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颅内压联合脑组织氧分压监测在颅脑外伤治疗中的作用

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摘　要

颅脑损伤是临床上常见的急症之一，主要由外界暴力伤害所致，比如高空坠落、交通事故、异物严重撞击等，其致残率和致死率均较高，且易处于脑组织缺血缺氧状态，发生低氧血症、低血压症，对患者的日常生活带来极大的不良影响，对家庭和社会也带来重大负担。颅内压(Intracranial pressure, ICP)和脑组织氧分压(partial pressure of brain tissue oxygen, $PbtO_2$)监测并管理显著降低了颅脑损伤患者的死亡率。ICP作为反应颅内顺应性指标的概念，是对几个世纪前Monroe和Kellie提出的学说，与标准颅内压指导治疗相比，ICP联合$PbtO_2$监测指导治疗相结合被认为可以改善创伤性脑损伤(Traumatic brain injury, TBI)患者的预后。本文将对ICP联合$PbtO_2$监测对TBI患者治疗中的临床意义和前景进行综述。

关键词

创伤性脑损伤，颅内压监测，脑组织氧分压，脑氧监测

The Role of Intracranial Pressure Combined with Brain Tissue Oxygen Partial Pressure Monitoring in the Treatment of Traumatic Brain Injury

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Abstract

Brain injury is one of the common clinical emergencies, mainly caused by external violent injuries, such as falling from high altitude, traffic accidents, severe impact of foreign objects, etc. It has high disability rate and high fatality rate. In hypoxic state, hypoxemia and hypotension occur, which have a great adverse effect on the daily life of the patient, and also bring a heavy burden to the family and society. Monitoring and management of intracranial pressure Intracranial pressure (ICP) and partial pressure of brain tissue oxygen ($PbtO_2$) can significantly reduce the mortality of patients with traumatic brain injury. The concept of ICP as an indicator of intracranial compliance is based on the theory proposed by Monroe and Kellie centuries ago, and the combination of ICP combined with $PbtO_2$ monitoring-guided therapy is believed to improve traumatic brain injury compared with standard intracranial pressure-guided therapy (Traumatic brain injury, TBI) patients' prognosis. This article will review the clinical significance and prospects of ICP combined with $PbtO_2$ monitoring in the treatment of TBI patients.

Keywords

Traumatic Brain Injury, Intracranial Pressure Monitoring, Partial Pressure of Brain Tissue Oxygen, Brain Oxygen Monitoring

1. 颅内压监测

1.1. ICP 的概述

颅腔内容物包括脑组织和血液以及脑脊液，颅内压就是它们对颅腔壁产生的压力。正常成年人颅内压为 10~15 mmHg，美国脑外伤基金会(BTF)建议，当重度颅脑损伤患者的颅内压持续增高>20 mmHg 时，早期的监测与干预更能有效降低患者的病死率[1]。ICP 升高是颅脑损伤患者病情恶化的危险因素，在治疗期间，需要加强对 ICP 的监测，改善患者的预后[2]。大脑对颅内压及脑氧含量变化均有很好的代偿机制，当这种代偿储备耗尽时，会发生高颅压或低氧相关的神经损伤。

1.2. ICP 监测的价值

关于 ICP 监测的临床价值，研究者们一直在寻找循证医学证据。通过 Cochrane Library、PubMed、Embase、万方和 CNKI 等进行了系统检索，并在固定模型下进行分析，提取患者的住院死亡率、功能预后、住院时间和相关并发症，包括 6 项随机对照试验(880 例)和 12 项队列研究(12,606 例)。综合分析发现，ICP 监测可有效降低电解质紊乱的风险率，降低肾功能衰竭的风险率，改善预后。然而，单独 ICP 监测引导治疗对医院死亡率、肺部感染率、机械通气率和住院时间无显著意义[3] [4]。

美国脑外伤基金会指南明确规定了 TBI 后 ICP 监测的适应症[5]。TBI 是脑损伤最常见的形式之一。继发性脑损伤是脑外伤患者预后差的关键因素。继发性脑损伤包括细胞损伤、炎症及血流调节的改变，随着脑组织肿胀，颅内空间内容物上的压力升高[6]。ICP 测量是神经危重症护理中脑损伤神经监测的基石，尤其是严重 TBI 后的 ICP 测量，是继发性脑损伤的重要监测手段。最新的指南为重型颅脑损伤后的

ICP 监测提供了 II 级建议，并提出降低 ICP 的治疗策略对长期神经功能保护有积极影响[7]。

1.3. ICP 监测设备

目前临床上所讲的颅内压监测手段可分为有创颅内压监测和无创的颅内压监测两种。前者精确度高，被视为金标准，但同时其费用较后者高，而后者风险相对较前者小，并发症少，但其准确度不如前者佳，因此，近几年来有创颅内压监测已经成为广大科研工作者及临床工作者进行研究和探索的热点课题。

目前临床上可用于 ICP 监测的设备和技术众多，因此有必要制定 ICP 监测仪的标准。1) 设备压力范围应在 0 至 100 mm 汞柱之间；2) 其精度应为±2 mm 汞柱，范围为 0 至 20 mm 汞柱；3) 在 20~100 mm 的压力范围内，最大允许误差 Hg 应为±10% [8]。

1.3.1. 侵入性 ICP 监测

1) 脑室内压力监测装置

基于应变计微型传感器的 ICP 监测设备是侵入性颅内压监测的基本原理。这类设备有两种类型——基于压敏电阻的固态设备或采用光纤设计的设备。光纤设备，如 Camino ICP Monitor (美国新泽西州普兰斯伯勒 Township 的 Integra Life Sciences)通过光缆将光传输到尖端的可移动镜子。ICP 值的变化会使反射镜变形，反射光强度的差异会转化为 ICP 值。当传感器由于 ICP 值的变化而变形时，电阻发生变化，并将其转换为 ICP 值[7]。脑室内压力监测装置将导管直接插入脑室，是一个非常简单有效的策略。因此，该方法虽然是所述技术中最古老的，但仍然是测量颅内顺应性的金标准，也是标准化其他测量方法的标杆。该技术也称为脑室置管引流(External ventricular drain, EVD)技术[9]。传统的 EVD 放置方法通常是通过冠状钻孔法，但根据神经外科医生的个人偏好，也可以选择其他位置，其中同侧侧脑室或第三脑室是首选部位。脑室内放置 EVD 仍然是测量颅内顺应性的可靠选择，是金标准，应注意尽量减少感染和出血并发症的发病率。

2) 其他侵入方式

随着神经外科及微型传感器技术的发展。许多解剖位置，如脑实质、硬膜外和硬膜下间隙以及蛛网膜下腔已被以监测 ICP。其中微传感器最常见的放置位置是右额叶皮质实质，尽管根据大脑局部病理学，也会在脑实质中选择其他位置。微型传感器与脑室内装置有很大的相关性[10]。与 EVD 相比，它们更易于操作，并且不受患者体味的影响。此外，无流体耦合系统可改善感染风险，且安置所需的手术操作简单，可减少出血并发症，其测量误差的发生率小于 EVD 等流体耦合设备。

1.3.2. 非侵入性 ICP 监测

无创颅内压监测的构想令人们感到非常好奇，因为至少在理论上，这种方法是可行的，并且可以避免出血和感染等并发症。基于软件计算的神经成像技术和诊断工具的出现，促进了多种检测方法的发展，这些方法已被广泛研究，以取代作为金标准的侵入性监测。视神经鞘直径测量、鼓膜位移、组织共振分析、眼压计、经颅多普勒、脑电图、近红外光谱、瞳孔测量、前囟压力监测、颅骨弹性、颈静脉球监测、视觉诱发反应以及基于放射学的 ICP 评估等是非侵入性 ICP 监测策略。理想情况下，非侵入性 ICP 监护仪应在整个医院随时可用，价格便宜、准确，并且操作简单方便[11]。且具有最低限度的禁忌症和限制，以使用更多患者从中受益。新近的研究促进了非侵入性 ICP 监测技术的发展，但其是否可以替代侵入性 ICP 监测技术仍需进一步的临床证据支持[12] [13]。

2. 脑组织氧监测

2.1. 脑组织氧监测的起源及机制

脑组织氧监测的使用已经存在了大约三十年，最早使用是实验研究发现即使 ICP 监测的使用越来越

规范，脑缺氧仍时常发生[14]。脑缺氧通常发生在的脑外伤的早期，是TBI后不良预后的独立预测因子[15]。$PbtO_2$监测可以实时且灵敏的呈现脑组织氧含量，主管医生根据其监测数值做出准确的处理，就能明显减少神经外科手术术后相关并发症如缺血性脑卒中、局灶性脑梗死及术后脑血栓形成等的发生[16] [17]。研究者认为，脑组织氧分压(partial pressure of brain tissue oxygen, $PbtO_2$)监测可以在ICP升高之前检测出脑灌注障碍，也可能反映出大脑自动调节功能的损害[18]。

$PbtO_2$与ICP相比，对细胞损伤的检测灵敏度更高，这是因为ICP不能充分的反映大脑氧合状态，特别是当继发性损伤早期及恢复期，微血管塌陷、血管周围水肿以及创伤性脑损伤导致的内皮细胞肿胀，氧气向细胞扩散障碍时，此时ICP不高，但是脑组织氧代谢受限[19] [20] [21]。此时，毛细血管氧分压与细胞呼吸有更好的相关性，所以这在水肿发生早期及恢复期，ICP不高时，$PbtO_2$可以更好的评估脑组织代谢状态及损伤程度[22] [23]。

2.2. 脑组织氧监测的价值

多项对颅脑外伤患者进行的研究发现$PbtO_2$联合ICP监测引导治疗组的死亡率显著低于单独ICP监测引导治疗组。总的来说，脑组织氧监测与颅内压监测相结合，可以降低TBI患者的住院死亡率[24]。研究者认为$PbtO_2$监测和针对低$PbtO_2$治疗可通过减少脑缺氧发作和随后的继发性脑损伤的持续时间，改善患者的神经预后和生存率[25] [26]。此外McCarthy等人也发现，在3个月后，神经功能有改善的趋势[27]。但是，与仅接受ICP监测引导下治疗的患者相比，$PbtO_2$联合ICP监测引导下治疗的患者的重症监护室内住院时间和机械通气持续时间显著减少[28]。这是由于脑缺氧治疗增加了ICU住院时间和机械通气时间。总的来说，ICP + $PbtO_2$治疗组在6个月时脑缺氧时间减少，死亡率降低，神经功能预后改善[29] [30]。

2.3. 脑组织氧监测的方法

近期以来，国际重症监护协会和欧洲危重症协会的共识对神经危重症患者推荐进行脑组织氧分压监测或颈静脉氧饱和度监测，可以有效并充分评估患者的脑功能状态。颈静脉氧饱和度监测虽然是成熟的监测方法，但仅间歇性监测从大脑返回的静脉血氧浓度，间接提示大脑对氧的利用[31]。临床上常用的脑组织氧分压监测方法为有创颅内压探头植入下的持续监测技术。脑组织氧监测基于将微导管插入脑组织[32] [33]。可以在硬脑膜下约3.5厘米处插入监视器来监测局部脑氧分压。该监测能够测量颅内腔中的氧气，旨在提供额外的指标，以帮助临床医生制定治疗策略。通常来说，受重伤的TBI患者需要接受脑组织氧监测[34]。这些患者通常已经进行了ICP监测，$PbtO_2$探头的放置是获得指导治疗的信息的额外指标。无创脑组织氧监测方法一直以来颇受关注，其中近红外光谱检测(near-infrared spectroscopy, NIRS)通过测量脑组织中含氧血红蛋白和脱氧血红蛋白的浓度，从而获得脑组织氧供的信息[35] [36]。但现有的研究结果提示，NIRS的临床使用价值仍具有极大争议，尚不能取代现阶段的有创监测技术[37]。所以尽管有多种监测脑氧合的方式，但经颅脑组织氧张力监测被视为金标准[38]。

2.4. 脑组织氧监测的目标阈值

脑组织氧监测的使用已经存在了大约三十年，目前尚不清楚治疗的适当阈值。最新的一项研究中，研究者们发现将28 mmHg作为阈值是否与格拉斯哥昏迷评分(GCS)和格拉斯哥预后评分(GOS)相关。维持患者$PbtO_2$水平≥以28 mmHg并保持在该水平可改善出院/医疗结束时的GCS和GOS。该课题组证明，在监测系统使用过程中，将最大$PbtO_2$水平始终高于28 mmHg的患者的GCS和GOS均有改善[4] [39]。此外，该组患者的死亡人数较少，但该人群的脑室置管引流持续时间和住院时间确实更长[40]。另外一项研究报道，TBI患者的$PbtO_2$最小阈值为19 mmHg，且提出$PbtO_2 \geq 33$ mmHg或≥45 mmHg时均可使患者获益更大[41] [42]。不同中心均对脑组织氧监测设定的阈值进行了研究，给出了28 mmHg的参考阈值，

但是不同病种、不同年龄及不同严重程度的患者在未来的研究或可得到进一步的优化[43] [44]。

2.5. 脑组织氧监测的适应症

脑组织氧监测的适应症与 ICP 监测的适应证相似。与颅内高压相比，脑缺氧可能对组织存活率有更直接的影响，因此脑组织氧张力($PbtO_2$)监测已被引入并评估为患者 ICP 监测的一种补充监测手段，主要用于患有严重脑外伤人群[30]。TBI 患者的治疗包括防止继发性脑损伤，如继发性低血压和脑缺氧，所以及时评估脑氧合非常重要[37] [45]。研究表明患者在受伤后的最初几天内最有可能发生脑缺血[46]。低 $PbtO_2$ 合并 ICP 升高预示着患者需要进一步干预，干预手段包括呼吸机通气设置的变化、血压的控制、镇静的变化乃至手术。脑组织氧合已成为 ICU 中指导 TBI 患者干预和优化治疗方案的重要工具[47]。

3. 结论与展望

总的来说，$PbtO_2$ 监测与 ICP 监测相结合比单纯使用 ICP 监测，可减少住院颅脑外伤患者的死亡率，改善其预后，在其他神经系统疾病中的应用仍需要进一步研究。随着技术的进一步发展，ICP 联合 $PbtO_2$ 监测能更广泛地应用于颅脑损伤患者的临床救治当中，为患者疾病的治疗与预后提供更多的受益。

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