临床论著

前路椎体骨化物复合体可控前移技术治疗颈椎后纵韧带骨化症的脊髓原位减压效果

罗 溪,朱 健,孙璟川,史建刚
(海军军医大学附属长征医院脊柱二科 200003 上海市)

【摘要】目的:观察颈椎前路椎体骨化物复合体可控前移(anterior controllable antedisplacement fusion,ACAF)技术治疗颈椎后纵韧带骨化症(ossification of the posterior longitudinal ligament,OPLL)的脊髓原位减压效果。**方法**:回顾分析 2017 年 6 月~2018 年 12 月我院收治的 78 例 OPLL 患者的人口学信息、影像资料以及术后指标(年龄、性别、症状持续时间、椎管侵占率和骨化累及椎体数量)。其中采用 ACAF 治疗 42 例,单开门椎管扩大椎板成形术(简称单开门椎板成形术 open-door laminoplasty,LAM)治疗 36 例,平均随访时间 21.7±4.0(12~30)个月。比较两组患者术前及末次随访时的 JOA 评分、脊髓面积、Cobb 角、Kang′s 分级以及 C5 神经麻痹、脑脊液漏、吞咽困难等并发症情况。**结果**:末次随访时,ACAF 组与 LAM 组相比,在 JOA 评分(14.17±0.81 分 vs 13.81±1.12 分,P<0.05)、脊髓面积(74.12±4.48mm^2 vs 70.36±5.60mm^2,P<0.05)、Cobb 角(20.07°±1.28° vs 9.99°±0.65°,P<0.05)和 Kang′s 分级(0.93±1.40 vs 2.00±0.89,P<0.05)方面具有优势。对比 ACAF 组与 LAM 组的术后并发症,两组间 C5 神经麻痹(4.8% vs 11.1%)、脑脊液漏(2.4% vs 2.8%)、吞咽困难(9.5% vs 0%)无统计学差异。ACAF 组 2 例出现 C5 神经麻痹的患者未能顺利完成原位减压。**结论**:ACAF 手术可通过恢复椎管容积和形态实现脊髓原位减压,减压效果良好。在恢复颈椎曲度和脊髓位置形态方面,ACAF 较 LAM 为优。

【关键词】颈椎前路椎体骨化物复合体可控前移技术;原位减压;后纵韧带骨化症;C5 神经麻痹
doi:10.3969/j.issn.1004-406X.2020.03.04
中图分类号:R683.2,R681.5 **文献标识码**:A **文章编号**:1004-406X(2020)-03-0202-10

Effect of in situ decompression during anterior controllable antedisplacement fusion for treatment of the cervical ossification of posterior longitudinal ligament/LUO Xi, ZHU Jian, SUN Jingchuan, et al// Chinese Journal of Spine and Spinal Cord, 2020, 30(3): 202-211

【Abstract】Objectives: To investigate the clinical effect of in situ decompression during anterior controllable antedisplacement fusion(ACAF) in treatment of cervical ossification of the posterior longitudinal ligament(OPLL). **Methods:** The demographic information, imaging data and postoperative indicators(age, sex, duration of symptom, occupying rate, and number of ossified vertebrae) from 78 patients diagnosed with OPLL were analyzed retrospectively. All patients were admitted from June 2017 to December 2018. 42 cases were treated with ACAF and 36 cases with open-door laminoplasty (LAM). The average follow-up time was 21.7±4.0 (12-30) months. The JOA score, area of spinal cord, Cobb angle, Kang′s grade, and the incidences of C5 nerve palsy, cerebrospinal fluid leakage and dysphagia were compared between the two groups before operation and at final follow-up. **Results:** At final follow-up, compared with LAM group, ACAF group had advantages in JOA score(14.17±0.81 vs 13.81±1.12, P<0.05), area of spinal cord(74.12±4.48mm^2 vs 70.36±5.60mm^2, P<0.05), Cobb angle(20.07°±1.28° vs 9.99°±0.65°, P<0.05) and Kang′s grade(0.93±1.40 vs 2.00±0.89, P<0.05). The postoperative complications of ACAF and LAM group demonstrated C5 nerve palsy (4.8% vs 11.1%), cerebrospinal fluid leakage(2.4% vs 2.8%) and dysphagia(9.5% vs 0%), there was no statistical difference between two groups. In ACAF group, 2 patients with C5 palsy failed to complete in situ decompression. **Conclusions:**

基金项目:上海市卫计委项目(编号:201640262);国家自然科学基金(编号:81650031)
第一作者简介:男(1995-),硕士在读,研究方向:脊柱外科
电话:(021)81886807 E-mail:brookluo@outlook.com
罗溪、朱健、孙璟川为共同第一作者
通讯作者:史建刚 E-mail:chzhshijg@126.com

ACAF can achieve in situ decompression to spinal cord by restoring the volume and shape of spinal canal, and the effect of decompression is significant. As to the recovery of cervical curvature and shape of spinal cord, ACAF is better than LAM.

【Key words】 Anterior controllable antedisplacement fusion; In situ decompression; Ossification of the posterior longitudinal ligament; C5 nerve palsy

【Author's address】 Department of Spine Surgery Ⅱ, Changzheng Hospital, Navy Military Medical University, Shanghai, 200003, China

长期以来,针对长节段(骨化累及 3 个节段以上)颈椎后纵韧带骨化症(ossification of the posterior longitudinal ligament,OPLL)的外科治疗,全世界研究团队开展了大量对比术式疗效的研究。随着手术技术日趋成熟,目前对骨化物侵占率<60%、颈椎前凸存在的病例采用后路手术进行减压的做法已获得普遍认同,并在临床上取得良好成效[1-4]。但是,以单开门椎管扩大椎板成形术(简称单开门椎板成形术 open-door laminoplasty,LAM)为代表的后路手术需要使脊髓后漂来实现对骨化物的躲避和对脊髓神经的减压,造成了脊髓自然位置的改变,这与 C5 神经根麻痹、脊髓旋转等神经应力异常表现密切相关[5-7]。临床实践中,我科应用颈椎前路椎体骨化物复合体可控前移手术(anterior controllable antedisplacement fusion,ACAF)对长节段 OPLL 患者进行治疗。ACAF 手术可将骨化物及前方椎体一同向前方提拉,在完成直接减压的同时使脊髓继续保持在自然位置,实现了对脊髓的"原位减压"[8-11]。笔者旨在通过回顾分析 ACAF 和 LAM 治疗长节段 OPLL 的手术疗效,对原位减压这一手术理念及其应用意义进行阐释。

1 资料和方法

1.1 一般资料

回顾分析 2017 年 6 月~2018 年 12 月我科收治的 78 例影像学诊断为颈椎 OPLL 并行 ACAF 手术或 LAM 手术治疗的患者资料,平均随访时间 21.7±4.0(12~30)个月。术前行颈椎正侧位 X 线片、CT 及 MRI 检查。其中,ACAF 组 42 例,LAM 组 36 例。两组患者在性别、年龄、症状持续时间、椎管侵占率以及骨化累及节段方面比较,差异无统计学意义(P>0.05,表 1)。

表 1 一般资料统计

Table 1 General information

	ACAF组 ACAF group	LAM组 LAM group	*P*
例数/*n*	42	36	
年龄(岁)/Age(year)	59.7±3.6	57.8±3.7	0.724
性别/Sex			0.724
男/M	25	20	
女/F	17	16	
症状持续时间(月) Duration of symptom (month)	14.5±6.6	16.5±5.6	0.142
椎管侵占率(%) Occupying rate	51.6±11.4	54.6±7.9	0.177
骨化累及椎体(个) Ossified vertebrae	3.45±0.50	3.33±0.48	0.052

纳入标准:(1)确诊为颈椎后纵韧带骨化症,行 ACAF 或 LAM 手术治疗;(2)骨化累及椎体数量≥3 个。排除标准:(1)畸形、强直性脊柱炎、类风湿关节炎等累及颈椎者;(2)有颈椎外伤、手术史;(3)严重骨质疏松。(4)排除局限型骨化,且预计减压节段<3 个的患者;排除连续型或混合型骨化,且预计减压节段>5 个的患者;排除骨化广泛,预计减压节段>3 个,且合并有局限型巨大骨化灶或较大椎间盘突出的患者。所有患者均签署手术知情同意书,在明确告知 ACAF 和 LAM 的手术细节、预期获益、风险和并发症后,结合术者经验和患者意愿确定术式。

1.2 手术方法

ACAF 组:(1)显露,全身麻醉后取仰卧位,双肩垫软枕使颈部轻度后伸,作经前路右侧斜行切口,沿颈动脉鞘及颈内脏鞘间钝性分离,显露椎体及椎间盘,C 型臂 X 线机定位手术节段。(2)椎间隙处理,去除责任节段椎间盘及椎间隙后缘骨赘,处理上下终板使其平整,显露后纵韧带。在拟提拉节段头尾端,需于椎间隙切开并咬除后纵韧带,其余椎间隙后纵韧带则无需处理(图 1a)。(3)切除椎体前方骨质,根据各节段骨化物的厚度,切除椎体前方部分骨质,为责任节段整体向前提拉预留空间(图 1b)。(4)椎体两侧开槽,根据影像资料测量骨化物宽度,其在椎体前表面的投影向两侧旁开 1mm 即为开槽边界,操作时需注意确保开槽边

界宽于骨化物宽度。用磨钻和咬骨钳配合,于两边界线在椎体开槽,移除骨质,直至咬除椎体后壁的皮质骨。为操作安全,此时仅咬除术者对侧开槽的槽底皮质骨,而术者同侧的槽底椎体后壁则暂时保留,以维持椎体位置稳定(图 1c)。(5)安装椎间融合器、钛板和螺钉,于各间隙安装椎间融合器,然后将预弯的钛板置于椎体前缘,于各椎体安装椎体钉。此时待提拉椎体的螺钉只需旋拧至贴靠钛板,无需拧紧。同时,切除术者同侧槽底椎体后壁,使椎体从脊柱游离(图 1d)。(6)椎体-骨化物复合体前移,探查确定待提拉椎体完全游离后,逐步拧紧其椎体钉,可见椎体连同骨化物一并前移,直至椎体与钛板紧密贴合,完成提拉(图 1e、1f)。(7)植骨闭合切口,在两侧开槽内进行植骨。而后冲洗切口、止血引流,逐层缝合。

LAM 组:单开门手术的操作方法参考既往文献,应用微型钛板进行开门侧固定[12]。

1.3 评价指标

采用日本骨科协会(Japanese Orthopedic Association,JOA)评分标准评价神经功能,并计算 JOA 改善率(recover rate,RR)。RR=(术后评分-术前评分)/(17-术前评分)×100%。应用 Cobb 角评估颈椎曲度。Cobb 角测量方法为:X 线侧位片上 C2 椎体上缘与 C7 椎体下缘所在直线的交角,如 C2 椎体下缘为一弧线,则取椎体前下角和后下角连线参与成角。采用 Kang's MRI 椎管狭窄分级评价颈髓受压形变程度[13],具体标准为:0 级,无椎管狭窄;1 级,蛛网膜下腔受压超过 50%;2 级,脊髓受压出现变形;3 级,脊髓 T2 加权信号改变。采用骨化物侵占率和脊髓面积量化压迫程度。骨化物侵占率定义为骨化物厚度与椎管矢状径之比,于 CT 轴位片测量骨化最厚节段。脊髓面积定义为脑脊液带内边界围成的面积,于 MRI T2 加权轴位片测量骨化最厚节段。影像学指标由

图 1 ACAF 手术示意图 **a** C2-C5 椎间隙处理 **b** C3-C4 椎体前部骨质移除 **c** C3-C4 椎体两侧开槽 **d** 安装螺钉和钛板 **e** 旋转拧紧待提拉节段的椎体钉 **f** C3-C4 游离椎体完成前移(隐去螺钉和钛板)

Figure 1 Schematic diagram of ACAF operation **a** Treatment of C2-C5 intervertebral space **b** Anterior bone removal of C3-C4 vertebrae **c** Grooves on both sides of C3-C4 vertebrae **d** Installation of screws and plate **e** Tightening of vertebral screws in segments to be hoisted **f** Disconnection and hoisting of C3-C4 vertebrae(screws and plate are hidden)

2名具有 5 年工作经验的脊柱科医师分别测量 3 次后取平均值。对比以上指标术前及末次随访时的数值。统计术后 C5 神经麻痹、脑脊液漏以及吞咽困难的发生例数。C5 神经麻痹的诊断标准为：较术前无脊髓神经功能恶化的情况下，术后 2 周内出现三角肌和（或）肱二头肌肌力下降 1 级以上。

1.4 统计方法

采用 SPSS 22.0 进行统计学分析，计量资料以均数±标准差($\bar{x}\pm s$)表示。计量资料组间比较采用两独立样本 t 检验；组内手术前后比较采用配对 t 检验；计数资料比较采用 χ^2 检验；检验水准 α=0.05。

2 结果

两组患者术前 JOA 评分、Cobb 角和 Kang′s 分级无统计学差异(P<0.05)。末次随访时，ACAF 组的 JOA 评分、Cobb 角在数值上高于 LAM 组，差异有统计学意义（P<0.05)。而在 JOA 缓解率方面，两组差异不具有统计学意义。ACAF 组的 Kang′s 分级较 LAM 组为低，差异有统计学意义(P<0.05，表 2)。

末次随访时所有患者无融合失败或神经功能恶化发生。ACAF 组 C5 神经麻痹的发生率低于 LAM 组，吞咽困难的发生率则高于 LAM 组，差异无统计学意义(P>0.05)。两组均出现 1 例脑脊液漏，通过体位调节和伤口加压得到治愈。C5 神经麻痹予激素脱水治疗，吞咽困难则未给予特殊处理。所有并发症在末次随访时均明显缓解。

3 讨论

针对 OPLL 的治疗，LAM 手术和 ACAF 手术均未直接切除骨化物，而是扩大椎管容积进行减压，因而有效减少了器械对骨化–硬膜界面的侵扰，从而降低了脑脊液漏的发生风险。本研究两组患者各出现 1 例脑脊液漏，回顾资料均合并硬膜骨化(dural ossification，DO)。合并 DO 时，骨化与硬膜囊之间界限不清，难以分离，手术造成脑脊液漏的风险较高[14]。术前 CT“双影征”对诊断 DO 具有较高特异性。既往有研究对比 ACAF 和椎体次全切除术治疗 OPLL 合并“双影征”患者的疗效，ACAF 组脑脊液发生率明显低于椎体次全切除术组(3.5% vs 22.6%)[15]。分析 ACAF 发生脑脊液漏的原因，可能在于提拉过程各椎体未能同时前移，使硬膜骨化节段在前移时出现前后落差，导致硬膜损伤。因此，对于术前 CT 提示“双影征”的骨化患者，提拉时需严格确保各节段前移的同步性。另外，ACAF 组在术后出现 4 例吞咽困难，LAM 组则未见此并发症。吞咽困难是前路手术并发症之一，与钛板占位效应、椎前组织水肿、喉上神经损伤等因素具有一定相关性[16]。对于 ACAF 手术，术后吞咽困难除与上述因素有关外，还可能与钛板压扯椎前筋膜有关。ACAF 手术常进行多节段内固定置入，为减少手术创伤，术中头尾端节段的暴露视野一般较小，故安装螺钉钛板时需重点关注头尾椎体，避免椎前筋膜卡压于钛板下方。

生理状态下，脊髓在椎管内位于平衡正中位

表 2 手术信息及疗效统计

Table 2 Operative information and outcomes

	ACAF组 ACAF group	LAM组 LAM group
提拉(减压)节段(个) Decompression vertebrae	3.26±0.66	3.52±0.70
JOA评分 JOA score		
术前 Preoperation	9.04±0.95	9.31±1.00
末次随访 Final follow-up	14.17±0.81①②	13.81±1.12②
缓解率(%) Improvement rate	64.04±11.43	58.23±14.30
Cobb角(°) Cobb angle		
术前 Preoperation	12.70±1.80	11.90±1.57
末次随访 Final follow-up	20.07±1.28①②	9.99±0.65②
脊髓面积(mm^2) Area of spinal cord		
术前 Preoperation	65.04±5.37	64.11±6.38
末次随访 Final follow-up	74.12±4.48①②	70.36±5.60②
Kang′s分级 Kang′s grade		
术前 Preoperation	2.26±0.77	2.03±0.88
末次随访 Final follow-up	0.93±1.40①②	2.00±0.89
C5 神经麻痹 C5 palsy	2(4.8%)	4(11.1%)
脑脊液漏 CSF leakage	1(2.4%)	1(2.8%)
吞咽困难 Dysphagia	4(9.5%)	0(0%)

注：①与 LAM 组比较 P<0.05；②与同组术前比较 P<0.05

Note: ①Compared with LAM group, P<0.05; ②Compared with preoperation, P<0.05

置,其横截面形态对称,矢状面则顺脊柱曲度形成平滑的弯曲[17]。在致压物压迫、脊柱畸形、外科干预等因素的作用下,脊髓不仅会发生凹陷、弯曲等形态改变[18,19],还会出现位移和旋转等空间位置改变。而这种位置改变可通过影响脊髓神经应力和血供的方式对神经功能造成不良影响[20~25]。因此理论上来说,外科手术应避免造成脊髓的异位状态,使其各部分保持自然应力,从而减少机械性和继发生物化学性损害发生。但是,尽管已有学者通过动物试验和临床评分的方式来阐释脊髓异位对神经功能的影响[26,27],然而却一直难以量化脊髓异位、异常应力与神经损伤的关系。

在减压形式方面,ACAF 和 LAM 的区别在于:LAM 手术旷置骨化物,重建椎管后侧壁,扩大椎管的背侧偏侧空间进行间接减压 (图 2)。而 ACAF 手术前移骨化物,重建椎管前壁进行直接减压。扩大后的椎管更加接近自然形态,从而可为脊髓位置的恢复创造环境,实现原位减压(图 3)。

我科前期研究发现,ACAF 手术可以有效改善脊髓曲度[28],同时能恢复脊髓前移、后漂和旋转等异位状态 [29]。本研究末次随访时,ACAF 组的 JOA 缓解率略高于 LAM 组,而在 Cobb 角、脊髓面积和 Kang′s 分级等形态学指标上则有较为明显的恢复,提示恢复椎管的曲度和容积从而恢复椎管环境是改善硬膜囊、脑脊液带和脊髓形态的重要措施。相比于传统的 Nagata MRI 分级(0 级,脊髓无压迫;1 级,脊髓轻度受压;2 级,脊髓宽度减少 1/3;3 级,脊髓宽度减少大于 1/3)[30],Kang′s 分

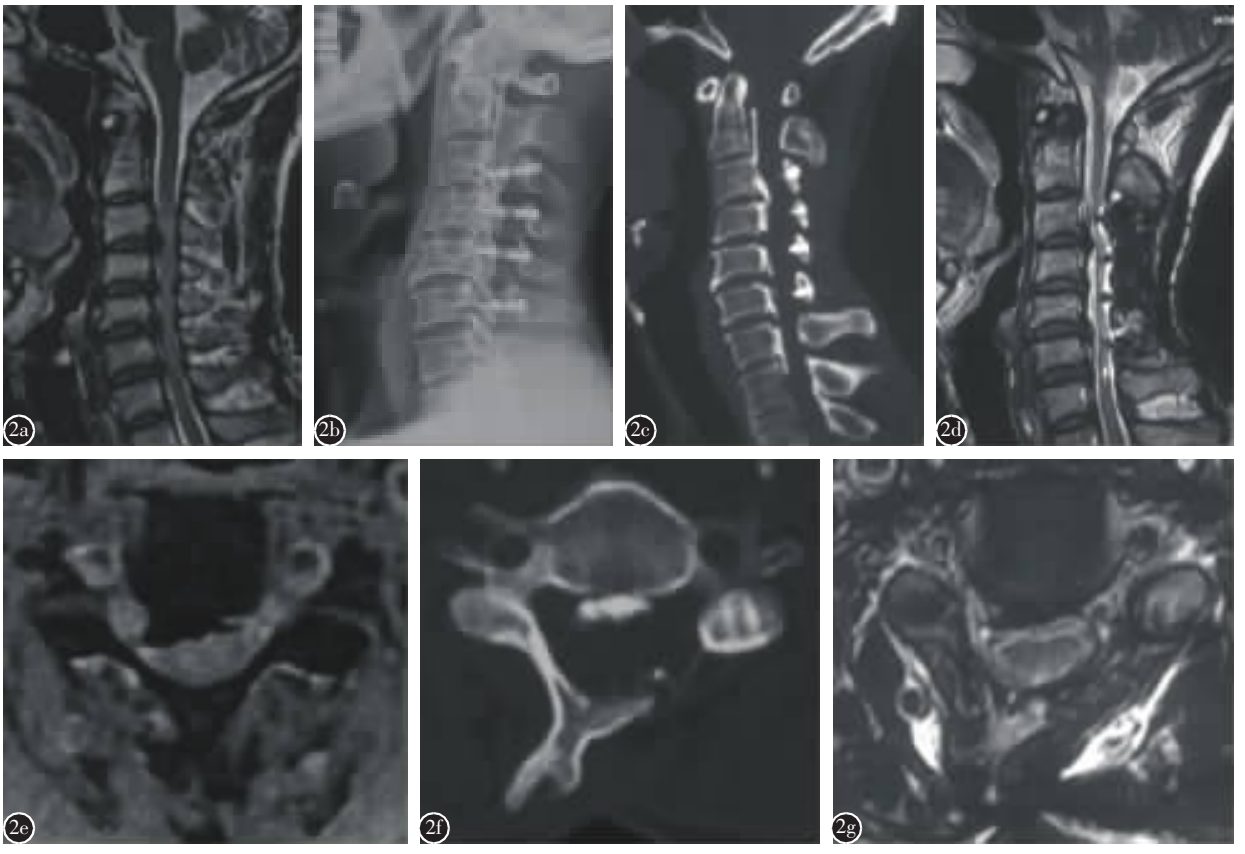

图 2 LAM 病例术前及术后影像 **a** 术前 MRI 矢状面 **b** 术后 X 线侧位片,示减压 C3–C6 **c** 术后 CT 矢状面 **d** 术后 MRI 矢状面 **e** 术前 C5 节段 MRI 横断面 **f** 术后 C5 节段 CT 横断面,示椎管空间在左背侧扩大 **g** 术后 C5 节段 MRI 横断面,示脊髓向左背侧漂移,两侧神经根走行不对称

Figure 2 Images of LAM before and after operation **a** Preoperative MRI sagittal plane **b** Postoperative X-ray lateral plane, showing decompression at C3–C6 **c** Postoperative CT sagittal plane **d** Postoperative MRI sagittal plane **e** Preoperative MRI cross section at C5 level **f** Postoperative CT cross section at C5 level, showed the expansion of the spinal canal space on the left dorsal side **g** Postoperative MRI cross section at C5 level, showed the left dorsal drift of the spinal cord and the asymmetric path of the nerve roots

级将脑脊液带的压迫纳入分级(Kang′s 1 级),同时未对脊髓形变进行阶梯分级 (即不论脊髓压迫程度,只要出现形变均视为 Kang′s 2 级)。因此,Kang′s 分级对脑脊液带和脊髓形态的轻微改变较为敏感,故前路直接减压、将骨化物移出椎管在改善 Kang′s 分级方面具有一定优势。尽管这无法完全阐释原位减压对于神经功能恢复的确切意义, 但从临床角度表明 ACAF 手术能够实现脊髓位置和形态的恢复, 对避免神经异常应力具有积极意义。C5 神经麻痹的重要发病机制之一是脊髓过度后漂或前移导致的神经根牵拉[31,32]。本研究中,ACAF 组 C5 神经麻痹发生 2 例,而 LAM 组发生 4 例,两者差异无统计学意义。回顾分析 ACAF 组 2 例出现 C5 神经麻痹的患者, 观察到 2 例均存在提拉相关的脊髓异位, 而其他患者则未出现类似情况。下面分别详述。

病例一:C5 椎体不对称提拉。45 岁男性,连续型骨化,行 ACAF 手术提拉 C3–C6 椎体。术后 24h 内出现左上肢上举无力。术后 3d 时 CT 示 C5 椎体后方骨化偏于右侧。同时被提拉的 C5 椎体并未垂直向腹侧移动,而是出现向右侧的偏移,导致椎管容积不对称扩大, 左腹侧出现一 “骨穴”。MRI 相应水平横断面示脑脊液向左腹侧扩张(图 4)。

病例二:C5 椎体过度提拉。47 岁男性,局限型骨化,行 ACAF 手术提拉 C4–C6 椎体。术后 24

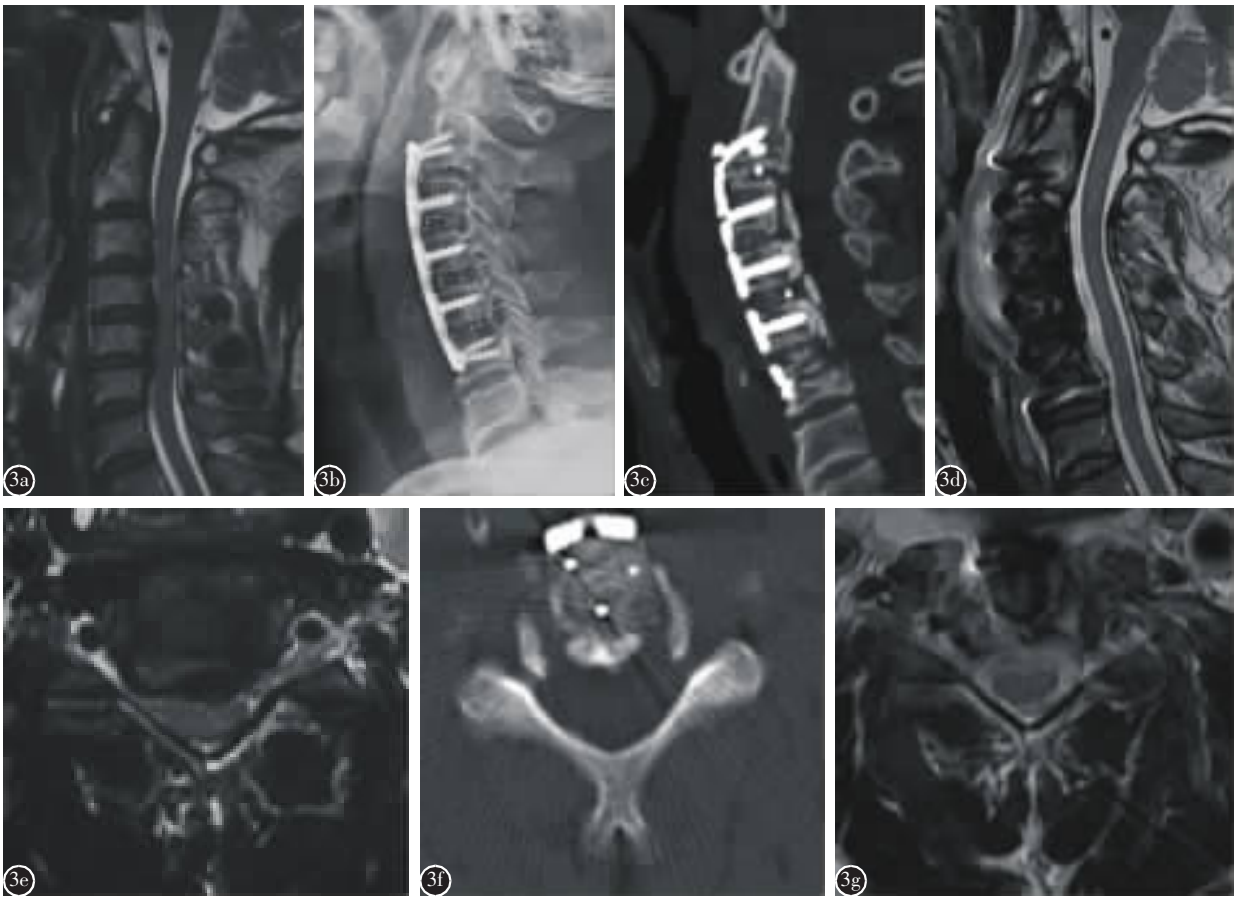

图 3 ACAF 病例术前及术后影像 **a** 术前 MRI 矢状面 **b** 术后 X 线侧位, 示提拉 C3–C5 **c** 术后 CT 矢状面 **d** 术后 MRI 矢状面 **e** 术前 C5 节段 MRI 横断面 **f** 术后 C5 节段 CT 横断面,示椎管空间在前方扩大 **g** 术后 C5 节段 MRI 横断面,示脊髓位置居中,两侧神经根走行对称

Figure 3 Images of ACAF before and after operation **a** Preoperative MRI sagittal plane **b** Postoperative X–ray lateral plane, showed the hoisted C3–C5 **c** Postoperative CT sagittal plane **d** Postoperative MRI sagittal plane **e** Preoperative MRI cross section at C5 level **f** Postoperative CT cross section at C5 level, showed the expansion of spinal canal space at the front **g** Postoperative MRI cross section at C5 level, showed the position of spinal cord on the mid–line and the symmetric path of the nerve roots

小时内出现左上肢上举无力。术后 3 天 CT 示:C5 椎体显著向腹侧移动,前移距离超过骨化物厚度,导致椎管前方容积明显扩大。MRI 相应水平横断面示脑脊液向腹侧膨胀,“填充” 于扩大的椎管前部空间(图 5)。

在 ACAF 术后发生 C5 神经麻痹的 2 例患者均可观察到一定程度的硬膜囊和(或)脊髓异位。产生这种现象的原因主要在于提拉后椎管空间未能恢复自然对称的形态。当硬膜囊和脑脊液因顺应椎管形态而发生明显的腹侧膨胀时, 脊髓可随之产生漂移,使神经根受到牵拉,导致 C5 神经麻痹发生。神经根牵拉效应(tethering effect)是 C5 神经麻痹发病机制的主流假说之一[33,34],最初用来解释脊髓后漂导致的神经麻痹。随着研究深入,脊髓前移与神经麻痹的相关性也逐渐受到关注。Odate 在针对前路椎体次全切除术的研究中发现, 手术开槽宽度小于 15mm 可有效防止硬膜囊和脊髓过度前移,C5 神经麻痹的发生率也明显减少。据此他提出,在致压物的作用下,颈髓发出的腹侧神经根可与硬膜发生粘连, 因而可随硬膜囊扩张一并移动[35],导致神经张力增高。Saunders 曾报道一项“前路限制性减压技术”,提出对于行椎体次全切除术的患者, 如把减压宽度从 20mm 降至 15mm,则可降低 C5 神经麻痹的发生率。然而这种做法却直接削弱了手术的减压效果[36,37]。Shiozaki 则发现,椎板成形术后早期(24h),硬膜囊迅速扩张, 此时脊髓可伴随硬膜囊扩张发生向后漂移。术后 2 周时硬膜囊稍微前移,脊髓初期的过度后漂状态得到缓解, 同时麻痹症状也逐渐恢复,表现出自限性特点[38]。尽管脊髓神经局部应力对神经功能的影响尚缺少统一量化的分析方法,但是在手术操作中仍应仅可能避免造成脊髓异位,以减少牵拉和其他异常应力形式的出现。

ACAF 手术的特点之一在于利用骨化物重建椎管前壁, 在保证充足减压宽度的同时避免硬膜囊和脊髓因缺少阻挡发生过度前移, 完成原位减压。本研究提示,为确保 ACAF 手术能够顺利重建椎管前壁, 术者必须在开槽和提拉过程中注意垂

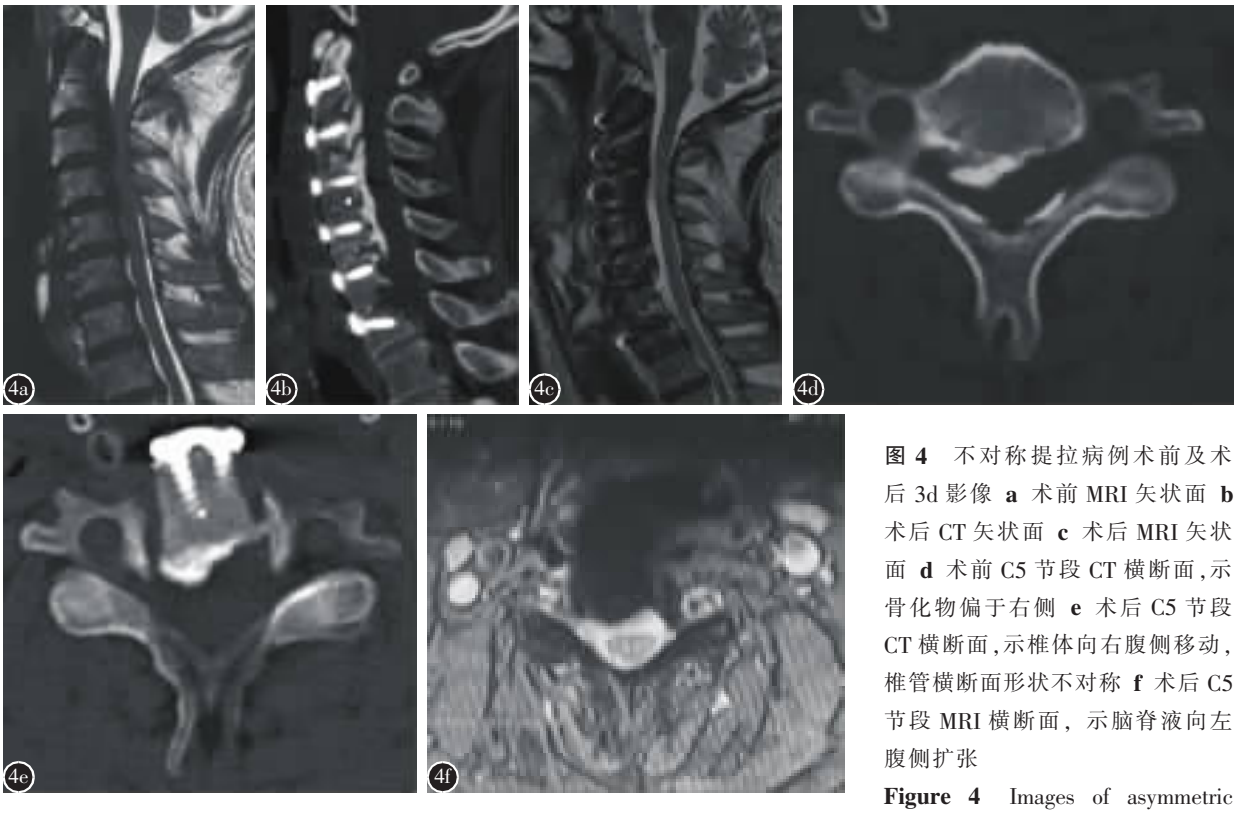

图 4 不对称提拉病例术前及术后 3d 影像 **a** 术前 MRI 矢状面 **b** 术后 CT 矢状面 **c** 术后 MRI 矢状面 **d** 术前 C5 节段 CT 横断面,示骨化物偏于右侧 **e** 术后 C5 节段 CT 横断面,示椎体向右腹侧移动,椎管横断面形状不对称 **f** 术后 C5 节段 MRI 横断面, 示脑脊液向左腹侧扩张

Figure 4 Images of asymmetric hoisting case before and 3 days after operation **a** Preoperative MRI sagittal plane **b** Postoperative CT sagittal plane **c** Postoperative MRI sagittal plane **d** Preoperative CT cross section at C5 level, showed ossification on the right side **e** Postoperative CT cross section at C5 level, showed the vertebra rotating to the right and the asymmetric cross-section of the spinal canal **f** Postoperative MRI cross section at C5 level, showed the expansion of CSF on the left ventral side

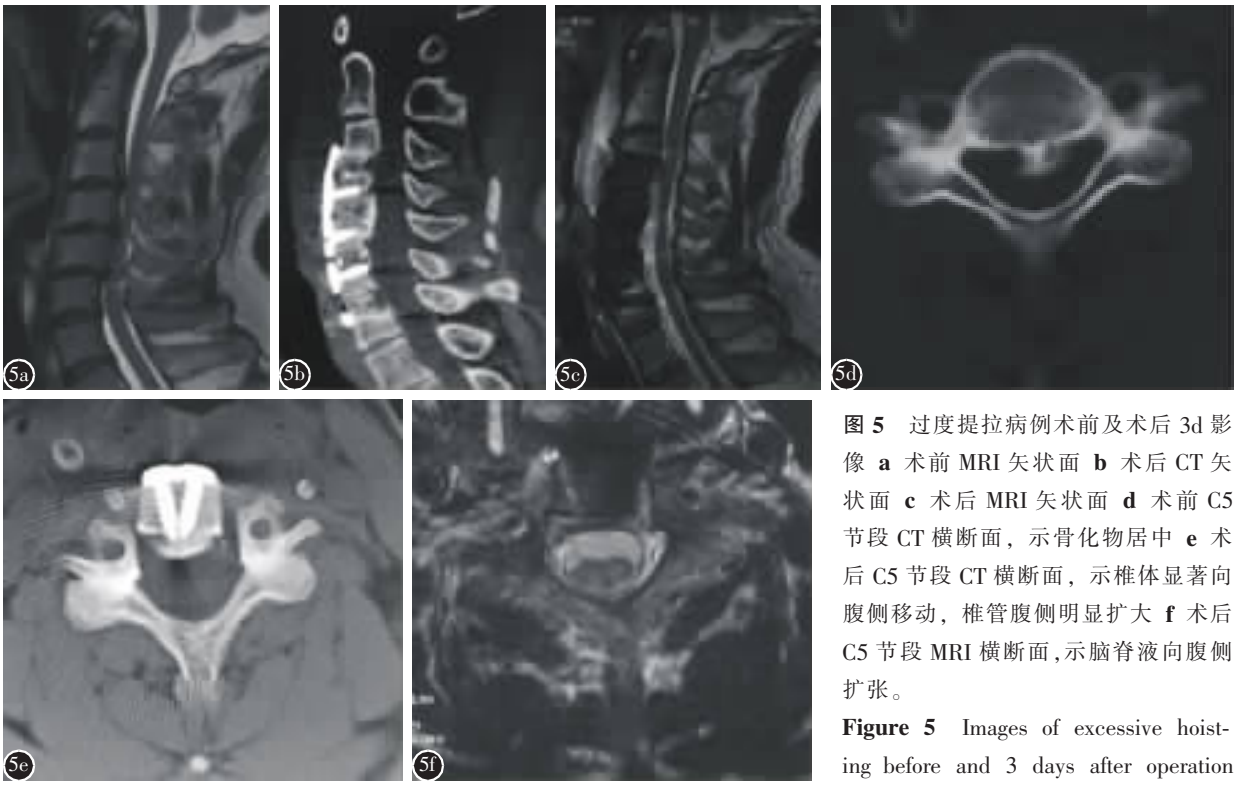

图 5 过度提拉病例术前及术后 3d 影像 **a** 术前 MRI 矢状面 **b** 术后 CT 矢状面 **c** 术后 MRI 矢状面 **d** 术前 C5 节段 CT 横断面，示骨化物居中 **e** 术后 C5 节段 CT 横断面，示椎体显著向腹侧移动，椎管腹侧明显扩大 **f** 术后 C5 节段 MRI 横断面，示脑脊液向腹侧扩张。

Figure 5 Images of excessive hoisting before and 3 days after operation **a** Preoperative MRI sagittal plane **b** Postoperative CT sagittal plane **c** Postoperative MRI sagittal plane **d** Preoperative CT cross section at C5 level, showed the ossification on the mid-line **e** Postoperative CT cross section at C5 level, showed the vertebra rotating ventrally and the ventral side of spinal canal expanding significantly **f** Postoperative MRI cross section at C5 level, showed the ventral expansion of CSF

直开槽和垂直提拉，从而确保椎体能沿中线向腹侧移动，避免出现单侧不对称提拉和脊髓偏移[39]。同时，术者需结合骨化物厚度和颈椎曲度确定适宜的提拉距离，防止过度提拉和脊髓过度前移的发生。理想的提拉以恢复椎管正常前后径为标准，即提拉后骨化物刚好移出椎管。因此理论上椎体前部骨质切除的厚度与后方骨化物厚度相等时可以实现理想提拉。但是，椎体实际提拉距离会受到预弯钛板曲度的影响，表现为曲度越大，提拉时椎体前表面与钛板间距离越大，实际提拉距离越大，导致椎管矢状径过度增加。因此，对颈椎曲度变直的患者安装预弯钛板进行纠正时，为避免提拉过度，需根据钛板预弯的目标曲度，适当减少椎前骨质切除厚度。术中可先预弯钛板置于椎前，利用神经剥离钩测量钛板-椎体间距，从而确定合理的椎前骨质切除厚度。

4 结论

ACAF 手术可以通过前移椎体-骨化物复合体完成对椎管容积和自然形态的重建，实现原位减压。在进行提拉椎体这一操作时，术者需特别注意提拉的方向和程度以确保良好的椎管前壁重建效果，从而恢复椎管自然形态，进而避免脊髓异位。在治疗颈椎长节段 OPLL 时，ACAF 手术与 LAM 手术均能获得良好的减压效果。而在恢复颈椎曲度和脊髓位置形态方面，ACAF 手术具有一定优势。

5 参考文献

1. Koda M, Mochizuki M, Konishi H, et al. Comparison of clinical outcomes between laminoplasty, posterior decompression with instrumented fusion, and anterior decompression with fusion for K-line (-) cervical ossification of the posterior longitudinal ligament [J]. Eur Spine J, 2016, 25(7): 2294-2301.
2. Liu W, Hu L, Chou PH, et al. Comparison of anterior decompression and fusion versus laminoplasty in the treatment of multilevel cervical ossification of the posterior longitudinal ligament: a systematic review and meta-analysis[J]. Ther Clin Risk Manag, 2016, 12: 675-685.

3. Wu JC, Chen YC, Huang WC. Ossification of the posterior longitudinal ligament in cervical spine: prevalence, management, and prognosis[J]. Neurospine, 2018, 15(1): 33-41.
4. Boody BS, Lendner M, Vaccaro AR. Ossification of the posterior longitudinal ligament in the cervical spine: a review [J]. Int Orthop, 2019, 43(4): 797-805.
5. Fargen KM, Cox JB, Hoh D J. Does ossification of the posterior longitudinal ligament progress after laminoplasty? Radiographic and clinical evidence of ossification of the posterior longitudinal ligament lesion growth and the risk factors for late neurologic deterioration[J]. J Neurosurg Spine, 2012, 17 (6): 512-524.
6. Lee CH, Sohn MJ, Lee CH, et al. Are there differences in the progression of ossification of the posterior longitudinal ligament following laminoplasty versus fusion? a Meta-analysis [J]. Spine(Phila Pa 1976), 2017, 42(12): 887-894.
7. Kawaguchi Y, Nakano M, Yasuda T, et al. Anterior decompressive surgery after cervical laminoplasty in patients with ossification of the posterior longitudinal ligament[J]. Spine J, 2014, 14(6): 955-963.
8. Zhang B, Sun J, Xu X, et al. Skip corpectomy and fusion (SCF) versus anterior controllable antedisplacement and fusion (ACAF): which is better for patients with multilevel cervical OPLL[J]. Arch Orthop Trauma Surg, 2019, 139(11): 1533-1541.
9. Yang H, Sun J, Shi J, et al. Anterior controllable antedisplacement fusion (acaf) for severe cervical ossification of the posterior longitudinal ligament: comparison with anterior cervical corpectomy with fusion(ACCF)[J]. World Neurosurg, 2018, 115: e428-436.
10. Sun K, Wang S, Sun J, et al. Analysis of the correlation between cerebrospinal fluid space and outcomes of anterior controllable antedisplacement and fusion for cervical myelopathy due to ossification of the posterior longitudinal ligament[J]. World Neurosurg, 2019, 122: e358-e66.
11. Sun J, Shi J, Xu X, et al. Anterior controllable antidisplacement and fusion surgery for the treatment of multilevel severe ossification of the posterior longitudinal ligament with myelopathy: preliminary clinical results of a novel technique [J]. Eur Spine J, 2018, 27(6): 1469-1478.
12. 陈广东, 杨惠林, 王根林, 等. 微型钛板在颈椎单开门椎管扩大椎板成形术中的应用 [J]. 中国脊柱脊髓杂志, 2010, 20 (10): 850-854.
13. Kang Y, Lee JW, Koh YH, et al. New MRI grading system for the cervical canal stenosis [J]. AJR Am J Roentgenol, 2011, 197(1): 134-140.
14. Chen Y, Guo Y, Chen D, et al. Diagnosis and surgery of ossification of posterior longitudinal ligament associated with dural ossification in the cervical spine[J]. Eur Spine J, 2009, 18(10): 1541-1547.
15. Yang H, Sun J, Shi J, et al. Anterior controllable antedisplacement fusion as a choice for 28 patients of cervical ossification of the posterior longitudinal ligament with dura ossification: the risk of cerebrospinal fluid leakage compared with anterior cervical corpectomy and fusion [J]. Euro Spine J, 2019, 28(2): 370-379.
16. 陈智, 黄轩, 李凤宁, 等. 颈椎前路术后吞咽困难的相关因素分析[J]. 中国脊柱脊髓杂志, 2012, 22(11): 979-983.
17. Kameyama T, Hashizume Y, Sobue G. Morphologic features of the normal human cadaveric spinal cord[J]. Spine(Phila Pa 1976), 1996, 21(11): 1285-1290.
18. Jones CF, Cripton PA, Kwon BK. Gross morphological changes of the spinal cord immediately after surgical decompression in a large animal model of traumatic spinal cord injury[J]. Spine(Phila Pa 1976), 2012, 37(15): E890-899.
19. Chu WC, Man GC, Lam WW, et al. Morphological and functional electrophysiological evidence of relative spinal cord tethering in adolescent idiopathic scoliosis [J]. Spine (Phila Pa 1976), 2008, 33(6): 673-680.
20. Fu Y, Pei X, Zhang J, et al. Morphological changes of the lower cervical spinal cord under neutral and fully flexed position by MRI in Chinese patients with Hirayama's disease [J]. Amyotroph Lateral Scler, 2008, 9(3): 156-162.
21. Panjabi M, White A, 3RD. Biomechanics of nonacute cervical spinal cord trauma[J]. Spine(Phila Pa 1976), 1988, 13(7): 838-842.
22. Shimizu K, Nakamura M, Nishikawa Y, et al. Spinal kyphosis causes demyelination and neuronal loss in the spinal cord: a new model of kyphotic deformity using juvenile Japanese small game fowls[J]. Spine(Phila Pa 1976), 2005, 30(21): 2388-2392.
23. Saunders RL. On the pathogenesis of the radiculopathy complicating multilevel corpectomy [J]. Neurosurgery, 1995, 37(3): 408.
24. Liu Y, Qi M, Chen H, et al. Comparative analysis of complications of different reconstructive techniques following anterior decompression for multilevel cervical spondylotic myelopathy[J]. Eur Spine J, 2012, 21(12): 2428-2435.
25. Scoville WB. Cervical spondylosis treated by bilateral facetectomy and laminectomy[J]. J Neurosurg, 1961, 18: 423-428.
26. Yamada S, Won DJ, Pezeshkpour G, et al. Pathophysiology of tethered cord syndrome and similar complex disorders [J]. Neurosurg Focus, 2007, 23(2): E6.
27. Fukushima T, Ikata T, Taoka Y, et al. Magnetic resonance imaging study on spinal cord plasticity in patients with cervical compression myelopathy [J]. Spine (Phila Pa 1976), 1991, 16(10 Suppl): S534-538.
28. Yang H, Sun J, Shi J, et al. In-situ decompression to spinal cord during anterior controllable antedisplacement fusion treating degenerative kyphosis with stenosis: surgical out-

comes and analysis of C5 nerve palsy based on 49 patients [J]. World Neurosurg, 2018, 115: E501–508.

29. Sun K, Wang S, Sun J, et al. Surgical outcomes after anterior controllable antedisplacement and fusion compared with single open–door laminoplasty: preliminary analysis of postoperative changes of spinal cord displacements on t2 – weighted magnetic resonance imaging [J]. World Neurosurg, 2019, 127: e288–298.
30. Nagata K, Kiyonaga K, Ohashi T, et al. Clinical value of magnetic resonance imaging for cervical myelopathy[J]. Spine (Phila Pa 1976), 1990, 15(11): 1088–1096.
31. Kawaguchi Y, Kanamori M, Ishihara H, et al. Minimum 10–year followup after en bloc cervical laminoplasty [J]. Clin Orthop Relat Res, 2003, 411: 129–139.
32. Denaro V, Longo UG, Berton A, et al. Favourable outcome of posterior decompression and stabilization in lordosis for cervical spondylotic myelopathy: the spinal cord "back shift" concept[J]. Eur Spine J, 2015, 24(Suppl 7): 826–831.
33. Hirabayashi K, Toyama Y, Chiba K. Expansive laminoplasty for myelopathy in ossification of the longitudinal ligament[J]. Clin Orthop Relat Res, 1999, 359: 35–48.
34. Tsuzuki N, Zhogshi L, Abe R, et al. Paralysis of the arm after posterior decompression of the cervical spinal cord [J]. Eur Spine J, 1993, 2(4): 191–196.
35. Beatty RA. Re: Odate S, Shikata J, Yamamura S, et al. Extremely wide and asymmetric anterior decompression causes postoperative C5 palsy[J]. Spine(Phila Pa 1976), 2014, 39(7): 632.
36. Saunders RL. On the pathogenesis of the radiculopathy complicating multilevel corpectomy[J]. Neurosurgery, 1995, 37 (3): 408–413.
37. Odate S, Shikata J, Yamamura S, et al. Extremely wide and asymmetric anterior decompression causes postoperative C5 palsy: an analysis of 32 patients with postoperative C5 palsy after anterior cervical decompression and fusion [J]. Spine (Phila Pa 1976), 2013, 38(25): 2184–2189.
38. Shiozaki T, Otsuka H, Nakata Y, et al. Spinal cord shift on magnetic resonance imaging at 24 hours after cervical laminoplasty[J]. Spine(Phila Pa 1976), 2009, 34(3): 274–279.
39. Sun J, Xu X, Wang Y, et al. How to avoid postoperative remaining ossification mass in anterior controllable antedisplacement and fusion surgery[J]. World Neurosurgery, 2019, 3: 100034.

（收稿日期：2020–01–03 修回日期：2020–03–06）
（英文编审 谭 啸）
（本文编辑 彭向峰）