论著·临床医学

经颅多普勒超声联合有创颅内压预测颅脑创伤患者早期治疗转归

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[摘要] **目的** 探讨经颅多普勒超声(intracranial pressure, TCD)联合有创颅内压(intracranial pres sure, ICP)监测在中重型颅脑创伤(moderate-to-severe traumatic brain injury,msTBI)患者ICP探头置入术后早期治疗转归中的预测作用。**方法** 通过回顾性病例对照研究分析联勤保障部队第九〇四医院2021年1月至2025年3月收治的65例伤后24 h内仅行有创ICP探头置入术及术后常规行TCD检查的msTBI患者的临床资料。根据疾病进展是否达开颅手术指征分为保守治疗成功组(37例)和保守治疗失败组(28例),收集2组的临床基线数据、ICP和TCD的监测参数。通过单因素分析比较2组差异指标,分别对纳入ICP和TCD参数的模型1及纳入潜在混杂因素的模型2,采用多因素Logistic回归分析筛选保守治疗失败的独立预测因素,并利用受试者工作特征曲线(receiver operating characteristic curve,ROC)评估各预测因素的诊断效能。**结果** 2组患者的入院时格拉斯哥昏迷量表(Glasgow coma scale,GCS)评分、术后ICP均值(mean intracranial pressure,ICPm)、术后灌注压均值(mean cerebral perfusion pressure,CPPm)、原伤侧颈内动脉颅外段(internal cerebral artery terminal,ICAt)及原伤侧大脑中动脉(middle cerebral artery,MCA)的搏动指数(pulsatility index,PI)值、原伤侧MCA的平均血流速度(mean velocity,Vm)值对比差异具有统计学意义(P<0.01)。在调整了年龄、入院时GCS评分、血肿量、术后脑温均值后,多因素Logistic回归分析结果表明,ICPm(OR=1.248,95%CI:1.044~1.491,P=0.015)、原伤侧MCA. Vm(OR=0.964,95%CI:0.933~0.997,P=0.034)、原伤侧MCA. PI(OR=1.612,95%CI:1.026~2.533,P=0.038)是msTBI患者保守治疗失败的独立显著预测因子。进行校正后的ROC曲线分析结果显示,原伤侧MCA. PI、原伤侧MCA. Vm与ICPm的联合模型预测效能达到了0.931(95%CI:0.873~0.988),高于ICPm单一模型的预测效能0.875(95%CI:0.791~0.959)。**结论** TCD和ICP联合监测能更准确预测ICP探头置入术后msTBI患者早期治疗转归情况,为msTBI患者的早期临床诊疗提供更有效的评估方法。

[关键词] 中重型颅脑创伤;有创颅内压;经颅多普勒超声;平均血流速度;搏动指数
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Prediction of early treatment outcomes in patients with traumatic brain injury using transcranial Doppler ultrasound combined with invasive intracranial pressure

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[**Abstract**] **Objective** To investigate the predictive role of transcranial Doppler (TCD) ultrasound

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combined with invasive intracranial pressure (ICP) monitoring in the early outcomes for patients with moderate-to-severe traumatic brain injury (msTBI) after ICP probe insertion surgery. **Methods** A retrospective case-control analysis was conducted on the clinical data of 65 msTBI patients who underwent invasive ICP probe insertion surgery within 24 h after injury and routine TCD examination postoperatively in No. 904 Hospital of Joint Logistic Support Force of Chinese PLA between January 2021 and March 2025. Based on whether disease progression met the indications for craniotomy, they were divided into a failed conservative treatm ent group (n=28) and a successful conservative treatment group (n=37). Baseline clinical data, and parameters of TCD and ICP monitoring were collected in both groups. Univariate analysis was used for comparing differences in various parameters between the groups. The variables related to ICP and TCD were denoted as Model 1, and variables that significantly affected the outcome were incorporated as potential confounding factors into Model 2 based on clinical experience. Multivariate logistic regression analysis was performed to screen for independent predictors of conservative treatment failure. Receiver operating characteristic (ROC) curves were plotted to evaluate the diagnostic efficacy of each predictive factor. **Results** Statistical differences were observed between the 2 groups in terms of Glasgow Coma Scale (GCS) score at admission, postoperative mean intracranial pressure (ICPm), postoperative mean cerebral perfusion pressure (CPPm), and pulsatility index (PI) of the ipsilateral internal carotid artery extracranial segment (ICAt), and mean flow velocity (Vm) and pulsatility index (PI) of the ipsilateral middle cerebral artery (MCA) (all P<0.01). After adjusting for age, GCS score at admission, hematoma volum, and mean postoperative brain temperature, multivariate logistic regression analysis revealed that ICPm (OR=1.248, 95%CI: 1.044~1.491, P=0.015), ipsilateral MCA. Vm (OR=0.964, 95%CI: 0.933~0.997, P=0.034), and ipsilateral MCA. PI (OR=1.612, 95%CI: 1.026~2.533, P=0.038) were independent predictors of failure in conservative treatment in msTBI patients. After adjustment, ROC curve analysis demonstrated that the combined model of ipsilateral MCA. PI, ipsilateral MCA. Vm, and ICPm achieved a predictive efficacy of 0.931 (95%CI: 0.873~0.988), which was obviously higher than that of the single model of ICPm (0.875, 95%CI: 0.791~0.959). **Conclusion** Combined monitoring of TCD and ICP can provide a more accurate prediction of the early outcomes for msTBI patients after ICP probe insertion, providing a more effective assessment for clinical diagnosis and treatment.

[**Key words**] moderate-to-severe traumatic brain injury; intracranial pressure; transcranial Doppler ultrasound; mean flow velocity; pulsatility index

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颅脑创伤(traumatic brain injury,TBI)是指头部受到撞击或外力冲击导致正常脑部结构或功能的获得性破坏,具有极高的发病率、致残率和病死率。TBI是伤害相关残疾与死亡的三大原因之一,全球新发病例每年5 000万~6 000万人[1]。JIANG等[2]回顾性分析了中国2001—2016年TBI患者125 474例,其发病率为554~641/10万人,病死率约为13/10万人,给全球带来了沉重的疾病负担。

颅内压(intracranial pressure, ICP)增高是TBI患者疾病进展与恶化的关键因素,进一步导致脑灌注压(cerebral perfusion pressure, CPP)降低,引发脑组织缺血缺氧,甚至脑疝。开颅手术是降低颅内高压、改善脑血流的重要手段,然而相当一部分中重型颅脑创伤(moderate-to-severe traumatic brain injury,msTBI)患者在伤后早期并未达到传统开颅手术指征,即使进行了有创ICP探头置入术,仍然可以根据病情变化选择保守治疗或是开颅手术,在此基础上如何准确判定开颅手术时机,降低患者病死率与重残风险至关重要,成为治疗msTBI患者的关键环节之一。

有创ICP探头置入术是TBI患者临床管理中重要的监测手段,已经广泛应用于临床,但有创ICP监测仅能量化颅内压力、不能反映ICP升高的原因。经颅多普勒超声(intracranial pressure, TCD)作为一种无创、便捷技术,能实时监测颅内血流动力学变化,为临床

决策提供脑血流信息。目前关于TCD联合ICP监测在指导msTBI患者早期治疗方案选择的相关研究较少,因此,本研究回顾性分析联勤保障部队第九〇四医院2021年1月至2025年3月收治入院的65例进行TCD和ICP联合监测的msTBI患者的临床资料,探讨TCD联合ICP监测在患者早期治疗转归中的预测作用,以指导msTBI患者早期治疗方式的选择。

1 资料与方法

1.1 研究对象

通过回顾性病例对照研究分析联勤保障部队第九〇四医院2021年1月至2025年3月收治入院且伤后24 h内仅行有创ICP探头置入术及术后常规行TCD检查的msTBI患者的相关临床资料。共纳入msTBI患者65例,其中男47例,女18例;年龄18~82(55.63±15.17)岁;入院格拉斯哥昏迷量表(Glasgow coma scale,GCS)评分[3]3~12分(7.65±3.20分)岁;创伤原因包括交通事故损伤(73.85%)、坠落跌倒损伤(26.15%)。纳入标准:①头部外伤史明确,经影像学检查确诊为TBI患者;②GCS评分3~12分;③年龄≥18岁;④入院时符合ICP监测指征[4],但未达到TBI开颅手术指征[5];⑤ICP置入术后并常规行TCD监测。排除标准:①合并其他重要脏器损伤,严重危及生命的多发伤;②合并颅内肿瘤、急性严重脑血管病变及其它系统疾病;③既往开颅手术史;④病历资料不全。根据ICP探头置入术后疾病进展是否达到开颅手术指征将患者分为:保守治疗成功组(37例)和保守治疗失败组(28例);将术后ICP均值(mean intracranial pressure,ICPm)根据美国《重型颅脑创伤治疗指南(第四版)》ICP的阈值22 mmHg进行分层[6],ICPm<22 mmHg记为颅内压正常组(32例)、ICPm≥22 mmHg记为颅内压增高组(33例)。本研究经解放军联勤保障部队第九〇四医院伦理委员会批准(20250420),并遵循赫尔辛基宣言。

1.2 研究方法

1.2.1 有创颅内压探头置入术 所有患者完善头颅CT平扫及常规检查,对达ICP监测指征的患者在全身麻醉下行侧脑室穿刺有创脑室型ICP探头置入术,采用法国索菲萨公司或美国强生公司PSO-VTT型号的脑室型ICP探头监测并记录ICP,根据治疗指南予以规范的控制ICP阶梯治疗方案。统计术后24 h的ICP值、CPP值、脑温,每2小时记录1次(记录时避开如吸痰呛咳、翻身躁动、腰椎穿刺等情况下导致的异常增高或降低),获取ICPm、平均动脉压(mean arterial preasure,MAP)、术后CPP均值(mean cerebral perfusion pressure,CPPm)和术后脑温均值,计算公式CPP=MAP-ICP。具体方法如下:穿刺靶点多选择在脑挫伤、颅内血肿对侧的侧脑室额角,以冠状平面指向伤侧内眦、矢状平面上指向患侧外耳道假象连线为穿刺方向,穿刺点选择为冠状缝前2.5 cm和中线旁开2.5 cm的交点。穿刺针与头皮表面垂直,进针5~6 cm,拔出针芯,观察脑脊液是否流出并确认引流通畅后,关闭引流管。切口旁皮下引出引流管并固定于患者外耳道水平线处,与体外传感器及ICP监护仪相连。严密监测患者生命体征、意识及瞳孔的变化。

1.2.2 经颅多普勒超声检查 ICP探头置入术后立即行TCD监测,每8小时监测1次,统计术后24 h内3次的TCD监测数据均值。采用北京悦琦创通科技有限公司的TCD-2000F型彩色多普勒超声诊断仪监测脑血流的变化,利用设备中的2 MHz和4 MHz脉冲多普勒探头发出的超声束对脑血流进行分析。TCD超声检查前进行动脉血气分析,保持二氧化碳分压在4.66~6.00 kPa(35~45 mmHg)这一正常范围内,检查时避开所有刺激性护理和操作,所有操作由同一名熟练掌握该技术的医师完成。受检者取仰卧位,头置正位,将超声探头与探测平面垂直放置,获取最佳脑部二维图像后,开启彩色多普勒血流显像,观测颅内血管分布和走行等。TCD的检测血管为双侧大脑中动脉(middle cerebral artery,MCA)的主干段(M1段)和颈内动脉颅外段(internal cerebral artery terminal,ICAt)。检测部位[7]:颞中窗,即颧弓上方眼眶外缘与耳翼之间的颞骨鳞部;下颌下窗,即胸锁乳突肌的前缘中部附近下颌角后方约1~2 cm的区域。检测深度为40~65 mm[8]。所有患者在有创ICP探头置入术后常规进行TCD检查,获取监测动脉的血流参数,包括收缩期峰值速度(systolic peak velocity,Vs)、舒张末期速度(end of diastolic velocity,Vd)、平均血流速度(mean velocity,Vm)和搏动指数(pulsatility index,PI)等。

1.2.3 收集指标 一般资料:住院号、年龄、性别、创伤原因、创伤类型、既往病史(高血压、糖尿病、冠心病)、用药史(有无用抗凝药)、入院时GCS评分。护理及实验室检查:入院时体温、入院时收缩压、入院时舒张压、入院时血糖。CT影像学检查:中线偏移距离、血肿量、脑室积血与否、原发伤出血部位、出血类型。术中ICP均值、术后ICPm、CPPm、脑温均值。TCD监测数据:原伤侧MCA及ICAt的Vm、PI。

1.3 统计学分析

使用SPSS 26.0软件进行统计学处理。对于计量

资料,采用Shapiro-Wilk法评判资料正态性,符合正态分布的计量资料以$\bar{x}\pm s$表示,组间比较采用t检验;非正态分布的计量资料以$M(P_{25},P_{75})$表示,组间比较采用Mann Whitney U检验。计数资料采用n(%)表示,组间比较采用卡方检验。筛选单因素分析中与ICP和TCD相关的变量记为模型1,结合临床经验将对结局有显著影响的变量作为混杂因素纳入模型2,分别行多因素Logistic回归分析,采用受试者工作特征曲线(receiver operating characteristic curve,ROC)分析对保守治疗失败预测因子的预测效能进行评估,通过计算ROC曲线下面积(area under curve,AUC)、敏感性、特异性及约登指数(Youden index,YI)量化预测效能。P<0.05表示差异具有统计学意义。

2 结果

2.1 2组msTBI患者临床资料的单因素分析

单因素分析显示,保守治疗成功组和保守治疗失败组入院时GCS评分、术后ICPm、术后CPPm、原伤侧ICAt. PI、原伤侧MCA. PI、原伤侧MCA. Vm对比差异具有统计学意义(P<0.01,表1)。

表1 ICP探头植入术后保守治疗成功组和保守治疗失败组患者临床资料单因素分析[例(%),$M(P_{25},P_{75})$,$\bar{x}\pm s$]

Table 1 Univariate analysis of clinical data between the successful and failed conservative treatment groups after ICP probe insertion [n(%), $M(P_{25},P_{75})$, $\bar{x}\pm s$]

Variables	Successful conservative treatment (n=37)	Failed conservative treatment(n=28)	$t/\chi^2/Z$	P
Male	25(67.6)	22(78.6)	0.964	0.326
Age/years	60.00(48.50,65.50)	58.00(42.25,66.75)	−0.696	0.486
Blood glucose	9.40(7.73,10.66)	9.55(7.60,14.68)	1.332	0.183
Temperature/℃	36.50(36.50,36.70)	36.50(36.33,36.58)	−1.625	0.104
SBP/mmHg	145.84±31.99	145.96±32.12	0.016	0.987
DBP/mmHg	82.97±16.22	87.75±18.33	1.112	0.271
Underlying diseases				
Hypertension			1.473	0.225
Positive	16(43.2)	8(28.6)		
Negative	21(56.8)	20(71.4)		
Diabetes			0.000	1.000
Positive	6(16.2)	5(17.9)		
Negative	31(83.8)	23(82.1)		
Coronary heart disease			0.000	1.000
Positive	3(8.1)	3(10.7)		
Negative	34(91.9)	25(89.3)		
Anticoagulant drug			0.061	0.804
Positive	1(2.7)	2(7.1)		
Negative	36(97.3)	26(92.9)		
GCS score	9.00(7.00,12.00)	5.50(4.00,9.00)	−3.332	<0.001
Cause of injury			0.149	0.700
Car accidents	28(75.7)	20(71.4)		
Fall	9(24.3)	8(28.6)		
Type of injury			0.402	0.526
Open craniocerebral injury	13(35.1)	12(42.9)		
Closed craniocerebral injury	24(64.9)	16(57.1)		
Intraventricular bleeding			0.225	0.635
Positive	15(40.5)	13(46.4)		
Negative	22(59.5)	15(53.6)		

(表1续下页)

续表1 ICP探头植入术后保守治疗成功组和保守治疗失败组患者临床资料单因素分析[例(%), $M(P_{25},P_{75})$, $\bar{x}\pm s$]

Table 1(Continued) Univariate analysis of clinical data between the successful and failed conservative treatment groups after ICP probe insertion [n(%), $M(P_{25},P_{75})$, $\bar{x}\pm s$]

Variables	Successful conservative treatment (n=37)	Failed conservative treatment(n=28)	$t/\chi^2/Z$	P
Site			3.870	0.435
Frontal	14(37.8)	11(39.3)		
Brainstem	5(13.5)	2(7.1)		
Temporalis	12(32.4)	14(50.0)		
Cerebellum	2(5.4)	0		
Occipital lobe	4(10.8)	1(3.6)		
Type			5.382	0.104
CH	2(5.4)	0		
EDH	4(10.8)	0		
SDH	26(70.3)	26(92.9)		
PBSH	5(13.5)	2(7.1)		
CT hematoma volume/mL	17.03(9.19,19.37)	18.42(11.17,22.29)	0.715	0.474
CT MLS/mm	0.00(0.00,2.52)	0.00(0.00,2.73)	0.519	0.604
Intraoperative ICP/mmHg	10.00(7.50,13.00)	13.00(7.25,15.00)	1.429	0.153
Postoperative ICPm/mmHg	17.00(13.50,22.00)	23.50(22.00,26.00)	4.343	<0.001
Postoperative CPPm/mmHg	65.54±10.76	57.04±12.87	−2.899	0.005
POBTm/℃	37.44±0.95	37.11±0.80	−1.481	0.144
ICAt. Vm/(cm/s)	30.00(24.10,34.55)	27.20(24.15,31.43)	−1.683	0.092
ICAt. PI	1.04(0.93,1.19)	1.29(1.12,1.36)	4.254	<0.001
MCA. Vm/(cm/s)	78.10(57.50,97.50)	50.80(42.00,73.25)	−3.903	<0.001
MCA. PI	1.08±0.19	1.32±0.22	4.748	<0.001

SBP: Systolic blood pressure; DBP: Diastolic blood pressure; GCS: Glasgow coma scale; CH: Cerebellar hemorrhage; EDH: Epidural hematoma; SDH: Subdural hematoma; PBSH: Primary brainstem hemorrhage; MLS: Midline shift; POBT: Postoperative brain temperature; ICP: Intracranial pressure; CPP: Cerebral perfusion pressure; PI: Pulsatility index; Vm: Mean flow velocity; ICAt: Internal carotid artery extracranial segment; MCA: Middle cerebral artery

2.2 ICP探头植入术后msTBI患者保守治疗失败影响因素的多因素Logistic回归分析

为探究TCD联合ICP在msTBI患者保守治疗效果中的预测作用,从单因素分析得出的阳性指标中筛选与ICP和TCD相关的影响因素,将纳入符合标准的术后ICPm、原伤侧MCA. Vm及原伤侧MCA. PI记为模型1,分别对ICP单因素模型及ICP+TCD联合模型行多因素Logistic回归分析。由于CPP与ICP存在极强的内在相关性,作为混杂因素校正会破坏模型的独立性假设,导致分析结果偏倚。因此结合单因素分析结果及临床经验,将对结局有显著影响的入院时GCS评分、年龄、血肿量、术后脑温均值作为潜在混杂因素纳入模型2,分别对ICP单因素模型及ICP+TCD联合模型行多因素Logistic回归分析。其中模型1未调整混杂因素,模型2调整了入院时GCS评分、年龄、血肿量、术后脑温均值,以校正其对TCD和ICP联合模型预测效能的干扰。模型2中结果显示:术后ICPm、原伤侧MCA. Vm、原伤侧MCA. PI是影响msTBI患者治疗决策的独立显著因素(P<0.05)。其中原伤侧MCA. Vm值为保护因素,术后ICPm、原伤侧MCA. PI为危险因素(表2)。

2.3 ICP探头植入术后msTBI患者保守治疗失败影响因素的预测效能分析

对影响msTBI患者ICP探头植入术后保守治疗失败的独立显著因素进行ROC曲线分析,结果显示原伤侧MCA. PI对保守治疗失败的预测效能AUC为0.826(95% CI: 0.727~0.926),特异性为0.703,敏感度为0.821,YI为0.524,最佳截断值为1.165;对msTBI患者保守治疗失败的预测效能AUC优于术后ICPm(0.816)、原伤侧MCA. Vm(0.784),见表3。

表2 ICP探头植入术后患者保守治疗失败影响因素的多因素Logistic回归分析结果

Table 2 Multivariate logistic regression analysis on influencing factors for failure in conservative treatment in patients after ICP probe insertion

Variables			B	SE	Wald χ^2	*P*	*OR*	95%*CI*
Model 1	ICP	ICPm	0.262	0.072	13.089	<0.001	1.300	1.128~1.498
	TCD+ICP	ICPm	0.185	0.078	5.668	0.017	1.203	1.033~1.401
		MCA. Vm	−0.022	0.014	2.339	0.126	0.978	0.951~1.006
		MCA. PI×10	0.493	0.202	5.938	0.015	1.636	1.101~2.432
Model 2	ICP	ICPm	0.269	0.08	11.259	0.001	1.309	1.118~1.531
	TCD+ICP	ICPm	0.221	0.091	5.909	0.015	1.248	1.044~1.491
		MCA. Vm	−0.036	0.017	4.497	0.034	0.964	0.933~0.997
		MCA. PI×10	0.478	0.230	4.298	0.038	1.612	1.026~2.533

ICP: Intracranial pressure; TCD: Transcranial Doppler ultrasound; PI: Pulsatility index; Vm: Mean flow velocity; MCA: Middle cerebral artery

表3 ICP探头植入术后患者保守治疗失败影响因素的预测效能比较

Table 3 Comparison of predictive efficacy of factors affecting the failure of conservative treatment after ICP probe insertion

Variables	AUC	95%*CI*	SE	*P*	Sensitivity	Specificity	OCV	YI
ICPm	0.816	0.711~0.921	0.054	<0.001	0.714	0.784	22.5	0.498
MCA. Vm	0.784	0.671~0.897	0.058	<0.001	0.571	0.892	52.5	0.463
MCA. PI	0.826	0.727~0.926	0.051	<0.001	0.821	0.703	1.165	0.524

ICP: Intracranial pressure; PI: Pulsatility index; Vm: Mean flow velocity; MCA: Middle cerebral artery

分别对模型1和模型2中的ICP单因素模型及TCD+ICP联合模型进行ROC曲线分析,结果显示模型1中ICPm的预测效能为0.816(95%*CI*:0.711~0.921),明显低于原伤侧MCA. PI、原伤侧MCA. Vm与ICPm联合模型的预测效能。模型2中原伤侧MCA. PI、原伤侧MCA. Vm与ICPm联合模型的预测效能为0.931(95%*CI*:0.873~0.988),显著高于ICPm的预测效能,进一步证明了TCD+ICP联合监测在msTBI患者保守治疗失败中的预测作用,见表4和图1。

2.4 分层时msTBI患者TCD指标单因素Logistic回归分析

为展示不同水平ICP下TCD监测的效能,分别对ICPm<22 mmHg的颅内压正常组(32例)、ICPm≥22mmHg的颅内压增高组(33例)中的原伤侧MCA. PI及原伤侧MCA. Vm行单因素Logistic回归分析。结果显示不同ICPm情况下,原伤侧MCA. PI均可用于预测保守治疗失败与否(*P*<0.05,表5),更证明了TCD在msTBI患者早期保守治疗中预测价值的稳定性。

表4 ICP探头植入术后患者保守治疗失败预测模型的预测效能比较

Table 4 Comparison of predictive efficacy of the models for the failure in conservative treatment after ICP probe insertion

	Variables	AUC	95%*CI*	S. E.	*P*
Model 1	ICP	0.816	0.711~0.921	0.054	<0.001
	TCD+ICP	0.892	0.816~0.968	0.039	<0.001
Model 2	ICP	0.875	0.791~0.959	0.043	<0.001
	TCD+ICP	0.931	0.873~0.988	0.029	<0.001

ICP: Intracranial pressure; TCD: Transcranial Doppler ultrasound

表5 分层时TCD指标单因素Logistic回归分析

Table 5 Univariate logistic regression analysis of TCD indicators at different stratifications

Variables	ICP	B	S. E.	Wald x^2	*P*	*OR*	95%*CI*
MCA. Vm	ICPm<22	−0.083	0.036	5.268	0.022	0.921	0.858~0.988
	ICPm≥22	−0.017	0.014	1.591	0.207	0.983	0.957~1.010
MCA. PI×10	ICPm<22	1.227	0.531	5.349	0.021	3.411	1.206~9.651
	ICPm≥22	0.405	0.188	4.651	0.031	1.499	1.038~2.164

TCD: Transcranial Doppler ultrasound; ICP: Intracranial pressure; MCA: Middle cerebral artery; PI: Pulsatility index; Vm: Mean flow velocity

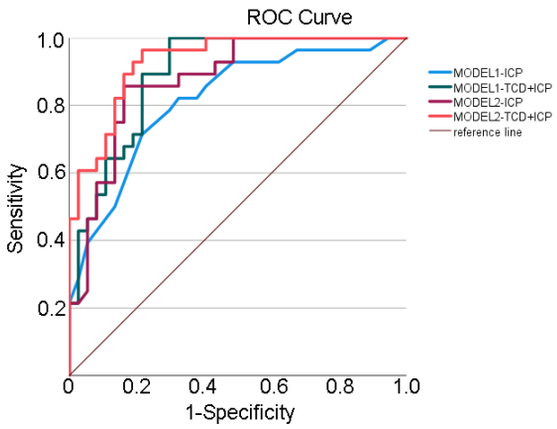


图1 ICP探头植入术后患者保守治疗失败影响因素ROC曲线

Figure 1 ROC curve of factors affecting the failure of conservative treatment in patients after ICP probe insertion

3 讨论

3.1 msTBI患者手术时机选择的重要性

TBI后的继发性损伤机制包括兴奋性谷氨酸毒性反应、线粒体功能障碍、自由基释放和血脑屏障破坏等[9],引起脑组织缺血缺氧、肿胀,最终导致患者ICP增高、CPP降低,甚至脑疝形成。因此,早期降低TBI患者颅内高压是TBI病人管理的核心。开颅手术作为减轻颅内高压的重要手段,在治疗作用中具有不可替代的作用,但手术时机选择仍存在争议。STITCH(Trauma)试验[10]表明:早期开颅行血肿清除手术的患者伤后6个月病死率低于初始保守治疗组,但二者的预后差异无统计学意义。RESCUE ICP试验[11-12]:去骨瓣减压手术(decompressive craniectomy, DC)可以降低伤后6个月和12个月的病死率,但植物生存和重残所占比例增加。以本研究对象为例,msTBI患者在伤后早期并未达到传统开颅手术指征,即使早期进行了有创ICP探头置入术,仍可以继续根据病情变化选择开颅手术或者保守治疗。因此,探索科学可靠的早期识别方法以确定最佳手术时机是提升临床治疗效果的重要环节。

3.2 TCD和ICP监测对msTBI患者的临床意义

GCS评分、血肿体积、中线偏移距离、ICP数值等均为开颅手术治疗的独立标准,是国内外制定TBI治疗指南的重要依据[3,6]。ICP探头植入术可实时监测ICP数值变化,已经被广泛应用于临床。BADRI等[13]对365例msTBI患者的研究发现,ICP是msTBI患者6个月随访时病死率及神经功能结果的独立预测指标,有效监控重症TBI患者的ICP对于降低其病死率具有重要意义[14]。然而,目前ICP的手术阈值尚未统一。2015年《中国颅脑创伤外科手术指南》建议对ICP>25 mmHg的患者予以手术治疗[6];2016年美国《重型颅脑创伤治疗指南(第四版)》[3],将ICP的阈值定为22 mmHg;2024年《急性颅脑创伤颅内高压处理流程》建议对ICP≥30 mmHg的患者行手术治疗[15]。此外,单一ICP指标评估存在局限性,比如ICP监测难以评估血流动力学层面的变化。TCD技术在TBI患者脑血流监测领域最具有代表性,且具有无创、实时、床旁监测便捷等优势。Vm和PI是评估脑血管血流动力学的重要指标,能够通过监测大脑远端小动脉血流速度、阻力顺应性和弹性,进一步评估ICP、CPP、大脑自动调节等,判定脑血流动力学状态,为TBI患者管理提供重要的数据支持[16]。目前已有大量研究证明PI与ICP呈显著正相关,而Vm与ICP呈显著负相关[17-19]。因此,应用TCD监测可以为住院患者制定更为精准且规范的治疗管理方案,从而更有效地改善TBI患者的远期预后、缩短住院时间、降低硬膜下积液发生的概率[20-21]。FATIMA等[22]表明:与TCD监测正常的TBI患者相比,TCD异常(Vm<35 cm/s或Vm>120 cm/s、PI>1.2)的TBI患者临床结局不佳的风险高出3倍以上,病死率高于9倍。ZIEGLER[23]分析了255名严重TBI患者的临床数据,结果表明TCD有助于确定早期预后。

3.3 TCD和ICP单一监测技术对msTBI患者早期治疗转归的指导意义

本研究通过多因素Logistic回归分析筛选出了ICP探头植入术后ICPm、原伤侧MCA. Vm、原伤侧MCA. PI是影响颅脑创伤患者治疗决策的独立显著因素。本研究结果显示:保守治疗失败组患者术后ICP较高,高的ICP表明脑组织可能处于较低的灌注,术后ICPm对保守治疗失败的预测效能特异性为0.784,敏感度为0.714,约登指数为0.498,最佳截断值为22.5,提示应重点关注术后ICPm高于22.5 mmHg的患者。本研究结果发现保守治疗失败组患者入院后原伤侧MCA. Vm较低、原伤侧MCA. PI较高,降低的Vm和升高的PI表明患者大概率出现ICP升高、CPP降低,原伤侧MCA. Vm对保守治疗失败的预测效能特异性为0.892,敏感度为0.571,约登指数为0.463,最佳截断值为52.5;原伤侧MCA. PI对保守治疗失败的预测效能特异性为0.703,敏感度为0.821,约登指数为0.524,最佳截断值为1.165。提示对于原伤侧MCA. Vm>52.5 cm/s、原伤侧MCA. PI<1.165的患者可优先

选择保守治疗的方式。由于ICP是决定手术与否的重要标准,为消除该因素对分析结果的影响[24],对ICPm进行分层分析,结果显示ICPm处于不同水平下,原伤侧MCA. PI均可用于指导手术治疗与否,进一步证明了TCD在sTBI患者早期治疗转归中的预测价值。

3.4 TCD联合ICP监测更精准地预测了msTBI患者的早期治疗转归

本研究发现,对处于手术与非手术"临界状态"的msTBI患者来说,术后ICPm<22.5 mmHg、原伤侧MCA. Vm >52.5 cm/s、原伤侧MCA. PI<1.165的患者脑血管自动调节能力较强,选择保守治疗成功的概率更高。为进一步提升对msTBI患者保守治疗成功与否的预判精准度,本研究分析了ICP联合TCD模型的预测效能,模型1的ROC结果显示ICP单一指标对判断患者保守治疗失败的AUC为0.816,校正前原伤侧MCA. Vm、原伤侧MCA. PI与术后ICPm的联合模型的AUC为0.892;模型2的ROC结果显示ICP单一指标对判断患者保守治疗失败的AUC为0.875,具有一定的判断价值,校正后的原伤侧MCA. Vm、原伤侧MCA. PI与术后ICPm的联合模型预测效能达到了0.931,具有较高的判断价值。校正后TCD与ICP联合模型的预测效能均明显优于ICP的单参数模型。由此可见,采用多模态联合监测,有助于为msTBI患者制定个体化、精准化的诊疗策略提供依据,以期提高患者的治疗效果和预后。

本研究存在一定的局限性,由于本研究是一项单中心回顾性病例对照研究,样本量固定,通过事后把握度分析[25]得出统计把握度为85.71%。因此未来还需要多中心、大量本的前瞻性研究来进一步验证结论。综上所述,TCD和ICP联合监测能更准确预测ICP探头置入术后msTBI患者早期治疗转归情况,为msTBI患者的早期临床诊疗提供更有效的评估方法。

利益冲突 本文所有作者声明不存在利益冲突

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