·泛血管医学时代“脑心同治”手术·

心血管外科围手术期的神经监测

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【摘要】 心血管外科手术神经系统并发症风险较高,可加重疾病负担,围手术期实时监测神经功能可辅助临床医师尽早发现神经系统异常,及时干预并降低神经系统并发症风险,其主要监测指标包括脑氧饱和度、脑电信号、脑血流量等。本文综述心血管外科围手术期常用的神经监测技术及其研究进展,以为减少神经系统并发症、提高患者预后提供理论依据。

【关键词】 心血管外科手术； 围手术期； 谱学,傅里叶变换红外； 脑电描记术； 诱发电位； 超声检查,多普勒,经颅； 综述

Perioperative neuromonitoring in cardiovascular surgery

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【Abstract】 Cardiovascular surgery has a high risk of neurological complications, which can increase the burden of disease. Perioperative real-time monitoring of neurological function in cardiovascular surgery can assist clinicians to detect neurological abnormalities as early as possible, intervene and reduce the risk of neurological complications in time. The main monitoring indicators include cerebral oxygen saturation (ScO_2), EEG, cerebral blood flow (CBF), etc. In this paper, the common perioperative neuromonitoring techniques and their research advances in cardiovascular surgery are reviewed to provide theoretical basis for reducing neurological complications and improve the prognosis of patients.

【Key words】 Cardiovascular surgical procedures; Perioperative period; Spectroscopy, Fourier transform infrared; Electroencephalography; Evoked potentials; Ultrasonography, Doppler, transcranial; Review

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心血管外科手术神经系统并发症风险较高,尤其是涉及心脏以及升主动脉、主动脉弓、颈总动脉、头臂动脉等重要血管的复杂手术,导致住院时间延长、生活质量降低,严重者可危及生命。成人心血管外科手术后脑卒中发生率为2%～3%[1],认知功能障碍为14%～48%[2-4],谵妄约为43.43%[5];主动脉弓部手术后缺血性卒中发生率为5%～11.5%,脊髓损伤为3.5%～6.2%[6]。围手术期实时监测神经功能可辅助临床医师尽早发现神经系统异常,及时干预并减少神经系统并发症风险。心血管外科围手术期神经监测指标主要包括脑氧饱和度(ScO_2)、脑电信号、脑血流量(CBF)等。本文拟综述心血管外科围手术期常用神经监测技术及其研究进展,以为临床减少神经系统并发症、提高患者预后提供理论依据。

一、近红外光谱

近红外光谱(NIRS)是监测脑氧饱和度的常用设备,操作简便,通过前额处放置的电极片无创性监测脑组织氧饱和度。该项技术通过分析光穿透组织时反射光的光谱特征计算组织中氧合血红蛋白与脱氧血红蛋白比值以获得氧饱和度,临床应用广泛。但该项技术仅可检测局部脑氧饱和度

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($rScO_2$),无法反映全脑状态。一项关于心血管外科手术前脑氧饱和度的Meta分析发现,约95%患者术前脑氧饱和度为51%~82%,平均66%[7]。心血管外科手术前脑氧饱和度可以反映心肺功能障碍严重程度,与病死率和并发症发生率密切相关[8]。研究显示,冠状动脉旁路移植术(CABG)体外循环阶段脑氧饱和度较麻醉诱导阶段降低>20%,且其与住院期间神经系统并发症风险呈负相关关系[9],基线高脑氧饱和度可以降低术后谵妄发生率,即使术后脑氧饱和度恢复也无法降低术后谵妄发生率[10];全主动脉弓置换术后脑氧饱和度低于基线值80%与术后永久性神经系统并发症相关[11];术后并发脑卒中的A型主动脉夹层患者术中脑氧饱和度变化率明显高于未并发脑卒中的患者,表明术中脑氧饱和度变化与术后脑卒中发生率密切相关[12];心肺复苏前脑氧饱和度与病死率和神经功能预后亦呈负相关关系[13]。目前关于脑氧饱和度与术后认知功能障碍之间的相关性尚存争议,de Tournay-Jetté等[14]发现,冠状动脉旁路移植术中脑氧饱和度降低与术后认知功能障碍发病时间相关;Holmgaard等[15]则认为,心血管外科手术中脑氧饱和度降低与术后认知功能障碍并无关联性;Zhu等[16]亦认为,提高二氧化碳分压($PaCO_2$)和脑氧饱和度对心脏瓣膜置换术后认知功能障碍无明显改善作用。一项基于心脏麻醉医师的调查显示,仅27%的医师定期应用近红外光谱监测脑氧饱和度[17],脑氧饱和度降低程度与临床干预必要性和有效性之间的关系尚无明确结论,待进一步研究证实。

二、脑电图

脑电图是临床常用的神经电生理检测技术,既可分析原始脑电图波形,又可使用处理后的数据即经过处理的脑电图(pEEG)。原始脑电图是头皮表面记录到的大脑皮质电活动,其波形受脑组织含氧量影响,脑组织含氧量减少时脑电图波形减慢,α波和β波波幅降低、θ波和δ波波幅增加[18]。主动脉夹层患者行体外循环手术时可通过脑电监测观察是否存在神经功能异常,如癫痫发作、脑缺血等[19-22]。约33%术中切开心室患者术后监测到异常脑电信号,约9%可见痫样放电,且痫样放电与术后谵妄密切相关[19-20];进一步从脑电频谱中提取α频段功率和峰值频率,发现心血管外科手术中α频段功率越低、术后谵妄风险越高[21]。永久性脑电图改变是心血管外科手术后发生脑卒中的重要预测因素,术中脑电监测异常患者术后10年总生存率显著低于无变化患者[22]。主动脉弓置换术需单独实施脑灌注,脑缺血及脑过度灌注风险较高,脑电监测对体温控制和脑保护具有重要作用。深低温停循环(DHCA)下主动脉弓置换术中,不同患者达到脑电静默所需的降温程度和持续时间不同,仅60%患者于18 ℃出现脑电静默[23];低温停循环下主动脉弓置换术中脑电监测异常与病死率密切相关,但与早期发生脑卒中或短暂性脑缺血发作并无相关性[24]。pEEG在心血管外科手术中应用较广泛,尤其是脑电双频指数(BIS)不仅可以评估麻醉程度和意识状态,还可以反映脑灌注状况,进而预测神经系统并发症风险。平均动脉压(MAP)低于自动调节下限(LLA)时,脑电双频指数降低;平均动脉压高于自动调节下限时,脑电双频指数相对不变,且脑血流速度和局部脑氧饱和度与脑电双频指数呈正相关关系,体外循环手术后谵妄患者平均脑电双频指数较低,且脑电双频指数<45的持续时间长于无谵妄患者[25]。心脏骤停后昏迷患者实施目标温度管理(TTM)前12小时内,平均脑电双频指数>26是预后良好的重要预测因素,灵敏度为89.5%、特异度75.8%;平均抑制比(SR)>24则是预后不良的重要预测因素,灵敏度为91.5%、特异度81.8%[26]。心血管外科手术中累积脑电双频指数<25和平均动脉压<60 mm Hg持续时间与术后3天内脑卒中发生率呈正相关关系[27]。pEEG还可用于指导术中和术后用药,与术中未应用pEEG监测的患者相比,应用pEEG监测的患者对血管活性药物的需求降低,且机械通气时间缩短、术中失血量减少,但二者器官功能障碍持续时间和病死率无明显差异[28]。脑电图虽可用于神经系统并发症的监测,但对临床医师脑电知识储备的要求较高,且术中和术后仍受既往神经功能障碍、药物应用史、生理因素和手术刺激的影响,加之脑电监测设备提供的数据代表复杂的神经生物学过程,未来尚待进一步研究。

三、诱发电位

诱发电位通过记录脑、脊髓或周围神经对特定刺激的反应以评估神经功能,业已成为心血管外科评估和保护神经功能的重要手段。开放式胸腹主动脉瘤(TAAA)手术中避免脊髓损伤的重要性已达成共识,术中需至少采取一种神经监测或保护方法,其中脑脊液引流占97.9%、近红外光谱占70.8%、运动诱发电位(MEP)或体感诱发电位(SEP)占

60.4%[29]。研究显示，开放式远端主动脉手术中和手术后，运动诱发电位和体感诱发电位缺失均与脊髓缺血有关，术中运动诱发电位缺失是术后脊髓缺血的重要危险因素，而体感诱发电位缺失进一步提高运动诱发电位的预测价值[30]。胸腹主动脉瘤腔内修复术中，切除股动脉鞘后导致的外周性缺血也可使运动诱发电位降低，需与脊髓缺血相区分。外周性缺血引起的运动诱发电位降低在胸腹主动脉瘤腔内修复术中较常见，运动诱发电位降低而复合肌肉动作电位（CMAP）无变化则提示中枢性缺血，故复合肌肉动作电位测定有助于区分中枢性缺血与外周性缺血[31]。诱发电位虽可预测脊髓缺血，但因其并非持续监测，部分短暂性脊髓缺血有可能无法监测到，且其易受体温、镇静药、肌肉松弛药等的影响，特别是低温手术中更为明显。由于术后栓塞事件或低血压也可导致脊髓缺血，目前研究主要集中于心血管外科手术中诱发电位，术后诱发电位相关研究鲜见，未来尚待进一步探究。

四、经颅多普勒超声

经颅多普勒超声（TCD）是一种非侵入性神经监测技术，通过测量高频（2、4和8 MHz）声波经颅脑后的回波反映脑血流动力学改变。由于声波经颅骨、脑组织和脑血管时可发生反射和多次散射，这些反射和散射的声波再返回监测探头，通过发射频率与接收频率差值计算脑血流速度可监测脑血管内栓子。研究表明，心血管外科手术前脑血管储备能力是术后神经功能预后的重要预测因素，Bydén等[32]采用TCD计算体外循环下心血管外科手术前屏气指数（BHI），发现屏气指数 < 0.69提示脑血管储备能力下降，且术后谵妄患者屏气指数显著低于无谵妄患者。脑低灌注可显著影响主动脉弓部手术患者的神经功能预后，脑血流量减少是采取选择性顺行脑灌注的主动脉弓部手术后神经功能缺损的独立危险因素[33]；脑过度灌注则导致体外循环下冠状动脉旁路移植术后认知功能恢复延迟[34]。左心室辅助装置（LVAD）是将左心房或左心室血流引入辅助泵体，再经泵体驱动血流进入主动脉，可完全替代左心泵血功能，应用左心室辅助装置的心力衰竭患者脑血管反应性明显改善，但仍低于健康人群，表明连续血流的左心室辅助装置并不能逆转脑血流动力学改变[35]。TCD还可以用于监测术中和术后目标脑血管内栓子和血栓形成，心室切开患者去除主动脉阻断钳后，其脑血管内栓子数量显著多于非心室切开患者，且这些栓子更多地进入右大脑中动脉[36]。主动脉瓣置换术中总微栓子信号（MES）数量与体外循环时间相关[37]。房颤射频消融术中，TCD可检测到大量微栓子信号，尤其是应用射频电流期间，且微栓子信号数量取决于手术时间和射频消融过程中活化凝血时间[38]。此外，TCD发泡试验还可用于评估卵圆孔未闭的右向左分流，卵圆孔未闭患者术前解剖结构可影响残留右向左分流程度，长期抗血小板治疗可能对具有高危解剖结构如房间隔膨出瘤、希阿里网（CN）、卵圆孔未闭 > 4 mm的患者有益[39]。由于脑血流量与神经系统并发症之间关系复杂，患者个体差异较大，持续TCD监测对操作者的技术要求较高，目前关于心血管外科围手术期TCD监测脑血流量的研究较少，相关研究主要集中于脑血流量变化与体循环、栓子与神经系统并发症的关系，脑血流量与神经系统并发症之间的相关性尚待进一步探究。

五、多模态监测

多模态监测是一种综合应用多种神经电生理检测和血流动力学监测技术实时评估生理和神经功能的方法。由于近红外光谱监测范围较局限，TCD监测存在广泛个体差异，脑电双频指数受镇静药的影响较大，因此目前多联合应用多种神经监测技术以提高神经监测的准确性[24,27,40-42]。一项大规模回顾性研究显示，与未行神经监测的体外循环下心血管外科手术患者相比，多模态监测（包括脑电图、双侧体感诱发电位、TCD和近红外光谱）患者围手术期严重神经系统并发症发生率显著降低[43]。

综上所述，神经监测技术已广泛应用于心血管外科围手术期，近红外光谱在神经系统并发症监测中的应用价值尚未获得广泛共识；TCD对脑血管内栓子的监测能力较强，但个体差异较大，其相关监测指标与神经系统并发症之间的关系尚待进一步探究；脑电图和诱发电位作为常见的非侵入性神经监测技术，临床应用广泛，但易受多种因素的干扰，未来应开展多中心大样本随机对照试验以进一步明确各种神经监测技术和多模态监测的应用价值。

利益冲突 无

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·小词典·

中英文对照名词词汇（一）

屏气指数 breath-holding index（BHI）

短暂性脑缺血发作 transient ischemic attack（TIA）

对比增强经颅多普勒超声
contrast-enhanced transcranial Doppler ultrasound（cTCD）

非体外循环下冠状动脉旁路移植术
off-pump coronary artery bypass grafting（OPCABG）

冠状动脉旁路移植术
coronary artery bypass grafting（CABG）

国际标准化比值 international normalized ratio（INR）

恒定自然杀伤T细胞 invariant natural killer T cells（iNKT）

活化凝血时间 activated clotting time（ACT）

减压病 decompression sickness（DCS）

近红外光谱 near infrared spectroscopy（NIRS）

经导管主动脉瓣置换术
transcatheter aortic valve replacement（TAVR）

经颅多普勒超声 transcranial Doppler ultrasonography（TCD）

经皮冠状动脉介入术
percutaneous coronary intervention（PCI）

经食管超声心动图 transesophageal echocardiography（TEE）

经食管超声心动图声学造影
transesophageal echocardiography contrast-enhanced acoustics（cTEE）

经胸超声心动图声学造影
transthoracic echocardiography contrast-enhanced acoustics（cTTE）

颈动脉夹层 carotid artery dissection（CAD）

颈动脉内膜切除术 carotid endarterectomy（CEA）

颈动脉支架成形术 carotid artery stenting（CAS）

颈内动脉 internal carotid artery（ICA）

抗原呈递细胞 antigen-presenting cell（APC）

卵圆孔未闭 patent foramen ovale（PFO）