·临床研究·

短程高颈段脊髓电刺激术治疗脑损伤意识障碍患者10例

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[摘 要] **目的**:分析短程高颈段脊髓电刺激术治疗脑损伤重度意识障碍患者的技术要点及该术式的临床诊疗价值。**方法**:回顾性总结南京医科大学第一附属医院神经外科于2023年6—9月开展的10例短程高颈段脊髓电刺激手术,解析手术过程技术要点,并结合随访分析其临床应用价值。**结果**:全麻下取俯卧位在胸8椎间隙经皮行硬脊膜外腔穿刺,在X线透视下动态调整脊髓刺激电极可顺利将其顶端置入颈2水平,进行为期2~3周的刺激治疗。刺激参数选择:频率5/70 Hz电压1~5 V;刺激小周期:开15 min,关15 min;刺激大周期:8点开机,20点关机。在术后4周进行随访,8例术前植物状态(vegetative state,VS)患者中1例到达微小意识状态(minimally conscious state,MCS)+,5例MCS-,2例仍为VS状态;2例术前MCS-患者中1例脱离微小意识,1例MCS+,均无手术相关并发症出现。**结论**:短程高颈段脊髓电刺激术微创、安全并且有效,有短程的治疗价值和诊断价值,在意识障碍促醒诊疗中有着广泛的应用前景,手术过程需要注意穿刺置入电极特有的难点和技术操作要领。

[关键词] 短程高颈段脊髓电刺激;意识障碍;技术要点;诊疗价值

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The treatment of 10 patients with consciousness disorders due to brain injury using short-term high cervical spinal cord stimulation

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[**Abstract**] **Objective**: To analyze the technical key points of short-term high cervical spinal cord electrical stimulation in the treatment of severe consciousness disorders in patients with brain injury and clinical diagnostic and therapeutic value of this procedure. **Methods**: A retrospective analysis was conducted on 10 cases of short-term high cervical spinal cord stimulation performed at the Department of Neurosurgery, the First Affiliated Hospital of Nanjing Medical University from June to September 2023. The technical key points of the surgical process were analyzed, and the clinical application value was evaluated through follow-up analysis. **Results**: Under general anesthesia, with the patient in the prone position, a percutaneous puncture of the thoracic 8 intervertebral space was performed to access the extradural space, and under X-ray fluoroscopy, the top of the spinal cord stimulation electrode was successfully placed at the level of C2. Stimulation therapy was conducted for 2-3 week, with stimulation parameters selected as follows: frequency 5/70 Hz, voltage 1-5V, small stimulation cycle: on for 15 min, off for 15 min, large stimulation cycle: on at 08:00 am, off at 20:00 pm. Follow-up was conducted at 4 weeks post-surgery, with 1 out of 8 patients in a vegetative state(VS)reaching a minimally conscious state (MCS)+, 5 patients remaining MCS-, and 2 patients still in a VS status. Among the 2 patients who were MCS- preoperatively, 1 patient recovered from a MCS, and 1 patient reached MCS+, with no surgery-related complications observed in either case. **Conclusion**: Short-term high cervical spinal cord stimulation is minimally invasive, safe and effective, with short-term therapeutic and diagnostic value. It has broad prospects for application in the diagnosis and treatment of consciousness disorders. Attention should be paid to the specific difficulties and technical aspects of electrode placement during the surgical procedure.

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[Key words] short-term high cervical spinal cord stimulation；consciousness disorders；technical key points；diagnosis and therapeutic value

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高颈段脊髓电刺激术(high cervical spinal cord stimulation，hcSCS)是将电极置入椎管内，以脉冲电流刺激高位颈髓从而改善意识障碍患者意识状态的一种治疗手段[1]。研究发现，hcSCS可以增加脑血流灌注、减轻脑内氧化应激反应，激活脑干网状结构上行激动系统及增加大脑皮层活动[2-5]。根据留置时间不同，分为短程和长程，长程往往在直视暴露下放置电极，短程则采取穿刺手段置入电极。短程hcSCS由北京天坛医院何江弘教授率先应用于慢性意识障碍促醒治疗。相比长程电刺激具有创伤小、手术时间短、并发症少及费用低的优点，作用时间2~4周，具有短程治疗价值，同时具有诊断价值，可以根据患者对脊髓电刺激治疗的反应情况制定后续促醒方案。但穿刺置入电极具有其特有的难点和技术操作要领。本研究根据笔者的临床经验，详细介绍短程hcSCS的技术要领并结合随访结果分析其诊疗价值。

1　对象和方法

1.1　对象

10例患者中，男8例，女2例；年龄33~60岁。原发病因：脑出血3例，颅脑创伤7例。排除继发性脑积水、癫痫持续状态等影响意识的情况后诊断10例患者的意识状态，8例为植物状态(vegetative state，VS)，修订昏迷恢复量表(revised coma recovery scale，CRS-R)评分3~8分；2例为微小意识状态(minimally conscious state，MCS)，且均为MCS-，CRS-R评分8~11分。

1.2　方法

使用数字减影血管造影(digital subtraction angiography，DSA)机器及植入式脊髓神经电刺激电极(型号：L3213-75，北京品驰医疗设备有限公司)。

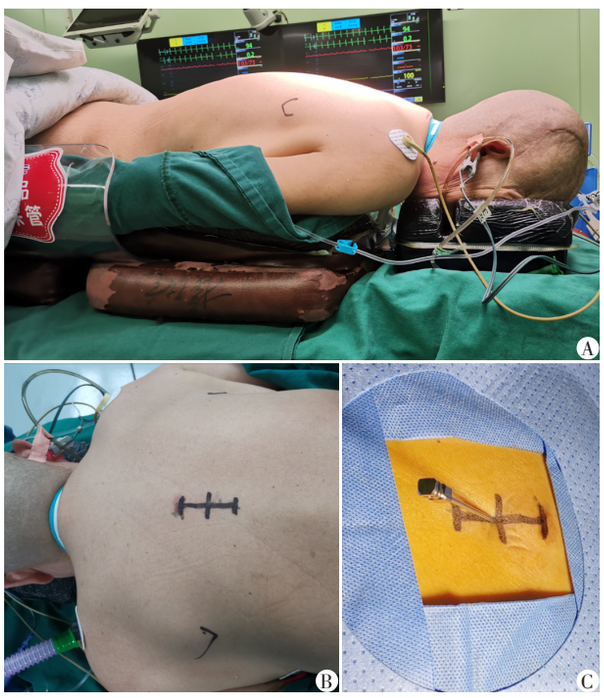
短程hcSCS手术适应证：脑卒中或脑外伤后遗留慢性意识障碍(包括VS和MSC)患者。慢性意识障碍定义为各类脑损伤所导致意识丧失超过28 d的病理状态[6]。禁忌证：①继发性脑积水未经处理者；②癫痫持续状态患者；③由于神经退行性疾病；恶性脑肿瘤所致的慢性意识障碍患者；④生命体征不稳定患者；⑤颈胸椎严重畸形患者。

1.2.1　术前准备

完善头颅CT、脑电图检查和CRS-R评分，必要时进行颈胸椎CT检查，确定患者意识状态处于VS或MCS，并排除脑积水、癫痫持续状态及颈胸椎畸形。将手术目的、可能出现的并发症及应对措施等与患者家属充分沟通，签署知情同意书。

1.2.2　体位、穿刺定位与操作

患者取俯卧位，胸部垫高，摆正头部使得颈胸椎尽量呈一直线(图1A)。使用双侧肩胛骨下缘连线与后正中线交点确定第七胸椎棘突位置，穿刺点选择胸椎第6~7椎间隙或第7~8椎间隙(图1B)。使穿刺针尖端指向患者头端、与背部呈30°~45°角，自穿刺点沿正中线方向逐层缓慢进针(图1C)。感到突破感后提示针尖穿透黄韧带，继续进针0.5 cm、拔出针芯、置入通条，若通条放入通畅提示此时针尖



A：The patient was in the prone position with the chest elevated and the head aligned so that the cervicothoracic spine was in a straight line. B：The puncture point was positioned at the 6-7 or 7-8 intervertebral space of the thoracic spine. C：The puncture needle was pointed at the patient's head along the midline and at a 30°-45° angle to the back.

图1　短程hcSCS手术体位、定位与穿刺

Figure 1　Surgical positioning，localization and puncture for short-term hcSCS

开口位于硬膜外间隙且位置良好，若通条放置不畅，则需要调整针尖位置直至通条置入通畅。

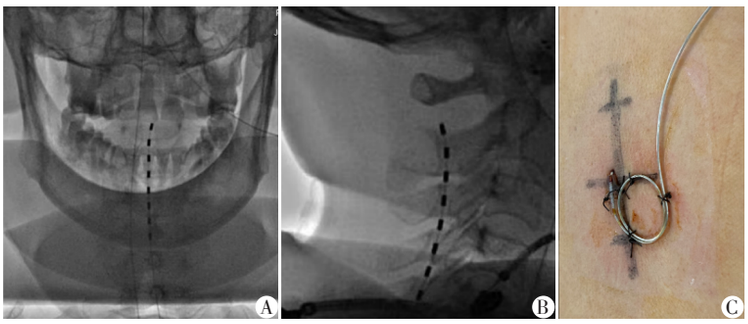
1.2.3 术中DSA机器定位和引导刺激器置入

穿刺针尖端进入硬膜外隙后，若通条放置不顺畅，可在DSA正位透视下检查穿刺针位置是否有偏斜，根据偏斜情况做适当调整使穿刺针处于正中角度。角度调整好后，再次置入通条，若通条置入仍不顺畅，则在感受到阻力时停止动作、使通条头端保持在阻力位置。此时使用DSA机器进行侧位透视，注意在遥控DSA机头旋转时应防止机头或C型臂牵拉移动患者呼吸机管路及静脉通路。若侧位片结果显示通条在穿刺针口较近位置受阻则提示穿刺针进针过深或与硬膜外腔成角过大所致，把穿刺针向外轻轻拔出1~2 mm或调整角度等相应处理后再进通条检验。若侧位片结果显示通条受阻部位远离穿刺针口，则提示硬膜外隙中有狭窄部位，记住所处的锥体节段为下一步刺激器置入做准备。

通条置入通畅后，拔出通条，开始置入刺激器。在DSA正位持续透视引导下将刺激器头端在硬膜外隙中沿正中线缓慢向患者头颈方向移动。刺激器头端走行偏斜时通过旋转刺激器尾端改变头端指向，在走行过程因遇到狭窄部位而受阻时同样通过旋转刺激器尾端避开狭窄部位。待正位透视上提示刺激器电极位置居中且头端接近枢椎齿状突附近时（图2A），将DSA机器转为侧位透视角度，在该角度下将刺激器头放置到枢椎层面（图2B）。

1.2.4 固定

刺激器达到目标位置后，拔出穿刺针，再次使用DSA机器拍摄正侧位片确定拔针过程中刺激器



A：Anteroposterior fluoroscopy showed that the stimulator electrode position was centered. B：Lateral fluoroscopy showed that the tip of the stimulator electrode reached the axis level. C：Clamp and sutures fixed stimulator wire.

图2 短程hcSCS电极置入位置及电极固定

Figure 2 Placement and fixation of short-term hcSCS electrodes

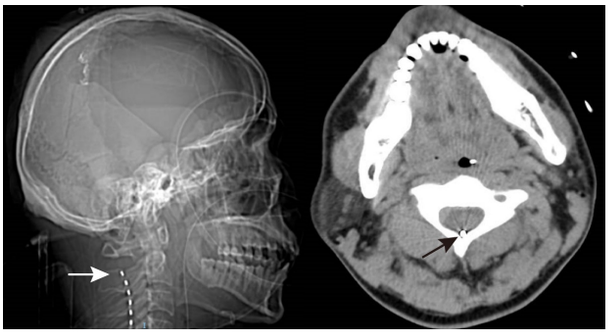
没有发生移位。连接程控仪，检测刺激器的电极电阻。调试正常后，穿入固定夹并将其移动至穿刺口，将固定夹和周围皮肤进行缝合固定（图2C）。

1.2.5 电刺激治疗

在刺激电极植入术后的次日行颈部CT检查再次核实电极位置（图3）后开始进行电刺激治疗，高颈段脊髓电刺激需要设置的参数包括刺激电流的脉宽、频率、波幅以及刺激周期。刺激电流的参数设置一般为频率5~100 Hz，脉宽100~240 μs，电压1.0~5.0 V。研究发现，在电流频率5~100 Hz之间，仅70 Hz的刺激电流可以同时改善大脑血供及增强大脑功能连接[3]。同时，Bai等[7]报道5 Hz及70 Hz的刺激频率可以激活丘脑皮层网络，明显改善意识障碍患者脑电图表现。有研究认为5 Hz刺激频率容易引发肢体抽动，对意识障碍患者是有益的功能神经康复[8]。因此本研究刺激电流频率调试过程选择5 Hz及70 Hz两个频段。电流波幅在1.0~5.0 V范围内逐步调节到以患者肢体轻微抖动且心率轻度上升为宜[9]。脉宽多选择210 μs[7,10-11]。每日刺激大周期设置为08：00到20：00开机工作，刺激小周期设置为刺激15 min、间歇15 min。

1.2.6 评价指标

在脊髓电刺激术后4周进行随访，内容包括患者意识状态评估及是否合并术后并发症。在临床医师主导及患者亲属参与的情况下进行CRS-R评分，根据评分结果评估患者意识状态。功能性物体运用或功能性交流代表脱离MCS；有遵嘱动作、识别物体、出现可理解的言语表达或有交流但不完全准确定义为MSC+；实现物体定位或视觉追踪，存在自主性运动反应、可以摆弄物品或疼痛定位定义为MSC−，否则为VS状态。通过与术前患者意识状态对比评价治疗效果。



A:CT localization image of the cervical spine showed that the stimulator electrode tip(as indicated by arrow)was located in the axis level. B:Cervical CT at the axis level showed that the stimulator electrode position was centered(as indicated by arrow).

图3 短程hcSCS术后颈椎CT验证电极放置部位

Figure 3 Postoperative cervical spine CT verification of electrode placement for short-term hcSCS

2 结 果

患者开机首日调试过程,选择5 Hz及70 Hz分别刺激6 h,结果发现10例意识障碍患者在同等电压下均表现为5 Hz频率刺激下上肢肢体抖动更显著,而70 Hz频率刺激下心率升高较明显,同时70 Hz刺激频率下患者自主睁眼时间相比5 Hz刺激频率更长,提示意识觉醒状态维持时间更久。因此,调试后刺激阶段固定选择70 Hz频率。

刺激2~3周后拔除刺激电极,穿刺口消毒后覆盖敷料。术后4周进行随访,在临床医师主导及患者亲属参与下进行CRS-R评分,结果显示:8例术前VS患者中1例到达MCS+,5例为MCS-,2例仍为VS状态;2例术前MCS-患者中1例脱离MCS,1例到达MCS+。10例患者中8例意识状态得到不同程度改善,其中1例脱离MCS,提示意识状态改善效果显著。所有患者均无手术相关并发症出现。

3 讨 论

脑损伤患者易遗留意识障碍,然而目前较为普及的高压氧及常规康复锻炼手段对重度意识障碍促醒治疗的效果不确切。hcSCS是将电极植入C2-C4水平硬脊膜外,以脉冲电流刺激脊髓改善意识状态的方法。既往研究报道,接受长程hcSCS治疗后VS患者的意识障碍改善率为42.3%,MCS患者的改善率为69.0%[12]。Xu等[13]发现,12例接受长程hcSCS治疗的VS患者中3例脱离MSC、2例达到MSC。然而,由于使用短程hcSCS治疗意识障碍在全球处于初期阶段,相关治疗效果的报道较少。Yang等[14]在2022年首次报道了1例VS患者经短程hcSCS治疗后第21天意识状态改善为MSC。Huang等[15]则发现,14例原发性脑干出血合并意识障碍患者中有10例在接受短程hcSCS治疗后CRS-R评分改善。本研究使用短程hcSCS技术治疗VS及MCS-患者,结果发现在脊髓电刺激后4周,8例术前VS患者中6例意识状态改善,2例术前MCS-患者意识状态均改善,提示短程hcSCS对脑损伤后慢性意识障碍患者具有较高的治疗价值。我们认为对于短程hcSCS后意识状态改善、但未脱离MSC状态的患者,建议可进一步行长程hcSCS治疗,而短程hcSCS治疗后意识无改善的患者则不推荐行长程hcSCS治疗。

短程hcSCS治疗具有创伤小、手术时间短、经济等优点,但穿刺置入电极对比直视下放置电极在电极位置准确性的控制上令人担忧。而电极放置位置和刺激疗效及不良反应密切相关。刺激器电极应尽量居中覆盖脊髓后中线,偏离中线的电极接触通常会因背根神经受累产生震动刺激的不良反应[16]。同时既往研究报道,电极与中线偏移角度超过30°的患者相比偏移较小的患者阵发性交感神经过度活跃发生率显著增高,且术后CRS-R评分改善率显著下降[17]。目前绝大多数研究都推荐改善意识障碍为治疗目的的脊髓电刺激应靶向C2~C4节段[8,16],因此刺激器头端第一个电极的位置应尽量靠近或略高于C2棘突上缘。在手术中,需要术者提高实践经验,有效地利用术中DSA透视引导,以期达到更好的电极置入位置。

在刺激频率上,目前研究主要推荐5 Hz和70 Hz,在调试阶段发现患者在70 Hz刺激频率下出现相比5 Hz刺激更久的自主睁眼表现,提示70 Hz对意识改善的效果可能更好。近期,Zhuang等[18]通过CRS-R评分及脑电图检查证实70 Hz频率的短程hcSCS对意识障碍患者的意识状态及脑电活动的改善效果。在并发症上,长程hcSCS的研究报道部分患者存在切口愈合不佳、前胸壁皮下血肿或癫痫样抽搐[10-11]。但目前研究报道短程hcSCS治疗的患者未发现手术相关并发症,可能与穿刺放置电极创伤小、手术时间短有关。

综上所述,短程hcSCS是脑损伤重度意识障碍患者促醒治疗的可行方案之一。手术过程微创、安全并且疗效较好,有短程的治疗价值和诊断价值,在意识障碍促醒诊疗中有广泛的应用前景。穿刺置入电极有其特有的难点和技术操作要领,需要临床医生注意操作细节,争取良好的电极置入位置。

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