·综述·

术中监测颈静脉球血氧饱和度临床意义及影响因素

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【摘要】 术中监测颈静脉球血氧饱和度($SjvO_2$)已广泛应用于临床，可全面监测脑血流和脑代谢情况。经颈内静脉逆向穿刺置管监测$SjvO_2$操作简便，可反复采集血液标本，实时动态评价脑氧供需情况和神经功能。本文简要综述术中监测$SjvO_2$的临床意义及影响因素，特别指出不能仅凭$SjvO_2$评价脑血流和脑代谢改变，应结合多项指标的变化趋势综合评价。

【关键词】 血氧测定法； 颈静脉球； 综述

Clinical value and influencing factors of intraoperative monitoring of jugular venous oxygen saturation

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【Abstract】 Intraoperative jugular venous oxygen saturation ($SjvO_2$) monitoring has been widely used in clinic, which can monitor cerebral blood flow (CBF) and oxygen metabolism. Reverse puncture and catheterization through jugular vein for monitoring $SjvO_2$ is easy to operate and can collect blood samples repeatedly. It is an effective method for real-time dynamic evaluation of cerebral oxygen supply-demand and neurological function. This article reviews the clinical significance and influencing factors of $SjvO_2$ monitoring during operation. It notes in particular that $SjvO_2$ can not be used as the only way to monitor CBF and oxygen metabolism, and a comprehensive evaluation should be done combining with the change of other parameters.

【Key words】 Oximetry; Glomus jugulare; Review

随着社会人口老龄化进程的加快和心脑血管病的增加，围手术期缺氧缺血性脑损伤的风险也与日剧增[1]。术中监测、早期诊断和及时治疗缺氧缺血性脑病(HIE)至关重要。术中监测颈静脉球血氧饱和度($SjvO_2$)可以早期诊断脑缺血、间接评价脑耗氧量和脑血流量(CBF)与脑代谢之间的关系，指导临床进行合理的通气治疗、液体输注、维持合理的脑氧供需平衡和脑灌注压(CPP)[2-3]，尤其是合并高血压、脑卒中等心脑血管病的患者术中需采用控制性降压技术，监测$SjvO_2$可以及时发现术中脑去氧饱和(desaturation)状态，避免脑组织低灌注，提高围手术期安全性[4]。

一、术中监测颈静脉球血氧饱和度的意义

颈静脉球为颈内静脉起始处膨大成球的部位，80%～90%的颅内静脉血仅需4～8秒即可经颈静脉窦回流至颈静脉球。颈静脉窦是乙状窦的延续，颈静脉球的血液绝大部分来源于颅内静脉血，颅外静脉血含量较少，因此，采用含光导纤维的监测导管经颈内静脉逆行置入颈静脉球，术中实时监测$SjvO_2$即可代表脑静脉血氧饱和度，间接反映全脑氧供需平衡和氧代谢情况[5]。

脑氧供率($CDRO_2$)和脑氧代谢率($CMRO_2$)的计算公式分别为：$CDRO_2$[ml/(100 g·min)] = CBF × 脑动脉血氧含量(CaO_2)；$CMRO_2$[ml/(100 g·min)] = CBF × [CaO_2 − 颈静脉血氧含量($CjvO_2$)]，其中，$CaO_2 - CjvO_2$ = 血红蛋白(Hb) × 1.39[即桡动脉血氧饱和度(SaO_2) − $SjvO_2$] + 0.0031[即脑动脉血氧分压(PaO_2) − 颈静脉球血氧分压($PjvO_2$)]。在桡动脉血氧饱和度和血红蛋白稳定的情况下，$SjvO_2$变化可以反映CBF/$CMRO_2$比值变化，进而反映全脑氧供需平衡情况。$SjvO_2$正常值范围为0.64～0.88，$SjvO_2$ > 0.75提示脑代谢率降低或脑组织过度灌注，常见于

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吸入纯氧、低温、镇静、脑血流量增加如脑过度灌注综合征(CHS)、病理性动-静脉交通支和脑死亡[6-7]；$SjvO_2$ < 0.50为脑去氧饱和状态，可能存在脑血流量和脑氧供率下降和(或)脑代谢率增加即脑缺氧，常见于重型颅脑创伤(TBI)、颅内高压和系统性原因，如大量失血Hb < 90 g/L(成年男性120 ~ 160 g/L，成年女性 110 ~ 150 g/L)、低氧、严重低血压、过度通气、脑血管痉挛、发热、抽搐等；$SjvO_2$ < 0.40则提示可能存在全脑缺氧、缺血。如果$SjvO_2$绝对值降低 > 0.25，尽管其仍处于正常值范围，但在颈动脉内膜切除术(CEA)中意义重大。Crossman等[8]对34例在局部麻醉下行颈动脉内膜切除术的患者实施术中$SjvO_2$监测和神经功能评价，发现$SjvO_2$下降0.25可以作为脑缺血的阈值，其灵敏度高达100%，特异度为80%。

二、术中监测颈静脉球血氧饱和度的方法

目前，临床最常用的方法是Seldinger法，即于手术侧胸锁乳突肌胸骨头端与锁骨相交顶点插入深静脉导管，于颈动脉搏动点外侧以15° ~ 20°角进针，经皮逆心脏方向穿刺，回吸静脉血通畅后，置入"J"形导丝，导管前端遇轻微阻力或估计导管尖端至乳突水平时移出导丝，固定导管。也可于甲状软骨下缘颈动脉搏动点略外侧向颅底方向进针，穿刺成功后置入导管，置管深度为穿刺点至乳突后缘直线距离或遇阻力后稍微回撤导管(撤管距离 < 1 cm)，使导管顶端位于枢椎(C_2)水平，术中X线显示导管尖端位于乳突中点附近。如果撤管距离 > 2 cm，血液标本可能混杂颅外静脉血(主要来自面静脉)。导管末端光导纤维探头与肺动脉导管监测混合静脉血的血氧饱和度相同，可连续监测$SjvO_2$，亦可自导管内中空管腔抽取血液标本进行血气分析。无论采用何种穿刺置管方式，其禁忌证均为颈椎损伤、局部感染或损伤、出血性疾病、凝血功能障碍、气管切开、颈静脉回流受阻等。穿刺置管术的并发症有颈动脉损伤、颅内高压、气胸、颈部神经损伤、感染和脑静脉系统血栓形成(CVT)等。

三、颈静脉球血氧饱和度的影响因素

临床有许多因素可以影响脑血流量和(或)脑氧代谢率，如温度、呼气末二氧化碳分压($PetCO_2$)、动脉血氧分压、血液黏滞度(blood viscosity)、超出调节范围的平均动脉压(MAP)、颅内压(ICP)和中心静脉压(CVP)等。

1. 操作技术因素 (1)导管与颈静脉球的位置关系：无论是左侧还是右侧颈内静脉，均混杂3% ~ 7%的颅外静脉血，故将导管尖端位于颈静脉球2 cm范围内。(2)血液回抽速度：血液回抽速度 < 2 ml/min时，约混合3%的颅外静脉血；血液回抽速度过快可增加颅外静脉血比例[9-10]。(3)脑静脉系统血栓形成和导管打折均影响数值读取的准确性。

2. 平均动脉压 若MAP维持于50 ~ 150 mm Hg (1 mm Hg = 0.133 kPa)时，脑组织血液循环可以调节其自身血管阻力而维持脑血流量恒定[11]。如果MAP < 50 mm Hg或 > 150 mm Hg，脑血流量随脑灌注压的变化而变化且二者呈正相关。颅内肿瘤患者因脑容积代偿能力受到限制，脑血流自动调节(CA)能力降低。崔燕红等[12]维持患者MAP于45 ~ 50 mm Hg，脑氧代谢率正常，脑组织无明显缺氧、缺血，脑氧供需平衡稳定，未出现神经功能缺损症状。

3. 麻醉药物 大多数吸入性麻醉药可以增加脑血流量、降低脑氧代谢率，也可以剂量依赖性增加脑血流量而继发颅内高压。七氟烷对脑血流量的影响相对较小，增加脑血流量、降低脑氧代谢率的综合作用结果是$CBF/CMRO_2$比值增加。有文献报道，七氟烷可以使$SjvO_2$增加(31.88 ± 3.15)%[13-14]。大多数静脉麻醉药可以减少脑血流量、降低脑氧代谢率和颅内压，但是由于脑氧代谢率下降程度往往超过脑血流量，故难以维持脑氧供需平衡。丙泊酚对脑氧代谢率的抑制作用较为明显，通过降低脑氧代谢率、减少脑血流量而维持$CBF/CMRO_2$比值恒定，具有脑保护作用[15]。由于丙泊酚对体循环影响较大，可以使颅内高压患者脑灌注压显著下降(< 50 mm Hg)。依托咪酯可以明显降低脑血流量、脑氧代谢率和颅内压，但对体循环影响较小，故对脑灌注压影响较小。氯胺酮具有扩张脑血管，增加海马、皮质、嗅区脑血流量，升高颅内压的作用，其增加脑氧代谢率的作用主要与增强边缘系统、锥体外系、听觉和感觉中枢兴奋性有关。

4. 颅内压 颅内压升高、脑灌注压降低和低氧血症引起脑血流量下降的同时，$SjvO_2$下降，甚至出现脑去氧饱和状态，从而发生脑组织缺氧、缺血。临床研究显示，硬膜外血肿患者去除骨瓣后脑血流量和$SjvO_2$均增加[16]。通过补充脑血容量(CBV)和应用升压药可以使脑灌注压升高，进而增加$SjvO_2$，且二者呈正相关。应用甘露醇等脱水药和过度通气可以降低颅内压，但并不增加脑供氧量，反而导致脑缺氧、缺血[14]。

5.体温 在体外循环(CPB)中，$SjvO_2$与体温呈直线负相关[17]。体外循环初始，MAP显著下降，只要MAP ≥ 45 mm Hg且不影响$SjvO_2$，仍可维持脑氧供需平衡，可能是由于血液稀释和降低脑温从而降低脑氧代谢率、减少CBF/$CMRO_2$比值；此外，也不排除脑组织过度灌注的可能[18]。复温期间，当MAP < 60 mm Hg时，部分心瓣膜置换术患者$SjvO_2 < 0.50$；当MAP > 60 mm Hg时，则较少出现$SjvO_2 < 0.50$[19]。复温过程中脑氧代谢率增加速度超过脑血流量，易发生脑血流灌注相对不足，故主张复温速度不宜过快，脑血流量增加速度不宜过快。其可能机制是，其一复温使脑氧代谢率和脑耗氧量增加，复温过快易加重脑血流-脑代谢耦联失调；其二非搏动性体外循环造成的反应性脑血管收缩和脑血管微栓塞，使脑血流自动调节能力受限，对脑耗氧量增加缺乏相应的补偿性反应。采用搏动泵能够较好地维持脑微循环，产生较低的脑血管阻力，增加脑动脉血血氧分压与脑静脉血氧分压的差值，提示搏动血流可以减少体外循环过程中的动-静脉分流，对于维持脑氧供需平衡具有重要意义[20-22]；其三血液高度稀释也可以使脑动脉血氧含量下降。在常温(鼻咽温度34 ~ 36 ℃)条件下实施体外循环较低温条件(鼻咽温度27 ~ 30 ℃)更易出现颈静脉球去氧饱和状态，研究显示，约54%和12%的心脏病患者在常温或低温条件下实施体外循环时出现颈静脉球去氧饱和状态[23]。常温条件下行体外循环可以较好地维持脑供氧量与脑耗氧量的平衡，而低温条件下行体外循环，脑供氧量过剩，脑氧供需失衡。研究显示，搏动性体外循环颈静脉球去氧饱和状态发生率较低，优于非搏动性体外循环[24]。

6.过度通气 术中持续监测$SjvO_2$可以减少过度通气引起的继发性损伤，通过收缩脑血管、减少脑血流量，从而降低颅内压，但不恰当的过度通气可以导致脑血管严重收缩、脑血流量明显减少，从而降低全脑供氧量。轻度过度通气($PetCO_2$为30 ~ 34 mm Hg)，动静脉血气分析、循环血流参数和脑氧供需指标虽变化，但多于正常水平，表明无脑氧供需失衡；中度过度通气($PetCO_2$为25 ~ 29 mm Hg)，$SjvO_2$明显降低，表明中度过度通气可能引起脑灌注不足、脑氧供需失衡，究其原因，可能是由于随着过度通气的加重，$PetCO_2$逐渐下降，从而引起脑血管收缩、脑血管阻力增加、脑血流量减少，但一定范围内脑血供代偿机制尚可满足脑代谢的需求；严重过度通气($PetCO_2$ < 25 mm Hg)，可以减少脑血流量，造成脑灌注不足，同时呼吸性碱中毒使氧解离曲线左移，使脑供氧受限，影响脑组织内环境稳定，使$SjvO_2$显著下降，脑动脉-静脉血氧含量差(Da-jvO_2)增加，导致脑缺氧、缺血和继发性脑损伤。研究显示，适度通气($PetCO_2$为30 ~ 35 mm Hg)较为安全[25]。神经外科手术中过度通气引起的$SjvO_2$降低，可以通过增加吸入氧浓度而增加脑动脉血氧分压以补偿或改善[26]。术中持续监测$SjvO_2$可以减少过度通气引起的继发性损伤。

7.二氧化碳气腹 二氧化碳(CO_2)是强效血管扩张剂。二氧化碳分压($PaCO_2$)于20 ~ 80 mm Hg时，与脑血流量呈线性正相关，二氧化碳分压每增加1 mm Hg，脑血流量增加1 ml/(100 g·min)。发生CO_2气腹时，由于腹膜吸收CO_2，引起二氧化碳分压或$PetCO_2$升高。经颅多普勒超声(TCD)显示，二氧化碳分压升高是导致人和兔在气腹状态下大脑中动脉(MCA)或基底动脉脑血流速度增快的原因，因此，二氧化碳分压升高可以引起$SjvO_2$升高[27]。此外，发生CO_2气腹时，膈肌抬高、胸腔内压力增加，使中心静脉压和呼吸道压力升高。中心静脉压升高时颈内静脉回流受阻，脑静脉系统淤血，引起颅内压和脑脊液压力升高。单闯等[28]观察到30例行腹腔镜胆囊切除术患者术中二氧化碳分压和$SjvO_2$均显著增加，脑动脉-静脉血氧含量差减小，认为存在脑组织过度灌注和细胞水平的脑缺氧、缺血。

四、术中监测颈静脉球血氧饱和度的优点和局限性

与脑氧分压(PO_2)、无创性局部脑氧饱和度(rSO_2)和脑电图等方法比较，术中监测$SjvO_2$不受血液pH值、血压、体温、颅骨厚度、骨骼肌、探头位置和间距、皮肤色素及术中麻醉药的影响，具有准确性高和创伤小等优点[29-30]。

$SjvO_2$可以反映全脑氧供需情况，但不能定位脑组织局部缺血。此外，无论是左侧还是右侧颈内静脉，均非完全的脑静脉血，双侧$SjvO_2$也往往不同，尤其是颅脑创伤患者。当脑血流量严重减少时，颅外静脉血混杂比例增加，可使$SjvO_2$升高[18]。

综上所述，术中动态监测$SjvO_2$和脑动脉-静脉血氧含量差，可以对术中患者脑血流和脑代谢情况进行综合评价，有助于更加准确地判断病情、合理地选择最佳治疗方案，有效减轻或防止继发性脑损伤，有利于患者预后。

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Comparison between the 2007 and the 2016 WHO classification of tumours of the central nervous system (Ⅱ)

The 2007 edition	The 2016 edition
Mesenchymal tumours	**Mesenchymal, non-meningothelial tumours**
Lipoma	Solitary fibrous tumour/haemangiopericytoma
Angiolipoma	Grade 1
Hibernoma	Grade 2
Liposarcoma	Grade 3
Solitary fibrous tumour	Haemangioblastoma
Fibrosarcoma	Haemangioma
Malignant fibrous histiocytoma	Epithelioid haemangioendothelioma
Leiomyoma	Angiosarcoma
Leiomyosarcoma	Kaposi sarcoma
Rhabdomyoma	Ewing sarcoma/PNET
Rhabdomyosarcoma	Lipoma
Chondroma	Angiolipoma
Chondrosarcoma	Hibernoma
Osteoma	Liposarcoma
Osteosarcoma	Desmoid-type fibromatosis
Osteochondroma	Myofibroblastoma
Haemangioma	Inflammatory myofibroblastic tumour
Epithelioid haemangioendothelioma	Benign fibrous histiocytoma
Haemangiopericytoma	Fibrosarcoma
Anaplastic haemangiopericytoma	Undifferentiated pleomorphic sarcoma/malignant fibrous histiocytoma
Angiosarcoma	Leiomyoma
Kaposi sarcoma	Leiomyosarcoma
Ewing sarcoma-PNET	Rhabdomyoma
	Rhabdomyosarcoma
Primary melanocytic lesions	Chondroma
Diffuse melanocytosis	Chondrosarcoma
Melanocytoma	Osteoma
Malignant melanoma	Osteochondroma
Meningeal melanomatosis	Osteosarcoma
Other neoplasms related to the meninges	**Melanocytic tumours**
Haemangioblastoma	Meningeal melanocytosis
	Meningeal melanocytoma
	Meningeal melanoma
	Meningeal melanomatosis