临床论著

# 伴发 Chiari Ⅰ型畸形和脊髓空洞脊柱侧凸患者一期后路脊柱矫形术后 5 年以上随访结果

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**【摘要】目的**:分析一期后路脊柱矫形术治疗伴发 Chiari Ⅰ型畸形(Chiari Ⅰ malformation,CM1)和脊髓空洞(syringomyelia,SM)脊柱侧凸患者的 5 年以上随访结果。**方法**:2007 年 1 月~2015 年 6 月收治 23 例伴发 CM1 和 SM 的脊柱侧凸患者,男 19 例,女 4 例,年龄 10~39 岁(16.0±5.9 岁)。均行一期后路脊柱矫形术,其中 10 例行后路全脊椎截骨矫形术(posterior vertebral column resection,PVCR),13 例行单纯脊柱矫形而未行短缩截骨术。所有患者手术前后和随访时行全脊柱 X 线片、CT 及 MRI 检查,在全脊柱 X 线片上评价患者的矢状位和冠状位矫形率,在 MRI 上测量 SM 的大小及变化。根据 MRI 结果,取颈脊髓空洞张力指数(cervical syrinx tension ratio,CSTR)平均值作为描述颈段 SM 大小及变化的指标,将末次随访时 CSTR 下降≥20%定义为 SM 改善,并将患者分为颈段 SM 改善组和无改善组;再根据术中是否行脊柱短缩截骨术,将患者分为 PVCR 组和非 PVCR 组。记录患者性别、手术年龄、顶椎节段、冠状位主弯角度、矢状位后凸角度、畸形角度比(deformity angular ratio,DAR)、SM 长度、平均 CSTR、术前牵引情况、融合节段数量、末次随访时冠状面矫形率与矢状面矫形率、SM 改善情况、随访时间等,并进行统计学分析。两组间定量变量的差异采用独立样本 $t$ 检验的方法进行比较,定性变量差异采用 $\chi^2$ 检验。**结果**:随访时间为 6.2±1.1 年(5~9 年)。术前冠状位主弯角度为 77.1°±28.0°(33°~122°),术后减少至 27.8°±18.4°,末次随访时为 29.5°±21.2°,冠状面侧凸矫正率为(65.7±13.0)%。术前矢状面后凸角度为 57.2°±31.9°(8°~155°),术后减少至 29.3°±15.2°,末次随访时为 32.4°±16.5°,矢状面后凸矫正率为(48.4±22.6)%。所有病例未见内固定螺钉松动、断裂,骨性融合均良好,无术后神经功能损害。CSTR 改善率为 47.8%(11/23),SM 改善组 11 例,SM 无改善组 12 例。SM 改善组患者的平均手术年龄(18.6±7.5 岁 vs. 13.7±2.4 岁,$P$=0.040)、接受 PVCR 术治疗的比例(81.8% vs. 16.7%,$P$=0.012)和融合节段数(14.2±0.9 vs. 12.3±2.9,$P$=0.044)均高于 SM 无改善组患者;而性别、顶椎节段、冠状位主弯角度、矢状位后凸角度、DAR、SM 长度、平均 CSTR、术前牵引运用、畸形矫正率和随访时间两组间比较均无统计学差异($P$>0.05)。PVCR 组患者较非 PVCR 组有更严重的侧凸畸形(98.8°±13.8° vs. 60.5°±24.5°,$P$=0.000)和后凸畸形(74.8°±37.5° vs. 43.6°±18.6°,$P$=0.032)、有更大的冠状面 DAR(15.6°±4.2°/节段 vs. 10.2°±4.2°/节段,$P$=0.006)和矢状面 DAR(12.0°±7.6°/节段 vs. 6.7°±3.9°/节段,$P$=0.040)、总 DAR(26.8°±11.4°/节段 vs. 15.3°±6.5°/节段,$P$=0.006)及更常接受术前牵引治疗(70.0% vs. 23.1%,$P$=0.024)、有更长的融合节段数(14.2±1.2 节段 vs. 12.4±2.7 节段,$P$=0.045)和 SM 获得更高的改善率(80.0% vs. 23.1%,$P$=0.007);而性别、平均手术年龄、顶椎节段、SM 长度、平均 CSTR、畸形矫正率和随访时间两组间比较均无统计学差异($P$>0.05)。**结论**:一期后路脊柱矫形术是治疗术前无明显神经功能受损表现的伴发 CM Ⅰ和 SM 脊柱侧凸患者的一种选择,可以在无需先行神经外科减压手术的前提下实现一期安全、有效的脊柱矫形,稳定和持续性改善大多数患者的 SM。

**【关键词】**脊柱侧凸;Chiari 畸形;脊髓空洞;外科矫形;随访结果
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**The follow-up outcomes of more than 5 years after one-stage posterior correction of scoliosis with Chiari Ⅰ malformation and syringomyelia/XIA Gushang, XIE Jingming, WANG Yingsong, et al//Chi-**

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**【Abstract】 Objectives:** To analyze the more than 5 years′ follow-up outcomes of scoliosis with Chiari Ⅰ malformation(CM1) and syringomyelia(SM) treated by one-stage spinal correction. **Methods:** A retrospective study was performed on 23 patients with CM1 and SM associated scoliosis treated from January 2007 to June 2015. The patients had complete clinical data and were followed up for more than 5 years after one-stage spinal correction. There were 19 males and 4 females with an average age of 16.0±5.9(range, 10–39) years old. The one-stage spinal correction was performed on all the patients, including 10 patients with posterior vertebral column resection (PVCR), 13 patients with simple spinal correction without shortening osteotomy. The spinal radiographs were obtained from all patients preoperatively, postoperatively and at final follow-up. Syringomyelia size and change were measured based on the results of MRI. According to full-spine standing radiographs, the spine sagittal and coronal correction rate were evaluated. According to the results of MRI, the average cervical syrinx tension ratio(CSTR) was used as an indicator of syrinx size and change, and a ≥20% decline was set as a boundary of syrinx improvement at the final follow-up. According to the degree of CSTR decline, all the cases were divided into two groups: with or without cervical SM improvement. And the cases were also divided into with or without PVCR based on whether the spinal shortening osteotomy was performed intraoperatively. Then gender, age at surgery, apical level, main scoliosis, kyphosis, deformity angular ratio (DAR), length of syrinx, average CSTR, preop traction, No. of fusion segments, coronal correction rate, sagittal correction rate, syrinx improvement, and period of the follow-up were compared separately. Differences between two groups were assessed by independent *t* test, and categorical variables were compared using Chi-square test. **Results:** The average follow-up period of all patients was 6.2±1.1 years(range, 5–9 years). The average scoliosis angle reduced from 77.1°±28.0° before surgery to 27.8°±18.4° after surgery and 29.5°±21.2° at the final follow-up, with a correction rate of scoliosis of (65.7±13.0)%. The average kyphosis angle reduced from 57.2°±31.9° to 29.3°±15.2° after surgery and 32.4°±16.5° at final follow-up, with a correction rate of kyphosis of (48.4±22.6)%. At final follow-up, the spinal correction and fusion were satisfied, and no patient experienced deterioration of neurological function. In all patients, the improvement rate of CSTR was 47.8%. There were 11 patients in the syrinx improvement group and 12 patients in the without syrinx improvement group. Of patients with syrinx improvement, the mean age at surgery was bigger(18.6±7.5 years vs. 13.7±2.4 years, *P*=0.040), the frequency of undergoing PVCR was more (81.8% vs. 16.7%, *P*=0.012), and the number of fusion segments was bigger(14.2±0.9 vs. 12.3±2.9, *P*=0.044) than those in the group without syrinx improvement. However, there was no significant difference in gender, apical level, main scoliosis, kyphosis, DAR, length of syrinx, average CSTR, preop traction, coronal correction rate, sagittal correction rate, and the follow-up period(*P*>0.05). The patients who underwent PVCR had severer scoliosis (98.8°±13.8° vs. 60.5°±24.5°, *P*=0.000) and kyphosis(74.8°±37.5° vs 43.6°±18.6°, *P*=0.032), as well as greater coronal DAR(15.6°±4.2° per level vs. 10.2°±4.2° per level, *P*=0.006), sagittal DAR(12.0°±7.6° per level vs. 6.7°±3.9° per level, *P*=0.040) and total DAR (26.8°±11.4° per level vs. 15.3°±6.5° per level, *P*=0.006) than those without PVCR. There were more frequent uses of preoperative traction(70.0% vs. 23.1%, *P*=0.024), longer fusion segments (14.2±1.2 levels vs. 12.4±2.7 levels, *P*=0.045), and higher syrinx improvement rate (80.0% vs. 23.1%, *P*=0.007) in the patients with PVCR. However, there was no significant difference in gender, age at surgery, apical level, length of syrinx, averaging CSTR, coronal correction rate, sagittal correction rate, and the follow-up period (*P*>0.05). **Conclusions:** One-stage spinal correction can be another good choice in selected patients without preoperative clinically detectable neurologic deficit of CM1 and SM associated scoliosis, which not only achieves safe spinal correction without neurological intervention, but also steadily improves and stabilizes SM in most patients.

**【Key words】** Scoliosis; Chiari malformation; Syringomyelia; Surgical correction; Follow-up outcomes

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Chiari畸形(Chiari malformation,CM)和脊髓空洞(syringomyelia,SM)是由先天性发育异常所致,CM 是一组涉及脑干、小脑和上段脊髓的先天性畸形,分为Ⅰ~Ⅳ型[1],主要病变特征表现为小脑扁桃体等结构疝入枕骨大孔以下;SM 则主要表现为脊髓中央管内异常液体积聚而呈筒样串联,可以在颈髓或上胸段脊髓内发生,也可向上、向下延展,是最常见的椎管内畸形。椎管内畸形常与脊柱侧凸相伴发,20%~60%的脊柱侧凸患者合并有 SM[2-4];在以 SM 首诊的患者中,25%~85%可伴发不同程度脊柱侧凸[5,6]。此外,脊柱侧凸也见于 13%~36%的 Chiari Ⅰ型畸形(Chiari Ⅰ malformation,CM1)患者中[3,7-9],在同时伴发有 CM 1和 SM 的患者中,脊柱侧凸的发生率高达 71%~85%[10-12]。对于伴发 CM1和 SM 的脊柱侧凸患者,最佳的治疗方案目前尚未达成共识。为避免一期脊柱矫形潜在的神经损伤风险,对于此类患者的传统治疗策略是在矫正脊柱侧凸前先行神经外科干预[13]。近年来,随着对伴发 CM1 和 SM 脊柱侧凸认识的深入和术中神经监测(intraoperation neurological monitoring,INM)技术的发展,在无需神经外科减压情况下,已有脊柱外科医生对此类患者开始尝试行一期后路脊柱直接矫形[14,15]。但目前尚缺乏关于采用这种治疗策略对伴发 SM 预后潜在影响的证据。本研究回顾性分析 23 例伴发 CM1 和 SM 脊柱侧凸患者接受一期后路脊柱矫形术治疗后 5 年以上随访观察的结果,同时对可能影响这类患者 SM 预后的潜在因素进行探讨。

## 1 资料与方法

### 1.1 纳入与排除标准

纳入标准:(1)CM1:小脑扁桃体下疝至枕骨大孔水平以下≥5mm;(2)颈脊髓为主型 SM:空洞主要位于颈段脊髓;(3)脊柱侧凸、CM1、颈段 SM 三者均见于同一患者且无明显神经功能受损表现;(4)随访时间≥5 年。排除标准:(1)任何曾接受过神经外科手术,如枕骨大孔减压术、SM 分流术等的患者;(2)既往有脊柱手术史者;(3)其他原因引起的脊柱畸形,包括先天性、结缔组织性、综合征等;(4)空洞仅位于胸段。

### 1.2 一般资料

根据纳入与排除标准,选取 2007 年 1 月~2015 年 6 月在本中心采用一期后路脊柱矫形术治疗的 23 例伴发 CM1 和 SM 脊柱侧凸患者作为研究对象,其中男 19 例,女 4 例,年龄 10~39 岁(16.0±5.9 岁)。手术均在本院骨科由同一教授团队进行,患者均知情同意,研究经伦理委员会批准。

### 1.3 治疗方法

均行一期后路脊柱矫形融合椎弓根螺钉内固定术。其中 10 例(男 8 例,女 2 例)患者行脊柱短缩截骨术,即后路全脊椎截骨术(posterior vertebral column resection,PVCR):全身麻醉,患者取俯卧位,采用后正中切开,骨膜下剥离显露融合节段内的脊柱后部骨性结构,采用徒手椎弓根螺钉置入方法进行置钉,并透视确定椎弓根螺钉位置的准确性。通过切除顶椎区拟进行截骨节段脊柱后方椎板、小关节,分别经凸侧、凹侧经椎弓根切除前方椎体及其相邻上下节段椎间盘及软骨板,并切除椎管前壁骨质结构,完成对侧凸顶椎行全脊椎切除。建立矫形间隙后,首先加压实现脊柱短缩,继以开放-闭合及提拉、旋棒等矫形力获得矫形。若矫形后切除脊椎间隙残留高度过大,可在截骨间隙内适当填充钛笼;若间隙小,则间隙内以自体骨打压植骨。完成矫形后,充分制作植骨床,利用自体骨(或同种异体骨)进行植骨融合。13 例(男 11 例,女 2 例)患者行单纯脊柱畸形矫形:广泛剥离椎旁组织充分松解顶椎区后,先于凸侧钉棒加压获得大部分矫形;再于凹侧上棒,依靠器械提供提拉、旋棒等矫形力矫形。术中注意脊柱整体力线。完成矫形后,充分制作植骨床,利用自体骨(或同种异体骨)进行植骨融合。所有手术均在脊髓电生理监测下进行,且术中常规行多次 Stagnara 唤醒试验,以判断术中是否出现脊髓、神经损伤并发症。

### 1.4 影像学与临床评估指标

所有患者均行手术前后和随访时的全脊柱 X 线片、CT 及 MRI 检查,详细收集术前影像学资料,包括脊柱畸形和 SM 的形态。基于站立位脊柱全长 X 线片,脊柱侧凸主弯的形态学数据包括:顶椎节段、冠状位 Cobb 角、矢状位后凸角、畸形角度比(deformity angular ratio,DAR)。DAR 是主弯的 Cobb 角与参与主弯构成的椎体节段数之比,包括冠状面 DAR、矢状面 DAR 和总 DAR[16]。根据 T2 加权像 MRI 结果,通过空洞累及脊髓长度和大小来量化 SM 的形态:测量 SM 在矢状位

跨越脊髓对应椎体节段数量和计算轴位像脊髓空洞张力指数(syrinx tension ratio,STR)。STR 被定义为是在同一横断面上空洞最大横径与矢状径之和除以脊髓最大横径与矢状径之和所得比值（图 1)。对于颈脊髓为主型 SM 患者,分别在 C2、C4、C6 颈椎的下终板水平测量 STR,并取平均值。治疗过程中相关评估指标收集包括术前是否使用牵引、术中内置物固定/融合的节段数、是否行椎体短缩截骨术(PVCR)等。

**1.5** 分组

在末次随访时,根据颈椎 MRI,每个测量水平上空洞的最大横径、最大矢状径和脊髓的最大横径、最大矢状径分别测量 2 次,取平均值为最终测量结果，并计算出颈脊髓空洞张力指数(cervical syrinx tension ratio,CSTR)的平均值,并将平均 CSTR 减少≥20%定义为 SM 改善。根据 SM 有无改善，将所有患者分为两组进行比较分析后找出与 SM 改善有关的因素。同时,根据是否行 PVCR,将所有患者分为两组后进一步比较,以论证脊柱短缩截骨术对 SM 的影响。

**1.6** 统计学分析

采用 SPSS 统计软件包进行统计分析。计量资料以平均数±标准差($\bar{x}\pm s$)进行统计描述。采用独立样本 $t$ 检验评估两组间的差异；使用 $\chi^2$ 检验比较分类变量。$P$<0.05 为差异有统计学意义。

## 2 结果

术前脊柱全长 X 线片上，冠状面主弯 Cobb 角为 77.1°±28.0°(33°~122°)，矢状面后凸角为 57.2°±31.9°(8°~155°)。12 例患者顶椎位于 T4~T10,11 例患者顶椎位于 T11~L2。冠状面 DAR、矢状面 DAR 和总 DAR 分别为 12.6°±4.9°/节段(4.7°~22.0°/节段)、9.0°±6.2°/节段（1.6°~31.0°/节段)、20.3°±10.5°/节段（4.7°~53.0°/节段)。根据术前 MRI 检查,SM 长度为 13.8±5.1 节段(2~19 节段),CSTR 为 0.4±0.2(0.1~0.9)。10 例患者术前接受了颅骨–股骨牵引治疗。手术矫形中,融合椎体节段数为 13.2±2.3 节段(7~16 节段),其中 43.5%(10/23)的患者接受脊柱短缩截骨术(PVCR)治疗。患者随访时间为 6.2±1.1 年(5~9 年)。术前、术后及末次随访时脊柱侧凸角和脊柱后凸角见表 1,术后及末次随访时脊柱侧凸角和脊柱后凸角与术前比较有统计学差异($P$<0.05),所有病例未见内固定螺钉松动、断裂,骨性融合均良好(图 2)。对于伴发 SM,11 例(47.8%)患者的平均 CSTR 减少≥20%(图 3)，纳入 SM 改善组；而其余 12 例(52.2%）患者的平均 CSTR 减少<20%，纳入 SM 无改善组:其中,10 例患者的 SM 较为稳定(8 例平均 CSTR 减少 1.1%~16.5%;2 例无改变)，仅 2 例患者平均 CSTR 增加，分别增加了 4.5%和 27.1%。无患者因脊柱矫形术后 CM 或 SM 恶化而接受进一步神经外科干预。

**2.1** SM 改善与 SM 无改善患者的比较

SM 改善组患者的平均手术年龄、接受 PVCR 术治疗的比例、融合节段数均高于 SM 无改善组患者($P$<0.05),而性别、顶椎节段、冠状位主弯角度、矢状位后凸角度、DAR、SM 长度、平均 CSTR、术前牵引运用、畸形矫正率和随访时间两组间比较均无统计学差异($P$>0.05,表 2)。

**2.2** 行 PVCR 治疗与非 PVCR 治疗患者的比较

行 PVCR 治疗组患者较非 PVCR 治疗组患者有更严重的侧凸畸形和后凸畸形，同时也具有更大的冠状面 DAR、矢状面 DAR 和总 DAR（$P$<0.05)。在治疗过程中,行 PVCR 治疗组患者更常

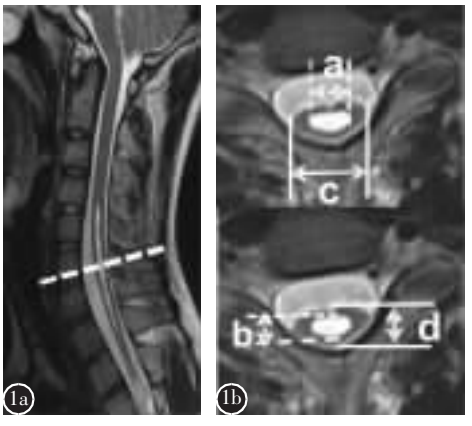


**图 1** 在 MRI T2 加权像上测量脊髓空洞张力指数 **a** 在矢状面成像中,测量水平被确定(C6 下终板),测量应垂直于脊髓空洞的纵轴 **b** 在横切面成像上,分别测量空洞的最大横径(a)和脊髓的最大横径(c),空洞的最大矢状径(b)和脊髓最大矢状径(d),将(a+b)/(c+d)的比值定义为脊髓空洞张力指数(STR)

**Figure 1** Measurement of syrinx tension ratio(STR) by T2-weighted MR imaging **a** On sagittal imaging, the measure level was decided (C6 lower endplate), which should be vertical to the axis of syrinx **b** On transverse imaging, maximal trans diameters of syrinx (a) and the cord (c), maximal sagittal diameters of syrinx(b) and the cord(b) were measured respectively, the ratio of (a+b)/(c+d) was defined as STR

接受术前牵引治疗、具有更长的融合节段数($P$<0.05)。在末次随访时,80.0%接受 PVCR 治疗的患者获得空洞改善;与之相比,非 PVCR 治疗的患者仅 23.1%获得空洞改善($P$=0.007)。而性别、平均手术年龄、脊柱侧凸的顶椎节段、SM 长度、平均 CSTR、畸形矫正率和随访时间两组间比较均无统计学意义($P$>0.05,表 3)。

**表 1 术前、术后及末次随访时脊柱侧凸角和脊柱后凸角**

**Table 1** The scoliosis angle and kyphosis angle before surgery, after surgery and at final follow-up

| | 侧凸 Scoliosis | 后凸 Kyphosis |
|---|---|---|
| 术前(°) Preoperation | 77.1±28.0 | 57.2±31.9 |
| 术后(°) Postoperation | 27.8±18.4① | 29.3±15.2① |
| 术后矫正率(%) Correction rate at postoperation | 67.4±20.8 | 51.5±21.7 |
| 末次随访(°) Final follow-up | 29.5±21.1① | 32.4±16.5① |
| 末次随访矫正率(%) Correction rate at the final follow-up | 65.7±13.0 | 48.4±22.6 |
| 矫正丢失率(%) Lost rate of correction | 6.1±.5.4 | 10.6±19.3 |

注:①与术前比较 $P$<0.05

Note: ①Compared with preoperative data, $P$<0.05

## 3 讨论

对于进展中的伴发 CM1 和 SM 脊柱侧凸患者,治疗的主要目的包括矫正和稳定脊柱畸形,避免神经功能恶化。对于这类患者,由于病态脊髓的存在,进一步增加了脊髓的张力,降低了脊髓对侧凸矫形时脊柱位移、脊髓移位、脑脊液(cerebrospinal fluid,CSF)压力变化的耐受性,而面临更高的围手术期神经并发症,故对于伴发 CM1 和 SM 脊柱侧凸患者的治疗策略需要更加谨慎和有预见性。对于此类患者最佳的治疗方案目前尚未达成共识,但是对于仍在进展和/或重度的脊柱侧凸患者而言,外科手术干预常不可避免[17]。传统治疗方案建议先行神经外科干预,以期解除枕颈部压迫和阻塞以及获得脊髓减压[18]。如果行枕骨大孔减压术(foramen magnum decompression,FMD)不能有效缩小空洞,则需要考虑包括脊髓空洞分流术(syrinx-shunting)等在内的进一步处理[19-22]。根据既往病因学认识,通过神经外科干预有望延缓、停止甚至改善伴发 CM1 和 SM 脊柱侧凸的进展。在部分年龄较小的轻度脊柱侧凸患者中,神经外科干预有机会获得脊柱侧凸进展停止甚至好转而避免后期的脊柱矫形手术[8,11,23,24]。然而,针对颅

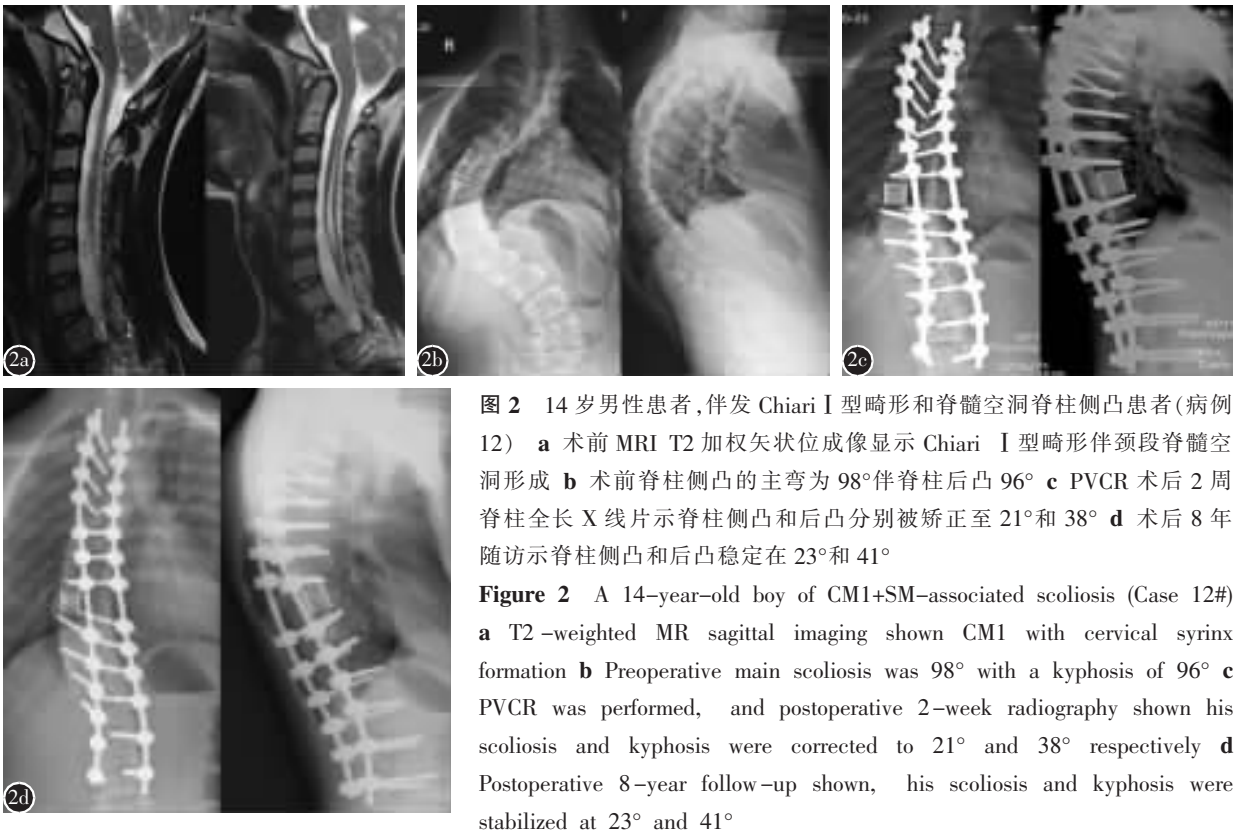


**图 2** 14 岁男性患者,伴发 Chiari Ⅰ型畸形和脊髓空洞脊柱侧凸患者(病例 12) **a** 术前 MRI T2 加权矢状位成像显示 Chiari Ⅰ型畸形伴颈段脊髓空洞形成 **b** 术前脊柱侧凸的主弯为 98°伴脊柱后凸 96° **c** PVCR 术后 2 周脊柱全长 X 线片示脊柱侧凸和后凸分别被矫正至 21°和 38° **d** 术后 8 年随访示脊柱侧凸和后凸稳定在 23°和 41°

**Figure 2** A 14-year-old boy of CM1+SM-associated scoliosis (Case 12#) **a** T2-weighted MR sagittal imaging shown CM1 with cervical syrinx formation **b** Preoperative main scoliosis was 98° with a kyphosis of 96° **c** PVCR was performed, and postoperative 2-week radiography shown his scoliosis and kyphosis were corrected to 21° and 38° respectively **d** Postoperative 8-year follow-up shown, his scoliosis and kyphosis were stabilized at 23° and 41°

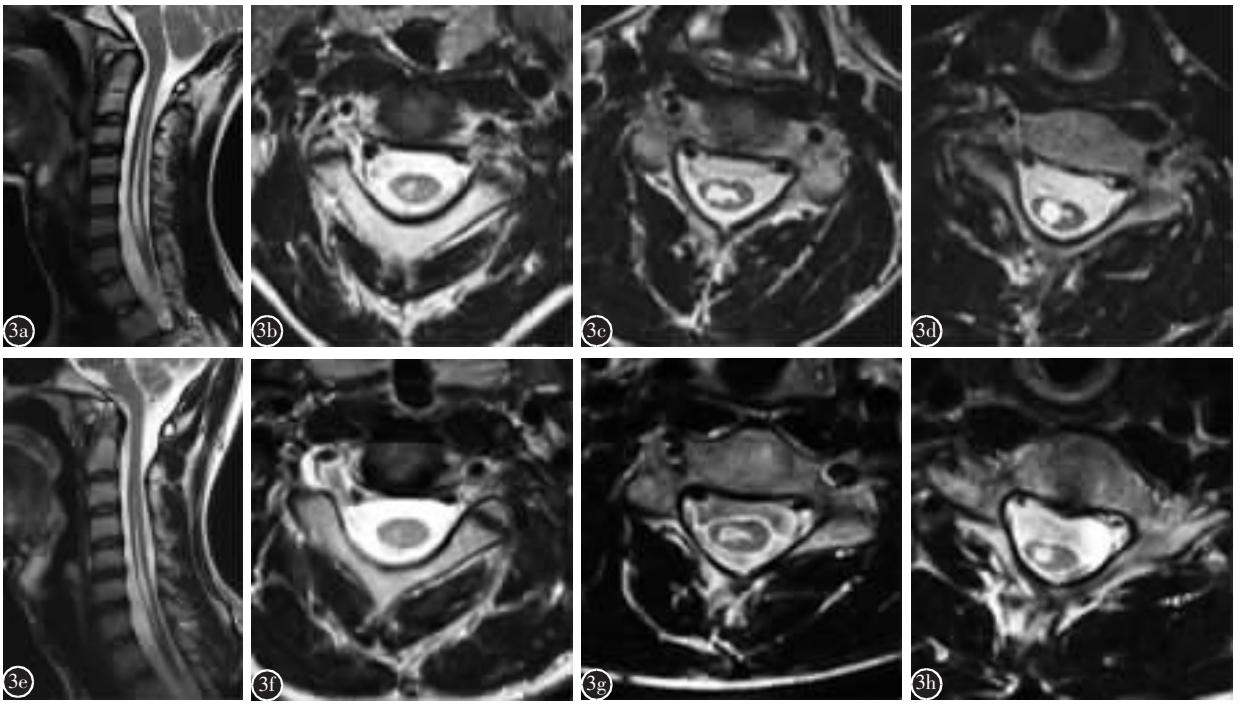


**图 3** 病例 12 一期脊柱矫形术后脊髓空洞改善(MRI T2 加权像) **a** 术前矢状位成像显示颈段脊髓有空洞 **b~d** 分别为术前 C2、C4、C6 下终板水平的横切面成像,平均颈脊髓空洞张力指数(CSTR)为 0.46 **e** 在术后 8 年随访时,矢状位成像显示颈段脊髓空洞长度缩短 **f~h** 分别为术后 8 年随访时 C2、C4、C6 下终板水平的横切面成像,显示脊髓空洞缩小,平均 CSTR 降至 0.31,脊髓空洞改善率为 32.6%

**Figure 3** Syrinx improvement after one-stage spinal correction of the same boy (T2-weighted MR imaging) (Case 12#) **a** Preoperative sagittal imaging shown a syrinx in the cervical cord **b–d** Preoperative transverse imaging at C2, C4, C6 levels, and the average CSTR was 0.46 **e** At his postoperative 8-year follow-up, sagittal imaging shown shortening length of the cervical syrinx **f–h** Postoperative transverse imaging at C2, C4, C6 levels shown reduced sizes of syrinx and reduced average CSTR to 0.31, and the improvement rate of syrinx was 32.6%

颈交界区畸形及 SM 的传统神经外科减压手术虽可获得 SM 缩小和神经症状改善,但却难以有效稳定或改善中重度脊柱侧凸患者的脊柱畸形,63%的患者在神经外科干预后侧凸仍然明显进展,甚至快速进展[8,25]。对于这些患者脊柱畸形矫形/融合术将是不可避免的[25]。此外,首先进行神经外科干预的另一方面考虑源于希望通过神经外科减压手术以期改善脊髓牵张,降低后期矫形风险。但神经外科减压手术本身也存在潜在的手术风险以及反复的手术将增加患者的痛苦和经济负担[26,27]。近年来,一些临床研究报道了在无需先前神经外科减压手术情况下尝试一期直接脊柱矫形术治疗伴发 CM1 和 SM 脊柱侧凸的成功经验,尤其是对于那些无明显神经功能受损的患者[14,15,28]。这些研究虽然包括的病例数有限,但使这类患者有机会避免多次手术。然而,并非所有伴发 CM1 和 SM 脊柱侧凸患者均适宜直接行一期后路脊柱矫形术。巨大 SM、术前有明显神经功能受损、较高的神经监测困难率都大大增加了这类患者接受一期脊柱矫形术时的潜在神经损伤风险[25,29]。因此,慎重选择恰当的病例对于一期脊柱矫形术的成功至关重要。经过严格评估后,选择术前无明显神经功能受损表现的伴发 CM1 和 SM 脊柱侧凸患者行一期后路脊柱矫形融合椎弓根螺钉内固定术。而对于已出现神经功能受损症状的患者(包括感觉、运动障碍和/或括约肌功能障碍),仍建议首先接受神经外科的干预和治疗。既往文献中依据空洞形态的不同可将其分为三种类型:肿胀型、纺锤型和裂隙型[30,31]。根据我们的经验,对于肿胀型 SM 患者、已存在或术前牵引诱发明显神经功能受损患者,并不适宜接受一期脊柱矫形术[32]。对于这些患者,首先接受神经外科干预将是最佳的选择。而对于那些无明显神经功能受损的患者,虽然病态脊髓的存在增加了围手术期的神经损伤风

**表 2 脊髓空洞改善与空洞无改善患者资料的比较**

**Table 2** Comparison of data between patients with and without syrinx improvement

| | 空洞改善组（*n*=11）With syrinx improvement | 空洞无改善组（*n*=12）Without syrinx improvement | *P*值 *P* value |
|---|---|---|---|
| 性别 Gender | | | 1.000 |
| 男 Male | 9(81.8%) | 10(83.3%) | |
| 女 Female | 2(18.2%) | 2(16.7%) | |
| 手术年龄（岁）Age at surgery(years) | 18.64±7.46 | 13.67±2.43 | 0.040① |
| 顶椎节段 Apical level | | | 0.827 |
| T4~T10 | 6(54.5%) | 6(50.0%) | |
| T11~L2 | 5(45.5%) | 6(50.0%) | |
| 主弯角度（°）Main scoliosis | 88.5±24.2 | 72.1±27.1 | 0.142 |
| 后凸角（°）Kyphosis | 61.6±25.8 | 53.1±37.3 | 0.533 |
| 畸形角度比 DAR(°/节段 level) | | | |
| 冠状面 DAR Coronal DAR | 13.8±4.6 | 11.5±5.2 | 0.287 |
| 矢状面 DAR Sagittal DAR | 9.6±3.9 | 8.5±8.0 | 0.705 |
| 总 DAR Total DAR | 22.2±8.6 | 18.6±12.1 | 0.425 |
| 脊髓空洞的长度（节段）Length of syrinx(levels) | 13.7±4.6 | 13.9±5.7 | 0.931 |
| 颈脊髓空洞张力指数 CSTR | 0.4±0.3 | 0.5±0.2 | 0.296 |
| 术前牵引 Preop traction | | | 0.100 |
| 是 Yes | 7(63.6%) | 3(25.0%) | |
| 否 No | 4(36.4%) | 9(75.0%) | |
| 脊柱短缩截骨术（PVCR）Spinal shortening osteotomy | | | 0.012① |
| 是 Yes | 9(81.8%) | 2(16.7%) | |
| 否 No | 2(18.2%) | 10(83.3%) | |
| 融合节段数量（节段）No. of fusion segments(levels) | 14.2±0.9 | 12.3±2.9 | 0.044① |
| 冠状面矫形率（%）Coronal correction rate | 65.2±9.0 | 66.9±17.2 | 0.775 |
| 矢状面矫形率（%）Sagittal correction rate | 48.2±18.1 | 48.6±26.9 | 0.971 |
| 随访时间（年）Follow-up (years) | 6.1±0.9 | 6.4±1.3 | 0.496 |

注：①*P*<0.05

Note: ①indicates *P*<0.05. DAR, deformity angular ratio; CSTR, cervical syrinx tension ratio

**表 3 行 PVCR 与非 PVCR 治疗患者资料的比较**

**Table 3** Comparison of data between patients with and without PVCR

| | PVCR治疗（*n*=10）With PVCR | 非 PVCR 治疗（*n*=13）Without PVCR | *P*值 *P* value |
|---|---|---|---|
| 性别（男/女）Gender(M/F) | 8/2 | 11/2 | 0.772 |
| 手术年龄（岁）Age at surgery(years) | 18.7±7.6 | 14.0±3.2 | 0.056 |
| 顶椎节段 Apical level | | | 0.855 |
| T4~T10 | 5(50.0%) | 7(53.8%) | |
| T11~L2 | 5(50.0%) | 6(46.2%) | |
| 主弯角度（°）Main scoliosis | 98.8±13.8 | 60.5±24.5 | 0.000 |
| 后凸角（°）Kyphosis | 74.8±37.5 | 43.6±18.6 | 0.032 |
| DAR(°/节段 level) | | | |
| 冠状面 Coronal | 15.6±4.2 | 10.2±4.2 | 0.006 |
| 矢状面 Sagittal | 12.0±7.6 | 6.7±3.9 | 0.040 |
| 总计 Total | 26.8±11.4 | 15.3±6.5 | 0.006 |
| 脊髓空洞的长度（节段）Length of syrinx(levels) | 13.9±5.7 | 13.8±4.8 | 0.953 |
| CSTR | 0.38±0.25 | 0.42±0.23 | 0.648 |
| 术前牵引 Preop traction | | | 0.024 |
| 是 Yes | 7(70.0%) | 3(23.1%) | |
| 否 No | 3(30.0%) | 10(76.9%) | |
| 融合节段数量（节段）No. of fusion segments | 14.2±1.2 | 12.4±2.7 | 0.045 |
| 冠状面矫形率（%）Coronal correction rate | 65.7±11.4 | 65.7±14.6 | 0.994 |
| 矢状面矫形率（%）Sagittal correction rate | 51.0±16.9 | 46.4±26.6 | 0.641 |
| 空洞改善 Syrinx improvement | | | 0.007 |
| 是 Yes | 8(80.0%) | 3(23.1%) | |
| 否 No | 2(20.0%) | 10(76.9%) | |
| 随访时间（年）Follow-up (years) | 6.3±1.1 | 6.2±1.2 | 0.906 |

注：PVCR，经后路全脊椎截骨术

Note: PVCR, posterior vertebral column resection

险，但这类患者的脊髓对侧凸矫形时脊柱位移、脊髓移位、脊髓张力、脑脊液压力的变化具有一定的耐受性，适宜接受一期脊柱矫形术。本研究 23 例行一期脊柱矫形术治疗的伴发 CM1和 SM 脊柱侧凸病例，脊柱侧凸和后凸的平均矫正率分别为 65.7%以及 48.4%，在平均 6.2 年的随访中，无一例患者发生术后神经功能恶化，这有力地证明了采用一期脊柱矫形术治疗伴发 CM1 和 SM 脊柱侧凸患者的可行性，但应基于严格的纳入标准。

然而，采用一期脊柱矫形术治疗伴发 CM1 和 SM 脊柱侧凸患者，不仅面临如何在术中保障脊髓安全的情况下实现良好的脊柱矫形问题，而且还需要关注直接行脊柱矫形术治疗后对 SM 的潜

在影响。MRI 是监测 SM 变化常用的手段,但由于术后椎弓根内置物造成的金属伪影，干扰了对 SM 观察和测量的准确性。因颈椎内置物在脊柱侧凸患者中较少使用，因此在本研究中，只包括 SM 主要位于颈髓的患者，以利于提高术后随访时观察、测量和比较的准确性。此外，如何量化 SM 的形态变化是面临的另一个问题。SM 的量化需要包括其矢状面上的长度和横断面上的大小。长度通常由 SM 从头端到尾端所跨越椎体的节段数来记录。Tokunaga 等[33]首次报道的空洞/脊髓比（S/C）是衡量空洞大小的常用指标，其定义为在 SM 最大扩张水平面上空洞的前后径与同水平面脊髓前后径的比值。S/C 最大值有助于描述 SM 的宽度差,但不足以反映 SM 的真实变化。在大多数情况下,SM 的大小不仅在矢状径上发生变化,而且在横径上也将有所变化。因此,在本研究中采用 STR 能更全面地反映 SM 的大小变化。此外,测量 C2、C4 和 C6 三个节段的平均 CSTR 旨在间接表示 SM 的长度变化。

在本研究中，经过 5 年以上随访,11 例伴发 CM1 和 SM 脊柱侧凸患者的平均 CSTR 减少≥20%。对 SM 改善和无改善的患者进行比较后,发现前者接受 PVCR 术治疗的比例更高。PVCR 作为最有效的脊柱短缩截骨术，是基于完全切除一个或多个椎体所建立的空间，通过短缩脊柱来主动降低脊髓张力,从而实现脊柱畸形的安全、有效矫正[34]。脊髓高张被认为是 SM 发生和发展的主要原因之一[7,35],在行 PVCR 手术过程中,整个脊柱的长度被缩短以降低脊髓张力，并可间接改善枕骨大孔处的拴系和神经张力，这对于改善所伴发 SM 将发挥重要作用。经进一步比较分析,行 PVCR 术治疗的患者较非 PVCR 术治疗的患者术前有更严重的脊柱畸形、更常接受术前牵引、术中融合固定节段更长；而二者的术前 SM 大小并无差异。在末次随访时,行 PVCR 治疗的患者 80.0% CSTR 减少≥20%;与之相比,非 PVCR 术治疗的患者中仅 23.1%获得 SM 改善。表明 PVCR 降低脊髓张力可能是影响伴发 CM1 和 SM 脊柱侧凸患者 SM 预后的一个重要潜在因素。此外,对 SM 改善和无改善的患者进行比较后，发现前者具有更长的融合节段数。由上述分析得知,行 PVCR 治疗的患者较非 PVCR 治疗的患者术中融合固定节段更长；而 SM 改善患者较无改善患者接受 PVCR 治疗的比例更高，故本研究中 SM 改善和无改善患者融合节段数的差异考虑由是否行 PVCR 造成。

本研究的主要局限性在于纳入的病例数少，还不足以完成多因素回归分析，从而进一步探讨影响 SM 预后的主要因素。今后更多病例的积累将有助于我们进一步了解哪些因素将影响 SM 的预后。此外,PVCR 和脊髓张力调节如何影响所伴发的 SM,均值得进一步关注和研究。

综上所述，对于术前无明显神经功能受损表现的伴发 CM1 和 SM 脊柱侧凸患者,一期后路脊柱矫形术是治疗此类患者的另一种选择。它不仅能在无需神经外科干预的情况下实现安全、有效的脊柱矫形，并可实现大部分患者所伴发 SM 的稳定和改善。对于此类患者而言,在无需神经外科干预的情况下,接受一期脊柱截骨矫形术治疗,特别是对于重度畸形患者接受 PVCR 治疗，脊柱短缩降低脊髓张力是影响术后所伴发 SM 预后的重要因素。

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