中诊断标准;②年龄≥18岁。排除标准:①入院时已存在明确感染;②住院时间<48 h;③临床资料不全者。本项目研究通过首都医科大学附属北京天坛医院伦理委员会审查批准(审批号:KY2024-167-02),所有研究对象均在入院时签署泛知情同意书。

1.2 研究方法

通过医院电子病历系统收集患者资料,包括:①一般资料:性别、年龄、身高、收缩压、舒张压等;②临床特征:卒中类型、病变部位、意识状态、既往史(包括糖尿病、高血压、脑血管病、肿瘤、肝病、心脏病、肾病、慢性

肺病、低蛋白血症、吸烟、饮酒等);③治疗与操作:是否行气管插管、鼻饲、留置导尿管、是否置入胃管等;是否存在术后昏迷、完全卧床、吞咽困难;④实验室指标:白细胞计数、中性粒细胞计数、淋巴细胞计数、嗜酸性粒细胞计数、嗜碱性粒细胞计数、单核细胞计数、血小板计数、血小板分布宽度、平均血小板体积、大血小板比率、血小板压积、红细胞压积、C反应蛋白等。

1.3 病原学检测方法

所有卒中后疑似发生医院感染的患者,均依据临床指南规范采集相应感染部位标本,包括痰液、血液、尿液及脑脊液等。痰液标本分别接种于血琼脂平板、巧克力平板和麦康凯平板;尿液标本接种于血琼脂平板和麦康凯平板;血液标本分别注入需氧与厌氧血培养瓶;脑脊液标本则接种于儿童专用血培养瓶。所有培养物置于35℃恒温孵育箱中培养18~24 h;血培养瓶及儿童专用培养瓶在未检出微生物生长时,培养时间不超过5 d。菌株鉴定采用基质辅助激光解吸/电离飞行时间质谱(matrix-assisted laser desorption/ionization time-of-flight mass spectrometry, MALDI-TOF MS)。药敏试验使用VITEK®2系统的AST药敏卡(基于最小抑菌浓度法的自动化检测),结果判读严格遵循美国临床和实验室标准协会(clinical and laboratory standards institute, CLSI)M100最新版标准。

本研究对常见耐药表型定义如下:产超广谱β-内酰胺酶(extended-spectrum β-lactamase, ESBL)肠杆菌科细菌,指因产生能够水解青霉素类、第三代头孢菌素及单环β-内酰胺类抗生素的酶,而对上述药物耐药的菌株;耐甲氧西林金黄色葡萄球菌(methicillin-resistant *S. aureus*, MRSA),指对苯唑西林耐药的金黄色葡萄球菌;碳青霉烯类耐药肠杆菌科细菌(carbapenem-resistant enterobacteriaceae, CRE),指对任一碳青霉烯类药物(如亚胺培南、美罗培南、厄他培南)耐药的肠杆菌科细菌;泛耐药(extensively drug-resistant, XDR)指对绝大多数抗菌药物类别耐药,仅对1~2类敏感。基于上述定义,本研究重点监测的耐药表型包括大肠埃希菌中的ESBL表型、金黄色葡萄球菌中的MRSA表型、肺炎克雷伯菌中的CRE表型,以及鲍曼不动杆菌中的XDR表型。

1.4 统计学方法

采用SPSS 26.0和R 4.3.0软件进行统计分析。计量资

料中,符合正态分布的变量以 $\bar{x} \pm s$ 表示,组间比较采用 t 检验;不符合正态分布的变量以中位数(四分位数)表示,组间比较采用 Mann-Whitney U 检验。计数资料采用例数(百分比)表示,组间比较采用 χ^2 检验或 Fisher 精确检验。采用单因素 logistic 回归初步筛选潜在影响因素,将其中 $P < 0.1$ 的变量纳入多因素 logistic 回归模型(向前 LR 法),以确定医院感染的独立影响因素,计算优势比(odds ratio, OR)及其 95% 置信区间(confidence interval, CI)。基于多因素分析结果,使用 R 语言 rms 包构建预测医院感染风险的列线图模型。将总数据集按 7:3 的比例随机分为训练集与验证集。采用受试者工作特征(receiver operating characteristic, ROC)曲线及其曲线下面积(area under the curve, AUC)评估模型的区分度;绘制校准曲线并辅以 Hosmer-Lemeshow 检验评估模型的校准度。 $P < 0.05$ 为差异有统计学意义。

2 结果

2.1 患者基线特征

结果见表 1。本研究共纳入 393 例脑卒中患者,其中

发生卒中后医院感染者 184 例(感染组, 46.8%), 未发生感染者 209 例(非感染组, 53.2%)。两组患者在人口学特征(如年龄、性别、身高、体质量)及卒中类型、高血压史、肿瘤病史和心脏病史等方面,差异均无统计学意义(均 $P > 0.05$)。

与非感染组相比,感染组患者在炎症指标水平、临床干预措施及部分既往病史方面的数值或比例均更高,差异具有统计学意义($P < 0.05$)。具体而言,感染组的白细胞计数、中性粒细胞计数及 C 反应蛋白水平均显著高于非感染组(均 $P < 0.001$)。临床干预方面,感染组患者接受气管插管、鼻饲、导尿管留置、胃管插入及完全卧床的比例显著更高(均 $P < 0.001$),且意识障碍、术后昏迷及吞咽困难的发生率也显著更高(均 $P < 0.001$)。此外,感染组合并肝病、肾病史、慢性肺病史及低蛋白血症的比例均高于非感染组,而糖尿病史和脑血管病史的比例则低于非感染组,差异具有统计学意义(均 $P < 0.05$)。生活方式方面,感染组中有饮酒史者的比例低于非感染组($P < 0.001$),有吸烟史者也呈现较低比例($P = 0.034$)。此外,两组患者在卒中部位分布上差异亦有统计学意义($P = 0.017$),

表 1 比较感染组和非感染组患者的基线特征

Table 1 Comparison of baseline characteristics between infected and non-infected groups

Characteristic	Infected ($n = 184$)	Non-Infected ($n = 209$)	P
Demographics			
Age/yr., M (Q ₁ , Q ₃)	65.0 (52.8, 74.0)	63.0 (54.0, 71.0)	0.434
Male/case (%)	129 (70.1)	147 (70.3)	0.961
Stroke characteristics/case (%)			
Infarction	99 (53.8)	92 (44.0)	0.053
Bilateral stroke	51 (29.1)	34 (16.8)	0.017
Clinical features/case (%)			
Impaired consciousness	117 (63.6)	22 (10.5)	< 0.001
Dysphagia	145 (78.8)	35 (16.8)	< 0.001
Medical history/case (%)			
Alcohol history	54 (29.51)	100 (47.85)	< 0.001
Hypertension	129 (70.11)	159 (76.08)	0.182
Diabetes	61 (33.2)	93 (44.5)	0.022
Liver disease	92 (50.0)	64 (30.6)	< 0.001
Cerebrovascular disease	116 (63.0)	163 (78.0)	0.001
Renal disease	69 (37.5)	49 (23.4)	0.002
Hypoalbuminemia	72 (39.1)	19 (9.1)	< 0.001
Interventions/Procedures/case (%)			
Endotracheal intubation	116 (63.0)	4 (1.9)	< 0.001
Nasogastric feeding	125 (67.9)	10 (4.8)	< 0.001
Urinary catheterization	89 (48.4)	12 (5.7)	< 0.001
Postoperative coma	87 (47.3)	4 (1.9)	< 0.001
Laboratory parameters (M [Q ₁ , Q ₃])			
WBC count/($\times 10^9 L^{-1}$)	10.95 (7.85, 13.78)	6.90 (5.62, 8.54)	< 0.001
Neutrophil count/($\times 10^9 L^{-1}$)	9.18 (6.13, 11.83)	4.58 (3.42, 5.83)	< 0.001
CRP/(mg/L)	39.67 (12.73, 83.99)	2.81 (0.94, 7.35)	< 0.001

M: median; Q₁: 1st quartile; Q₃: 3rd quartile; WBC: white blood cell; CRP: c-reactive protein. Only statistically significant and clinically relevant variables are shown.

感染组中双侧卒中患者比例更高。

2.2 脑卒中患者发生医院感染的病原菌分布及耐药特征

本研究共收集脑卒中后发生医院感染患者184例,共分离出病原菌285株。病原菌以G⁻杆菌为主,共检出200株(占70.2%),其中肺炎克雷伯菌(75株,26.3%)和鲍曼不动杆菌(50株,17.5%)是最主要的致病菌,其次为大肠埃希菌(28株,9.8%)和铜绿假单胞菌(19株,6.7%)。革兰阳性(gram-positive, G⁺)球菌共检出81株(占28.4%),以金黄色葡萄球菌(46株,16.1%)为主,其次为屎肠球菌(10株,3.5%)和粪肠球菌(9株,3.2%)。此外,检出真菌4株(1.4%)。

在184例感染患者中,55.4%(102例)为单一病原菌感染,31.5%(58例)为两种菌混合感染,13.0%(24例)为两种以上病原菌感染。

药敏试验结果显示,病原菌总体耐药形势较为严峻:在50株鲍曼不动杆菌中,XDR的检出率为58.0%(29株);在75株肺炎克雷伯菌中,CRE的检出率为42.7%(32株);在28株大肠埃希菌中,ESBL的检出率为50.0%(14株);在46株金黄色葡萄球菌中,MRSA的检出率为56.5%(26株)。

感染部位以下呼吸道为主,共171例(92.9%),其次为泌尿系统感染(59例,32.1%)。值得注意的是,有31例(16.8%)患者存在两个及以上系统的混合感染。见表2。

2.3 脑卒中患者医院感染的影响因素分析

本研究采用单因素及多因素logistic回归分析,旨在探讨脑卒中患者发生医院感染的独立影响因素。单因素分析初步筛选出25项与感染存在统计学关联的变量($P < 0.05$),包括卒中部位、意识障碍、糖尿病史、吸烟史、饮酒史、肝病史、脑血管病史、肾病史、低蛋白血症、气管插管、鼻饲、导尿管留置、完全卧床、术后昏迷、吞咽困难、胃管置入,以及白细胞计数、淋巴细胞计数、中性粒细胞计数、中性粒细胞与淋巴细胞比值、嗜酸性粒细胞计数、单核细胞计数、血小板分布宽度、红细胞压积和C反应蛋白等实验室指标(网络资源附件附表1)。

为进一步控制混杂因素,将单因素分析中 $P < 0.1$ 的变量纳入多因素logistic回归模型。最终,多因素分析确定了8项独立影响因素,其中,脑梗死(OR=25.09,95%CI:5.38~117.10, $P < 0.001$)、无饮酒史(OR=4.47,95%CI:1.51~13.18, $P = 0.007$)、无脑血管病史(OR=5.04,95%CI:1.35~18.76, $P = 0.016$)、中性粒细胞绝对值(OR=1.29,95%CI:1.08~1.55, $P = 0.006$)升高和C反应蛋白(OR=1.03,95%CI:1.01~1.06, $P = 0.009$)升高是感染的危险因素;而未行鼻饲(OR=0.09,95%CI:0.03~0.31,

表2 脑卒中患者医院感染的病原菌分布

Table 2 Distribution of pathogenic bacteria in hospital-acquired infections among stroke patients

Variable	Case (%)
Gram-negative bacteria	200 (70.2)
<i>Klebsiella pneumoniae</i>	75 (26.3)
<i>Acinetobacter baumannii</i>	50 (17.5)
<i>Escherichia coli</i>	28 (9.8)
<i>Pseudomonas aeruginosa</i>	19 (6.7)
Other Gram-negative bacteria	28 (9.8)
Gram-positive bacteria	81 (28.4)
<i>Staphylococcus aureus</i>	46 (16.1)
<i>Enterococcus faecium</i>	10 (3.5)
<i>Enterococcus faecalis</i>	9 (3.2)
Other Gram-positive bacteria	16 (5.6)
Fungi	4 (1.4)
Number of co-infecting pathogens	
1	102 (55.4)
2	58 (31.5)
≥3	24 (13.0)
Drug resistance phenotypes	
Extensively drug-resistant (XDR) ^a	29/50 (58.0)
Carbapenem-resistant enterobacteriaceae (CRE) ^b	32/75 (42.7)
Extended-spectrum β-lactamase (ESBL) ^c	14/28 (50.0)
Methicillin-resistant <i>S. aureus</i> (MRSA) ^d	26/46 (56.5)
Site of infection	
Pulmonary infection	171 (92.9)
Urinary tract infection	59 (32.1)
Intracranial infection	7 (3.8)
Bloodstream infection	9 (4.9)
Infection at ≥ 2 sites	31 (16.8)

A single patient with multi-site infections may have multiple pathogens isolated. ^a XDR analysis was limited to *acinetobacter baumannii*. ^b CRE analysis was limited to *klebsiella pneumoniae*. ^c ESBL analysis was limited to *escherichia coli*. ^d MRSA analysis was limited to *staphylococcus aureus*.

$P < 0.001$)、未留置导尿管(OR=0.21,95%CI:0.06~0.77, $P = 0.019$)和无术后昏迷(OR=0.07,95%CI:0.01~0.36, $P = 0.001$)是感染的保护因素(表3)。

2.4 脑卒中患者发生医院感染风险的列线图构建及检验效能评价

结果见图1。基于多因素logistic回归分析所确定的独立影响因素,本研究构建了一个用于预测脑卒中患者医院感染风险的列线图模型。该模型通过计算各变量的单项得分并累加得到总分,从而预测患者发生医院感染的概率。将数据按7:3的比例划分为训练集与验证集,

表 3 脑卒中患者医院感染的单因素及多因素logistic回归分析

Table 3 Univariate and multivariate logistic regression analysis of hospital-acquired infections in stroke patients

Variable	Univariate OR (95% CI)	P	Multivariate OR (95% CI)	P
Cerebral infarction	1.55 (0.96-2.50)	0.073	25.09 (5.38-117.10)	< 0.001
No alcohol history	2.51 (1.52-4.16)	< 0.001	4.47 (1.51-13.18)	0.007
No cerebrovascular disease	2.23 (1.31-3.79)	0.003	5.04 (1.35-18.76)	0.016
No nasogastric feeding	0.03 (0.01-0.06)	< 0.001	0.09 (0.03-0.31)	< 0.001
No urinary catheterization	0.07 (0.03-0.14)	< 0.001	0.21 (0.06-0.77)	0.019
No postoperative coma	0.03 (0.01-0.09)	< 0.001	0.07 (0.01-0.36)	0.001
Neutrophil count	1.55 (1.39-1.72)	< 0.001	1.29 (1.08-1.55)	0.006
CRP	1.06 (1.04-1.08)	< 0.001	1.03 (1.01-1.06)	0.009

CRP: C-reactive protein; OR: odds ratio.

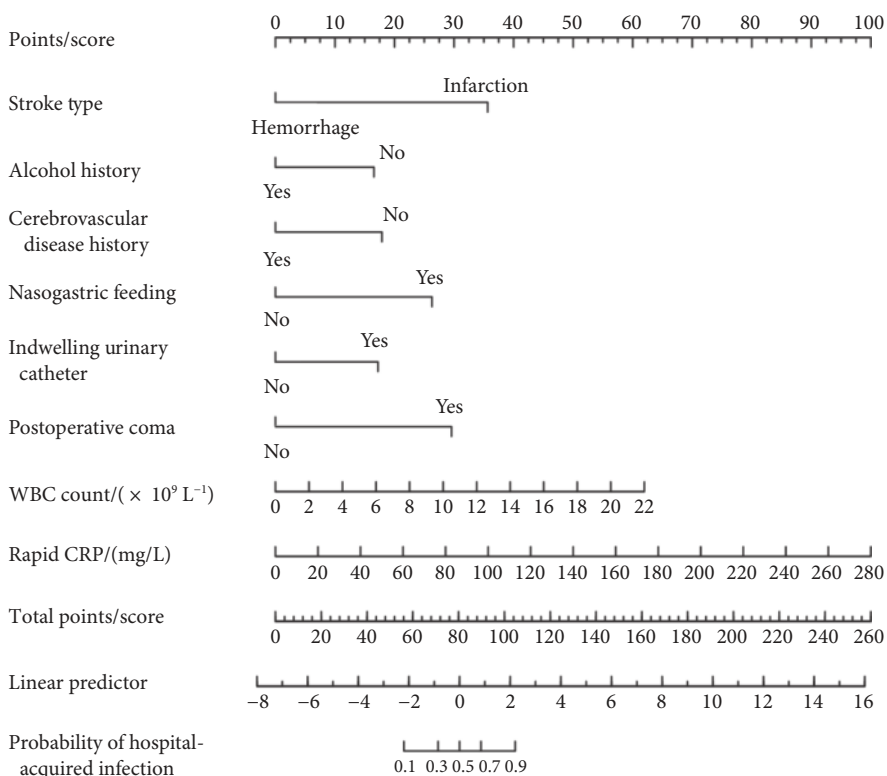


图 1 脑卒中患者医院感染风险的列线图模型

Fig 1 Nomogram for predicting the risk of hospital-acquired infection in stroke patients

All abbreviations are explained in the footnote to Table 1.

模型在训练集与验证集中均表现出良好的预测性能(表4)。训练集中的AUC高达0.96(95%CI: 0.94 ~ 0.98), 灵敏度为0.86, 特异度为0.95, 约登指数为0.81; 验证集中的AUC也达到0.94(95%CI: 0.90 ~ 0.99), 灵敏度为0.94, 特异度为

0.92, 约登指数为0.86, 表明模型具有优异的判别能力。训练集与验证集的ROC曲线表现接近, 模型具有较强的稳健性(图2)。此外, Hosmer-Lemeshow拟合优度检验显示, 训练集(P= 0.734)和验证集(P= 0.171)中校准曲线与

表 4 脑卒中患者医院感染风险预测模型的ROC曲线分析

Table 4 ROC curve analysis of the prediction model for hospital-acquired infection risk in stroke patients

Dataset	AUC (95% CI)	Se (95% CI)	Sp (95% CI)	PPV (95% CI)	NPV (95% CI)	Cut-off value
Training set	0.96 (0.94-0.98)	0.86 (0.81-0.92)	0.95 (0.91-0.99)	0.95 (0.92-0.99)	0.85 (0.79-0.91)	0.238
Validation set	0.94 (0.90-0.99)	0.94 (0.88-1.00)	0.92 (0.85-0.99)	0.91 (0.83-0.99)	0.95 (0.89-1.00)	0.238

ROC: receiver operating characteristic; AUC: area under the curve; Se: sensitivity; Sp: specificity; PPV: positive predictive value; NPV: negative predictive value.

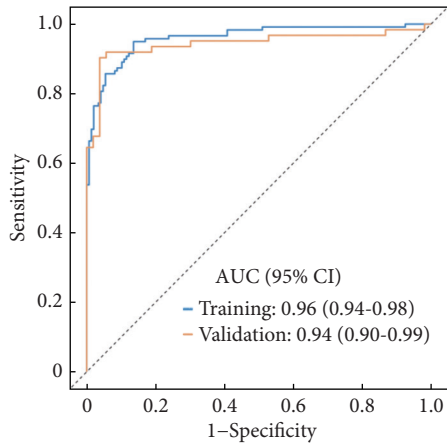


图 2 脑卒中患者医院感染风险预测模型的 ROC 曲线

Fig 2 ROC curve of the hospital-acquired infection risk prediction model in stroke patients

理想曲线均拟合良好, 预测概率与实际概率之间具有良好的—致性(图3)。

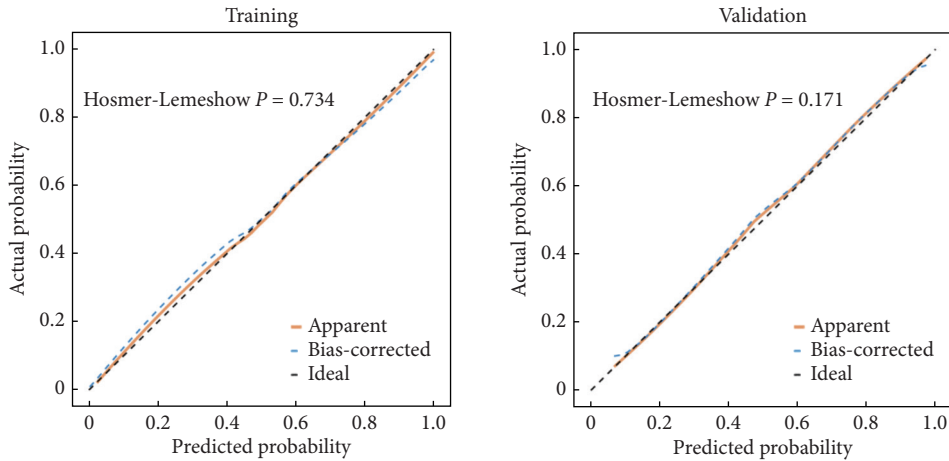


图 3 脑卒中患者医院感染风险预测模型的 Hosmer-Lemeshow 检验

Fig 3 Hosmer-Lemeshow test of the prediction model for hospital-acquired infection risk in stroke patients

表 5 感染革兰阳性 (G⁺) 菌、革兰阴性 (G⁻) 菌及混合感染 (G⁺菌和G⁻菌) 的单因素分析

Table 5 Univariate analysis of patients with gram-positive (G⁺), gram-negative (G⁻), and mixed (G⁺ & G⁻) bacterial infections

Variable	G ⁺ bacteria (n = 36)	G ⁻ bacteria (n = 108)	Mixed infection (n = 37)	P
Age/yr.	66.0 (54.0, 73.5)	67.0 (55.0, 75.0)	56.0 (45.0, 64.0)	< 0.001
Height/cm	165 (160, 172)	169 (161.8, 172.0)	175 (170, 177)	< 0.001
Male	21 (58.3)	73 (67.6)	33 (89.2)	0.010
Cerebral hemorrhage	11 (30.6)	43 (39.8)	28 (75.7)	< 0.001
Impaired consciousness	18 (50.0)	64 (59.3)	33 (89.2)	< 0.001
Cerebrovascular disease	26 (72.2)	71 (65.7)	17 (45.9)	0.043
Endotracheal intubation	12 (33.3)	68 (63.0)	33 (89.2)	< 0.001
Postoperative coma	5 (13.9)	47 (43.5)	32 (86.5)	< 0.001
Gastric tube insertion	15 (41.7)	61 (56.5)	29 (78.4)	0.006
WBC/(× 10 ⁹ L ⁻¹)	10.3 (7.8, 12.1)	11.2 (7.6, 13.5)	13.0 (10.4, 15.2)	0.019
Neutrophil/(× 10 ⁹ L ⁻¹)	8.3 (6.0, 9.6)	9.3 (5.9, 11.8)	10.8 (8.7, 13.2)	0.016
CRP/(mg/L)	24.6 (9.6, 69.0)	34.3 (11.7, 74.4)	67.1 (33.3, 119.8)	0.009

All abbreviations are explained in the footnote to Table 1. Data are presented as median (Q₁, Q₃) or case (%). Only variables with P < 0.05 are shown.

2.5 感染G⁻菌的影响因素分析

本次分析共181人, 其中感染G⁺菌的有36人, 占比19.89%, 感染G⁻菌的有108人, 占比59.67%, 同时感染G⁺菌和G⁻菌的有37人, 占比20.44%。单因素分析显示, G⁺菌感染、G⁻菌感染及混合感染(G⁺菌合并G⁻菌)三组患者的年龄、身高、卒中类型、性别、意识障碍、气管插管、术后昏迷、胃管置入、白细胞计数、中性粒细胞计数及C反应蛋白等指标差异均具有统计学意义(P < 0.05, 网络资源附件附表2和表5)。混合感染组患者年龄较小[56.0(45.0, 64.0)岁], 身高较高[175(170, 177) cm], 且以男性(89.19%)和脑出血类型(75.68%)为主。与G⁺菌或G⁻菌感染组相比, 该组患者的意识障碍(89.19%)、气管插管(89.19%)及术后昏迷(86.49%)发生率更高, 炎症指标如白细胞计数、中性粒细胞计数及C反应蛋白水平也更高, 且上述所有差异均具有统计学意义(均 P < 0.05, 网络资源附件附表2和表5)。

多因素logistic回归分析进一步探讨G⁻菌感染的独立影响因素。在校正性别、年龄、身高、体质量及体质量指数后(模型3),无意识障碍(OR=0.33, 95%CI: 0.11~0.98, P=0.046)、未行气管插管(OR=0.24, 95%CI: 0.07~0.80, P=0.021)及无术后昏迷(OR=0.12, 95%CI: 0.03~0.53, P=0.005)是G⁻菌感染的独立保护因素(表6)。

2.6 肺部感染的影响因素分析

本次研究共152人,其中肺部感染患者116人,占比76.32%,泌尿系统感染患者36人,占比23.68%。单因素分析显示(表7),肺部感染组与泌尿系统感染组在多个基线特征方面差异具有统计学意义(P<0.05)。肺部感染患者更为年轻[63.50(51.75, 72.00)岁 vs. 69.50(63.00, 75.25)岁,

P=0.019],身高更高[170.00(162.25, 174.50)cm vs. 163.50(160.00, 170.50)cm, P=0.023],且以男性居多(75.00% vs. 47.22%, P=0.002)。在临床特征方面,肺部感染组意识障碍(78.45% vs. 16.67%, P<0.001)、气管插管(78.45% vs. 2.78%, P<0.001)、术后昏迷(53.45% vs. 2.78%, P<0.001)、吞咽困难(87.07% vs. 50.00%, P<0.001)及胃管置入(68.10% vs. 22.22%, P<0.001)的比例高于泌尿系统感染组。实验室指标中,肺部感染组白细胞计数、中性粒细胞计数、中性粒细胞/淋巴细胞比值及C反应蛋白水平均较高,而淋巴细胞计数、嗜酸性粒细胞计数较低(均P<0.05)。

多因素logistic回归分析进一步识别出肺部感染的独立影响因素。在校正性别、年龄、身高、体质量及体质量

表 6 感染革兰阳性(G⁺)菌和革兰阴性(G⁻)菌的多因素分析

Table 6 Multivariable analysis of factors associated with gram-positive (G⁺) and gram-negative (G⁻) bacterial infections

Variable	Model 1		Model 2		Model 3	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
No chronic lung disease	0.38 (0.15-0.94)	0.037	0.38 (0.14-1.01)	0.053	0.36 (0.10-1.34)	0.128
No impaired consciousness	0.69 (0.32-1.47)	0.332	0.69 (0.32-1.47)	0.335	0.33 (0.11-0.98)	0.046
No tracheal intubation	0.29 (0.13-0.65)	0.003	0.26 (0.11-0.61)	0.002	0.24 (0.07-0.80)	0.021
No postoperative coma	0.21 (0.08-0.58)	0.003	0.20 (0.07-0.56)	0.002	0.12 (0.03-0.53)	0.005

All abbreviations are explained in the footnote to Table 3. Model 1, Unadjusted; Model 2, adjusted for sex and age; Model 3, adjusted for sex, age, height, weight, and body mass index. Only variables with a P-value < 0.05 in at least one model are shown.

表 7 肺部感染的单因素分析

Table 7 Univariate analysis of factors associated with pulmonary infection

Variable	Pulmonary infection (n = 116)	Urinary tract infection (n = 36)	P
Age/yr.	63.5 (51.8, 72.0)	69.5 (63.0, 75.3)	0.019
Height/cm	170.0 (162.3, 174.5)	163.5 (160.0, 170.5)	0.023
Male	87 (75.0)	17 (47.2)	0.002
Impaired consciousness	91 (78.5)	6 (16.7)	<0.001
Diabetes	30 (25.9)	19 (52.8)	0.003
Liver disease	64 (55.2)	12 (33.3)	0.022
Endotracheal intubation	91 (78.5)	1 (2.8)	<0.001
Nasogastric feeding	89 (76.7)	14 (38.9)	<0.001
Complete bed rest	29 (25.0)	2 (5.6)	0.011
Postoperative coma	62 (53.5)	1 (2.8)	<0.001
Dysphagia	101 (87.1)	18 (50.0)	<0.001
Gastric tube insertion	79 (68.1)	8 (22.2)	<0.001
WBC count/(× 10 ⁹ L ⁻¹)	11.67 (9.08, 14.89)	8.25 (6.54, 11.38)	<0.001
Lymphocyte count/(× 10 ⁹ L ⁻¹)	1.12 (0.72, 1.37)	1.27 (1.06, 1.53)	0.017
Monocyte count/(× 10 ⁹ L ⁻¹)	0.69 (0.48, 0.90)	0.53 (0.40, 0.72)	0.019
Neutrophil count/(× 10 ⁹ L ⁻¹)	9.70 (7.39, 12.40)	6.07 (4.43, 9.26)	<0.001
Neutrophil-to-lymphocyte ratio	8.32 (6.62, 13.47)	4.63 (3.27, 7.69)	<0.001
Eosinophil count/(× 10 ⁹ L ⁻¹)	0.02 (0.01, 0.11)	0.15 (0.05, 0.24)	<0.001
Basophil count/(× 10 ⁹ L ⁻¹)	0.02 (0.02, 0.03)	0.03 (0.02, 0.04)	0.015
Mean platelet volume/fL	9.90 (9.30, 10.70)	9.50 (8.65, 10.53)	0.036
Large platelet ratio/%	25.95 (21.30, 30.45)	23.00 (17.25, 30.55)	0.045
Rapid CRP/(mg/L)	45.74 (15.20, 92.14)	15.90 (7.09, 47.34)	0.003

All abbreviations are explained in the footnote to Table 1. Data are presented as median (Q₁, Q₃) or case (%). Only variables with P < 0.05 are shown.

指数后(模型3), 无意识障碍(OR=0.02, 95%CI: 0.00~0.14, $P<0.001$)、未行气管插管(OR=0.01, 95%CI: 0.00~0.12, $P<0.001$)、无鼻饲(OR=0.13, 95%CI: 0.04~0.48, $P=0.002$)、无术后昏迷(OR=0.02, 95%CI: 0.00~0.22, $P=0.001$)、无吞咽困难(OR=0.04, 95%CI: 0.01~0.22, $P<0.001$)、无完全卧床(OR=0.10, 95%CI: 0.01~0.91, $P=0.041$)及未插入胃管(OR=0.11, 95%CI: 0.03~0.45, $P=0.002$)是肺部感染的保因素。此外, 白细胞计数升高(OR=1.21, 95%CI: 1.02~1.43, $P=0.030$)、中性粒细胞计数升高(OR=1.27, 95%CI: 1.05~1.54, $P=0.016$)及中性粒细胞/淋巴细胞比值升高(OR=1.24, 95%CI: 1.06~1.46, $P=0.009$)是其独立危险因素(表8)。

表 8 肺部感染的多因素分析

Table 8 Multivariable analysis of factors associated with pulmonary infection

Variable	Model 1		Model 2		Model 3	
	OR (95% CI)	P	OR (95% CI)	P	OR (95% CI)	P
No impaired consciousness	0.05 (0.02-0.15)	< 0.001	0.05 (0.02-0.15)	< 0.001	0.02 (0.00-0.14)	< 0.001
No Diabetes	3.2 (1.5-7.0)	0.003	3.1 (1.4-6.9)	0.008	3.2 (0.9-11.0)	0.067
No liver disease	0.41 (0.19-0.89)	0.024	0.45 (0.20-1.02)	0.055	0.27 (0.07-0.99)	0.049
No hypoalbuminemia	0.51 (0.22-1.18)	0.114	0.36 (0.14-0.89)	0.028	0.33 (0.09-1.30)	0.113
No endotracheal intubation	0.01 (0.00-0.06)	< 0.001	0.01 (0.00-0.06)	< 0.001	0.01 (0.00-0.12)	< 0.001
No nasogastric feeding	0.19 (0.09-0.43)	< 0.001	0.19 (0.08-0.45)	< 0.001	0.13 (0.04-0.48)	0.002
No complete bed rest	0.18 (0.04-0.78)	0.022	0.18 (0.04-0.82)	0.027	0.10 (0.01-0.91)	0.041
No postoperative coma	0.02 (0.00-0.19)	< 0.001	0.02 (0.00-0.18)	< 0.001	0.02 (0.00-0.22)	0.001
No dysphagia	0.15 (0.06-0.35)	< 0.001	0.02 (0.00-0.18)	< 0.001	0.02 (0.00-0.22)	0.001
No gastric tube insertion	0.13 (0.06-0.32)	< 0.001	0.16 (0.07-0.40)	< 0.001	0.11 (0.03-0.45)	0.002
WBC count	1.28 (1.13-1.46)	< 0.001	1.23 (1.08-1.40)	0.002	1.21 (1.02-1.43)	0.030
Lymphocyte count	5.8 (1.4-24.7)	0.017	2.9 (0.6-13.1)	0.177	3.1 (0.4-27.7)	0.305
Neutrophil count	1.35 (1.17-1.55)	< 0.001	1.29 (1.12-1.48)	< 0.001	1.27 (1.05-1.54)	0.016
Neutrophil-to-lymphocyte ratio	1.27 (1.12-1.44)	< 0.001	1.24 (1.10-1.39)	< 0.001	1.24 (1.06-1.46)	0.009
Eosinophil count	0.00 (0.00-0.04)	< 0.001	0.00 (0.00-0.06)	< 0.001	0.00 (0.00-0.12)	0.005
Basophil count	0 (0-0.7)	0.046	0 (0-0)	0.010	0 (0-3.03)	0.545
Mean platelet volume	1.49 (1.05-2.11)	0.027	1.54 (1.06-2.23)	0.022	2.16 (1.12-4.16)	0.021
Large platelet ratio	1.06 (1.01-1.11)	0.037	1.06 (1.01-1.12)	0.031	1.11 (1.01-1.22)	0.027
Rapid CRP	1.0 (1.0-1.0)	0.007	1.0 (1.0-1.0)	0.023	1.0 (1.0-1.0)	0.117

All abbreviations are explained in the footnote to Table 1 and Table 3. Model 1, Unadjusted; Model 2, adjusted for sex and age; Model 3, adjusted for sex, age, height, weight, and body mass index. Only variables with $P<0.05$ in at least one model are shown.

3 讨论

本研究通过回顾性分析, 系统探讨了脑卒中患者医院感染的流行病学特征、病原分布、耐药情况、独立影响因素及预测模型, 并进一步分析了不同病原菌类型和感染部位的特异性风险模式, 为临床实施精准化防控策略提供了重要依据。

首先, 本研究揭示了脑卒中患者医院感染的病原菌分布以G⁻杆菌为主导(70.2%), 其中肺炎克雷伯菌(26.3%)和鲍曼不动杆菌(17.5%)是最常见的病原体, 这一发现与国内外多数报道一致^[14-16]。值得注意的是,

本研究揭示的耐药形势与国内外多项监测结果一致。本研究中鲍曼不动杆菌的泛耐药率高达58.0%, 这一数据与2023年全国细菌耐药监测网报道的碳青霉烯类药物耐药率(55.5%)相当^[9], 低于2023年CHINET中国细菌耐药监测报告的亚胺培南耐药率(73.4%)^[17], 可能与抗生素的规范使用有关。肺炎克雷伯菌中对碳青霉烯类耐药(carbapenem-resistant klebsiella pneumoniae, CRKP)的检出率达到42.7%, 与全国监测中CRKP检出率呈上升趋势的警告相符^[10, 18-19], 江西地区在2021年的检出率已高达50.8%^[20]。此外, MRSA和产ESBLs大肠埃希菌的比率均超过50%, 与2023年全国细菌耐药监测网报道的第三代头

孢菌素耐药率(50.8%)相当^[9]。这种高耐药性背景极大地限制了后续抗感染治疗的选择,显著增加了治疗难度、医疗费用和患者死亡率。因此,对于脑卒中患者,尤其是存在文中所述高危因素者,初始经验性抗生素治疗应充分考虑覆盖这些耐药菌,并应严格遵循抗菌药物管理原则,根据药敏结果及时降阶梯治疗,这与《中国脑卒中防治指导规范》中关于感染控制的建议相呼应。

多因素logistic回归分析共识别出八个医院感染的独立影响因素,勾勒出高风险患者的临床特征谱,其结果与既往研究既有共性也有新发现。侵入性操作是感染的核心机制,未行鼻饲(OR=0.09)和未留置导尿管(OR=0.21)作为保护因素,突显其破坏人体物理屏障的关键作用,这与KUMAR等^[21]关于医疗装置相关感染的研究结论一致。术后昏迷(OR=0.07)提示意识障碍导致免疫抑制与呼吸道防御功能下降,是公认的危险因素。本研究发现脑梗死患者(OR=25.09)感染风险显著高于脑出血患者,这一强烈的关联性较ZHANG等^[22]关于卒中感染风险的研究报道更为突出,可能与其研究人群通常年龄更大、基础疾病更多、神经功能缺损更持续有关。炎症标志物中性粒细胞计数(OR=1.29)和CRP(OR=1.03)升高,提示感染发生前机体已处于强烈应激和炎症状态这与张玉敏等^[23]的研究发现相吻合。本研究中无饮酒史(OR=4.47)和无脑血管病史(OR=5.04)是感染的危险因素,这一反直觉的现象值得深入探讨,其背后可能隐藏着独特的临床机制:一方面,提示乙醇的免疫调节作用可能对感染具有一定的抑制效应;另一方面,也反映出初发卒中患者作为一个特殊群体,其疾病防范意识 and 临床管理经验相对不足,这为未来针对不同病史人群制定精细化感染防控策略提供了新的线索。

基于上述变量构建的列线图模型表现出优良的预测效能。训练集与验证集AUC分别为0.96和0.94,准确度均超过0.90,其区分能力优于既往一些基于常规指标的预测模型^[24]。Hosmer-Lemeshow拟合优度检验提示校准度良好($P>0.05$)。该模型不仅区分能力强,而且预测概率与实际发生率高度一致,显示出较好的临床转化潜力,可用于入院卒中患者的个体化风险分层,并对高风险患者提前采取强化干预措施,如严格无菌操作、早期康复训练及针对性病原学监测等,从而实现前瞻性、精准化感染预防,这与当前提倡的精准医疗理念相契合。

本研究还发现,脑卒中后医院感染以下呼吸道为主(92.9%),这一比例高于II等^[25]基于一般卒中人群的报道(约70%),可能与本研究纳入患者病情更重、意识障碍和侵入性操作比例更高有关。多因素分析校正后,一系列

与气道保护和无意识障碍相关的因素被证实为保护因素,凸显侵入性操作在肺部感染中的关键作用,这一发现与国际卒中临床试验中关于肺炎预防的策略重点高度一致^[26]。这一发现强调,在感控实践中,对于意识障碍、需气道管理的患者,应重点强化呼吸道护理和尽早脱机拔管。

进一步按病原菌类型(G⁺菌、G⁻菌及混合感染)进行分层分析,结果提示混合感染患者更为年轻、体型更高大、男性居多,且意识障碍、气管插管、术后昏迷比例和炎症指标更高,表明混合感染多见于病情危重、炎症反应剧烈及接受广泛医疗干预的患者群体,这一特征与重症监护病房(intensive care unit, ICU)内感染患者的分布特点相似^[27-31]。G⁺菌与G⁻菌感染者在临床特征方面亦存在差异。未行气管插管(OR=0.24)、无术后昏迷(OR=0.12)等是G⁻菌感染的保护因素,进一步印证侵入性操作在医院感染,特别是G⁻菌感染中的核心作用,为世界卫生组织2023年全球指南中关于“减少不必要侵入性操作”的核心建议提供了来自中国卒中人群的强有力证据^[32]。这些发现为未来开展病原导向的针对性预防提供了理论依据。值得注意的是,近期研究揭示了CRKP中耐药性与高毒力基因融合的现象^[33],这提示未来研究需关注卒中患者感染病原体的分子特征,以更深入理解其临床异质性。

本研究仍存在一定局限性。首先,作为单中心回顾性研究,可能存在选择偏倚和信息偏倚。其次,预测模型虽经内部验证表现良好,但普适性仍需通过多中心、前瞻性研究进行外部验证。未来可将该模型嵌入医院信息系统,实现感染风险实时预测与临床决策支持,并基于风险分层开展干预性研究,以验证其在降低医院感染发生率方面的实际效果。

综上所述,本研究系统阐述了脑卒中患者医院感染的病原学特点、耐药现状及多重影响因素,构建出具有良好效能的个体化风险预测模型,并揭示了不同病原和感染部位的特异性风险模式,有助于早期识别高危患者、优化感染防控资源分配、实施精准化干预,从而为降低脑卒中患者医院感染负担、改善预后提供依据。

* * *

作者贡献声明 徐婷负责论文构思、数据审编、正式分析、调查研究、研究方法、研究项目管理、提供资源、监督指导、验证、可视化、初稿写作和审读与编辑写作,韩冰清负责数据审编、研究项目管理、提供资源和审读与编辑写作,张涵瑜负责调查研究、提供资源和验证,邵春青、王玉飞和焦场负责数据审编和审读与编辑写作,张国军负责经费获取、调查研究、提供资源和审读与编辑写作。所有作者已经同意将文章提交给本刊,且对将要发表版本进行最终定稿,并同意对工作的所有方面负责。
Author Contribution XU Ting is responsible for conceptualization, data curation, formal analysis, investigation, methodology, project

administration, resources, supervision, validation, visualization, writing--original draft, and writing--review and editing. HAN Bingqing is responsible for data curation, project administration, resources, and writing--review and editing. ZHANG Hanyu is responsible for investigation, resources, and validation. SHAO Chunqing, WANG Yufei, and JIAO Yang are responsible for data curation and writing--review and editing. ZHANG Guojun is responsible for funding acquisition, investigation, resources, and writing--review and editing. All authors consented to the submission of the article to the Journal. All authors approved the final version to be published and agreed to take responsibility for all aspects of the work.

利益冲突 所有作者均声明不存在利益冲突

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