

临床论著

行支具治疗的特发性脊柱侧凸患儿生长高峰期
Cobb 角进展速率变化及其对支具疗效的影响

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【摘要】目的:评估行支具治疗的特发性脊柱侧凸(idiopathic scoliosis, IS)患儿青春期生长高峰参数及生长高峰时的脊柱侧凸 Cobb 角进展速率(angle velocity, AV)变化情况, 评估正性和负性 AV 组之间支具疗效的差异及不同支具疗效组之间生长参数的差异。**方法:**选取初诊时 Y 三角软骨未闭、以 3~6 个月为周期随访至停止支具治疗或因侧凸进展而行手术治疗的女性 IS 患儿 35 例。随访时测量的指标包括实足年龄、Y 三角软骨闭合状态、Risser 征、身高、脊柱长度、主弯 Cobb 角和尺桡骨远端骨龄(digital radius and ulnar, DRU)分级。根据纵向数据判定身高和脊柱生长速率峰值(peak height growth velocity, PHGV; peak spinal growth velocity, PSGV)及相应年龄, 分析 AV 在该阶段的变化情况及其对支具疗效的影响。支具治疗失败定义为主弯 Cobb 角进展 $\geq 5^\circ$ 或进展至超过 40° 需行手术治疗。**结果:**35 例患儿初诊年龄为 10.2 ± 1.5 岁(8~12.5 岁), 初诊 Cobb 角为 $26.5^\circ \pm 5.0^\circ$ ($20^\circ \sim 38^\circ$), 20 例主胸弯或胸腰双弯患儿接受 Milwaukee 支具治疗, 15 例胸腰弯及腰弯患儿接受 Boston 支具治疗。随访时间为 5.1 ± 2.1 年(4.0~6.2 年), 末次随访年龄 15.3 ± 2.2 岁(12~18 岁), 末次随访 Cobb 角为 $34.0^\circ \pm 12.6^\circ$ ($9^\circ \sim 59^\circ$)。支具治疗成功 15 例(42.9%); 支具治疗失败 20 例(57.1%), 其中转为手术 16 例(45.7%)。支具治疗失败组患儿 PHGV 年龄、PSGV 年龄均较治疗成功组患儿更小($P < 0.05$), 而支具治疗失败组的末次随访 Cobb 角、胸弯百分率及 PSGV 时 AV 均高于成功组($P < 0.05$), PHGV 和 PSGV 的值、初诊 Cobb 角两组之间无统计学差异($P > 0.05$)。PSGV 时负性 AV 组 19 例(54.3%), 正性 AV 组 16 例(45.7%), 负性 AV 组的支具治疗失败率、手术率、PSGV 时 AV 及末次随访 Cobb 角均显著低于正性 AV 组($P < 0.05$)。**结论:**行支具治疗的 IS 患儿生长高峰期时 AV 变化与支具疗效显著相关。处于生长加速期的 IS 患儿, 其支具治疗失败率较高, 尤其是脊柱生长高峰发生时间较早的胸弯型患儿。生长高峰时负性 AV 预示着更好的远期支具治疗效果。

【关键词】特发性脊柱侧凸; 生长高峰; 侧凸进展; 支具疗效

doi: 10.3969/j.issn.1004-406X.2016.04.02

中图分类号: R682.3 文献标识码: A 文章编号: 1004-406X(2016)-04-0294-05

Variation of angle velocity during the pubertal growth peak and its influence on bracing outcome in brace-wearing idiopathic scoliosis patients/MAO Saihu, SHI Benlong, SUN Xu, et al//Chinese Journal of Spine and Spinal Cord, 2016, 26(4): 294-298

【Abstract】 Objectives: To analyze the pubertal growth parameters and the variation of angle velocity (AV) during the pubertal growth peak in brace-wearing idiopathic scoliosis (IS) patients, and to analyze the difference in bracing outcome between patients with alleviative and positive AV as well as the difference in pubertal growth parameters between patients with successful and failed bracing outcomes. **Methods:** 35 physically immature braced IS girls with open triradiate cartilage were evaluated every three to six months through their growth spurt until brace wearing or surgery. Serial measurements of Cobb angle and multi-dimensional maturity indicators involving chronological age, triradiate cartilage, Risser sign, height, spinal length and distal radius and ulnar (DRU) classification were recorded. The timing and magnitude of peak height growth velocity (PHGV) and peak spinal growth velocity (PSGV) were identified and compared between the failed and successful brace group. The AV fluctuated by onset of PSGV was also defined as alleviative if the AV was negative,

基金项目: 南京市科技发展计划项目(编号: 201402028); 国家自然科学基金青年基金项目(编号: 81301603)

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otherwise it was positive. The bracing outcome was defined as failed if curve progression $\geq 5^\circ$ or needing surgical intervention($>40^\circ$). **Results:** The average age and Cobb angle at initial visit were 10.2 ± 1.5 years(8–12.5 years) and $26.5^\circ \pm 5.0^\circ$ (20° – 38°), while the average values changed to 15.3 ± 2.2 years(12–18 years) and $34.0^\circ \pm 12.6^\circ$ (9° – 59°) at last follow-up, respectively. There were 20 and 15 patients undergoing Milwaukee and Boston braces, respectively. The average follow-up period was 5.1 ± 2.1 years(4.0–6.2 years). Bracing treatment through the pubertal growth spurt demonstrated the successful and failure rate of 42.9% and 57.1% respectively. Patients in the failed group had older PHGV and PSGV ages, greater Cobb angle at last follow-up, higher ratio of thoracic curve and AV at PSGV than patients in the successful group ($P < 0.05$). No difference was found in the magnitude of PHGV and PSGV, or initial Cobb angle($P > 0.05$). Onset of PSGV triggered the occurrence of positive and alleviative AV in 45.7% and 54.3% of the patients. The alleviative AV group had lower incidence of failed brace treatment, surgical rate, AV at PSGV and Cobb angle at last follow-up as compared with the positive AV group($P < 0.05$). **Conclusions:** The AV at pubertal spurt is significantly correlated with bracing outcome. Bracing prescribed before pubertal spurt is associated with higher risk of failed brace treatment, especially for those with relatively advanced onset of growth spurt, positive AV by growth peak and curve pattern being major thoracic scoliosis.

[Key words] Adolescent idiopathic scoliosis; Peak growth velocity; Curve progression; Bracing outcome

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生长速率的变化是特发性脊柱侧凸(idiopathic scoliosis, IS)患者支具治疗时一直需要被密切关注的生长潜能指标^[1-5]。既往研究表明,在青春期生长高峰前确诊的 IS 患儿,其脊柱畸形常呈现出快速进展的趋势^[6,7]。因此,高生长潜能被普遍认定为 IS 患儿侧凸进展的危险因素^[8]。然而在婴儿型脊柱侧凸的治疗中,患儿的生长潜能却常被认为是一种内在的矫形力,在支具和生长棒的辅助下可对脊柱侧凸进行一定程度的矫正^[9]。Wu 等^[10]和 Escalada 等^[8]进一步证实在进展型青少年特发性脊柱侧凸(adolescent idiopathic scoliosis, AIS)患儿中,生长速率可与相应的 Cobb 角进展速率呈负性相关。生长参数是多维性的,在身体不同部位呈现不同的生长次序和速率^[11,12],其中最常用的指标是身高的纵向生长速率^[13]。Tanner 等^[14]研究证实生长是呈现由远及近的阶梯式生长模式;而在此基础上 Busscher 等^[15]报道身高的生长高峰发生时间和坐高的生长高峰发生时间存在差异性,故其对侧凸进展的影响可能存在差异。青春期生长参数变化与支具治疗下脊柱侧凸进展行为的关系目前仍未明确。本研究旨在分别评估行支具治疗的 IS 患儿身高和脊柱生长高峰参数及生长高峰时的 Cobb 角进展速率(angle velocity, AV)变化情况,评估不同变化组之间支具治疗疗效的差异及不同支具疗效组之间生长参数的差异。

1 资料与方法

1.1 一般资料

本研究为回顾性。选取自 2007 年 6 月起在我院门诊行规范化支具治疗的女性 IS 患儿。入选标准:(1)患儿初诊时 Y 三角软骨(triradiate cartilage)未闭,Risser 征 0 级,尺桡骨远端骨龄(distal radius and ulnar, DRU)分级 $\leq$ R8 级^[16],简化手掌骨龄(simplified skeletal maturity scoring, SSMS)分级 $\leq$ 3 级^[17];(2)初诊 Cobb 角介于 $20^\circ \sim 40^\circ$,接受规范化支具治疗(Milwaukee 或 Boston 支具),以 3~6 个月为周期规律随访直至生长发育成熟(Risser 征 4 级及尺桡骨 DRU 分级 R11 级)^[16]而停止支具治疗或因脊柱侧凸进展而行手术治疗;(3)随访时拍摄立位全脊柱正侧位 X 线片(脱掉支具 >4 h)及左手掌正位 X 线片;(4)有完整的患者基本资料。排除标准:(1)既往有脊柱手术史;(2)支具佩戴不规律,治疗依从性 $<90\%$ (通过询问患儿及其父母实际支具佩戴时间而计算得到);(3)MRI 检查示任何神经系统异常。本研究获得本单位伦理委员会批准。

1.2 测量指标

人体测量学指标包括站立位身高及实足年龄。影像学参数在系列性纵向站立位全脊柱正侧位 X 线片上测量:(1)主弯 Cobb 角;(2)弯型;(3)Risser 征;(4)脊柱长度(T1 上终板至 S1 上终板之间各椎体终板中点和椎体对角线交叉点的连线

长度);(5)Y 三角软骨闭合状态。在左手掌正位 X 线片上评估尺桡骨 DRU 分级及掌指尺骨 SSMS 分级^[16,17]。所有影像学测量均在 PACS(Picture Archiving and Communications Systems)工作站进行。根据系列身高值和脊柱长度值计算每例患儿的身高生长速率(height growth velocity,HGV)和脊柱生长速率(spinal growth velocity,SGV)。将每例患儿 HGV 和 SGV 的值中各自的最大者定义为身高生长速率峰值(peak height growth velocity, PHGV)和脊柱生长速率峰值(peak spinal growth velocity,PSGV),计算生长高峰时的侧凸 Cobb 角进展速度(angle velocity,AV)。青春期生长高峰时根据 AV 的正负值分为正性 AV 组和负性 AV 组。比较不同 AV 反应组之间支具治疗失败率和手术率是否存在差异。支具治疗失败定义为主弯 Cobb 角进展 $\geq 5^{\circ}$ 或主弯 Cobb 角进展至超过 40° 需行手术治疗^[1]。另外,分别计算各组胸弯型患儿所占的比例。

1.3 统计学方法

采用 SPSS 17.0 软件对数据进行统计学分析。支具治疗成功组与失败组之间生长高峰参数、初诊 Cobb 角及成熟度分级差异的比较采用独立样本 *t* 检验,胸弯百分率的比较采用四格表卡方检验,生长高峰期正性和负性 AV 组之间支具治疗失败率、手术率、PSGV 时 AV、初诊及末次 Cobb 角、初诊及末次身高的比较采用四格表卡方检验。 $P<0.05$ 表示有统计学差异。

2 结果

本研究共入选 35 例女性 IS 患儿,初诊年龄 10.2 ± 1.5 岁(8~12.5岁),初诊 Cobb 角为 $26.5^{\circ}\pm 5.0^{\circ}$ ($20^{\circ}\sim 38^{\circ}$),20 例主胸弯或胸腰双弯(胸主弯)患儿接受 Milwaukee 支具治疗,15 例胸腰弯及腰弯患儿接受 Boston 支具治疗。随访时间为 5.1 ± 2.1 年(4.0~6.2年),末次随访年龄 15.3 ± 2.2 岁(12~18岁),末次随访 Cobb 角为 $34.0^{\circ}\pm 12.6^{\circ}$ ($9^{\circ}\sim 59^{\circ}$)。

支具治疗成功 15 例(42.9%);失败 20 例(57.1%),其中转为手术 16 例(45.7%)。支具治疗失败组患儿 PHGV 年龄、PSGV 年龄均较治疗成功组患儿更小($P<0.05$),而支具治疗失败组的末次随访 Cobb 角、胸弯百分率及 PSGV 时 AV 均高于治疗成功组($P<0.05$),PHGV 和 PSGV、初诊 Cobb 角两组之间无统计学差异($P>0.05$,表 1)。

PSGV 时负性 AV 组 19 例(54.3%),正性 AV 组 16 例(45.7%),负性 AV 组的支具治疗失败率、手术率、PSGV 时 AV 及末次 Cobb 角均显著低于正性 AV 组($P<0.05$),初诊 Cobb 角、胸弯百分率及末次随访身高两组之间未见明显差异($P>0.05$,表 2)。

3 讨论

青春期身高生长速率高峰前发病的 IS 患儿由于生长期较长,生长潜能较大,脊柱侧凸的进展风险亦相对较大。一般认为在无人工干预的条件下生长速率与脊柱侧凸进展速率呈现同步性趋势。Yrjonen 等^[18]研究发现身高生长速率 $>4\text{cm}/\text{年}$ 且 Cobb 角 $>25^{\circ}$ 的患儿脊柱侧凸可快速进展。Escalada 等^[8]报道支具治疗和随访观察的 IS 患儿,其生长高峰和和脊柱畸形进展高峰可同步发生。Sanders 等^[2]指出身高与生长高峰发生时间点之间的时间差可预示脊柱侧凸加速进展期的到来。基于此,高生长潜能的 IS 患儿常伴随着较高的支具治疗失败率和手术率。Lonstein 和 Winter^[19]研究指出 Milwaukee 支具治疗 Risser 征 0 级 IS 患儿的失败率约为 47%。针对月经初潮未至且 Risser 征 0 级的 IS 患儿,Wiemann 等^[20]报道

表 1 支具治疗失败组与成功组有关参数的比较

Table 1 Comparison between the failed and successful brace groups

	失败组 (n=15) Failed group	成功组(n=20) Successful group	P
PHGV[cm/年(cm/y)]	8.98 $\pm$ 1.39	9.59 $\pm$ 1.43	0.384
PSGV[cm/年(cm/y)]	4.16 $\pm$ 0.95	3.98 $\pm$ 1.41	0.658
PHGV年龄(岁) Age at PHGV(y)	11.48 $\pm$ 0.92	12.32 $\pm$ 1.31	0.046
PSGV年龄(岁) Age at PSGV(y)	11.84 $\pm$ 0.95	12.89 $\pm$ 1.55	0.025
初诊 Cobb 角($^{\circ}$) Cobb angle at initial visit	26.4 $\pm$ 5.4	26.7 $\pm$ 4.7	0.872
末次随访 Cobb 角($^{\circ}$) Cobb angle at last follow-up	42.5 $\pm$ 8.4	22.8 $\pm$ 7.3	0.000
胸弯百分率(%) Percentage of thoracic curve	80.0	26.7	0.002
PSGV时 AV($^{\circ}/\text{年}$) AV at PSGV($^{\circ}/\text{y}$)	2.3 $\pm$ 9.1	-6.5 $\pm$ 11.4	0.000

注:PHGV, 身高生长高峰速率;PSGV, 脊柱生长高峰速率;AV, Cobb 角进展速率

Note: PHGV, peak height growth velocity; PSGV, peak spinal growth velocity; AV, Cobb angle velocity

表 2 负性 AV 组与正性 AV 组之间相关参数的比较
Table 2 Comparison between negative and positive AV

groups			
	负性 AV 组 Negative AV	正性 AV 组 Positive AV	P
支具失败率(%) Rate of failed brace	36.8	81.2	0.016
手术率(%) Rate of surgery	21.1	75.0	0.002
PSGV 时 AV (°/年) AV at PSGV (°/y)	-9.6±7.6	8.2±4.0	0.000
初诊 Cobb 角(°) Cobb angle at initial visit	26.3±4.6	26.7±5.7	0.832
末次随访 Cobb 角(°) Cobb angle at last follow-up	29.4±9.1	39.6±14.2	0.015
胸弯百分率(%) Rate of thoracic curve	47.3(9/19)	68.8(11/16)	0.306
初诊身高(cm) Height at initial visit	145.2±7.2	138.3±8.2	0.013
末次身高(cm) Height at last follow-up	161.3±5.4	159.2±5.6	0.257

注:PSGV, 脊柱生长高峰速率;AV, Cobb 角进展速率

Note: PSGV, peak spinal growth velocity; AV, Cobb angle velocity

Charleston 夜间支具治疗的成功率为 29%。与之相对的,有研究表明脊柱侧凸患儿的生长潜在在脊柱侧凸的矫形中亦可以发挥积极作用。在支具治疗的前提下,快速纵向生长可作为一种主动矫形脊柱发挥矫正作用^[21]。支具治疗只适用于具有生长潜能的患儿也间接说明了生长的潜在矫形作用。Mehta 等^[9]报道在婴儿型 IS 中,患儿第一个生长高峰期的快速纵向生长被利用作为一种矫形力,在坚强的石膏支具固定的前提下诱导改变畸形脊柱的生长方向,从而实现脊柱侧凸的矫正。相应的,青春期的高速率生长作为第二个生长高峰期,在坚强支具治疗的前提下也可能实现侧凸的矫正。然而,目前国内文献尚未报道生长速率高峰下行支具治疗的脊柱侧凸的进展行为模式及其对支具治疗疗效的影响和预测价值。

本研究首先通过尺桡骨 DRU 分级及掌指尺骨 SSMS 分级成功筛选出生长高峰期前的患者并进行严密随访和规范化支具治疗。既往的长期纵向随访结果证实生长高峰期前确诊的 IS 患儿存在较高的支具治疗失败率(57.1%)和手术率(45.7%),这一比率在成熟度较高的患儿中只有约为 26%^[22]。本研究发现支具治疗失败组中胸弯患儿的比率明显高于治疗成功组,而既往文献报道胸弯型脊柱侧凸进展的风险明显高于胸腰弯和

腰弯,OR 值达 1.3~11.3^[23-25]。而在高生长速率前提下,本研究中 54.3%的患儿出现了负性 Cobb 角进展速率。这一数据提示青春期畸形脊柱的柔韧性相对较好,在坚强的支具固定下实现了脊柱纵向生长方向的调整 and 自发性的矫正。进一步随访研究发现,PSGV 时负性 AV 组的支具治疗失败率显著低于正性 AV 组患儿(36.8% vs. 81.2%),且支具治疗失败组的 AV 显著大于成功组,提示生长速率高峰时脊柱侧凸的行为模式,即 AV 变化,对预测远期支具疗效存在一定的价值。

既往研究发现可预测脊柱侧凸进展的多重危险因素^[26-28],包括:(1)初诊 Cobb 角>30°;(2)实足年龄 11~13 岁;(3)Risser 征 0 级;(4)DSA 评分 400~500 分;(5)身高生长速率>6cm/年,脊柱生长速率>2cm/年;(6)肋椎角差(RVAD)≥20°和凸侧肋椎角(CRVA)≤68°;(7)骨质疏松;(8)支具治疗后初始 Cobb 角进展速率。本研究首次提出生长高峰期的负性 AV 预示着更好的支具治疗效果。结合尺桡骨 DRU 分级及掌指尺骨 SSMS 分级对生长高峰期的准确预测,快速观察了解 AV 在该阶段变化将有助于预测支具治疗的效果及方案的调整。

在青春期生长参数方面,本研究发现支具治疗失败组患儿的生长高峰到来的相对更早,尤其是脊柱的生长高峰时间,而生长速率峰值的幅度却无明显差异。提示对于生长高峰较早到来的患儿需严密观察。本研究的不足之处在于入选的患儿来自单一中心,且均为女性。后期需要多中心的且入选男性患儿的进一步研究随访。另外,本研究病例数量较少,侧凸类型不一致,会在一定程度上影响本研究的结果。

总之,处于生长加速期的 IS 患儿支具治疗失败率较高,尤其是脊柱生长高峰发生时间较早的胸弯型患儿。生长高峰时负性 AV 预示着更好的远期支具治疗效果。

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(收稿日期:2015-12-21 修回日期:2016-02-23)

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