Is Homogeneous Spinal Cord Shortening and Axial Decompression (HSAD) Superior to Adults in The Treatment of Tethered Syndrome in Children

Wang Shunmin (✉ wangshunmin2020@126.com)

910th Hospital of PLA

Xi Luo

Shanghai Changzheng Hospital Department of Gastroenterology

Kai Qiang Sun

changzheng hospital

Jian Zhu

changzheng hospital

Feng Zhao

910th Hospital

Jian Gang Shi

Changzheng Hospital: Shanghai Changzheng Hospital

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Abstract

Objective: Childhood spinal cord syndrome is a refractory and intractable disease, which gradually worsens with developmental symptoms. The purpose of this study was to evaluate the long-term surgical effects of HSAD in the treatment of tethered cord syndrome in children and adults.

Methods: 50 Patients receiving HSAD tethered from January 2011 to September 2014 included in this study. At least 5 years after follow-up, imaging and clinical data collection. JOA score, VAS score, waist and leg dysfunction index (ODI) score were used to evaluate the patient's neurological function and pain improvement. ICI-Q-SF score, urodynamics, and residual urine volume (B-ultrasound) are used to assess urinary function. The Rintala score is used to assess stool function.

Results: A total of 50 patients were enrolled and the patients were divided into children group (n=26) and adult group(n=24). JOA improvement rate in children group ($54.95\% \pm 14.14\%$ vs $34.95\% \pm 11.82\%$), maximum urine flow rate improvement value (4.87 ± 5.49 vs 1.40 ± 1.88) and residual urine volume improvement value (118.46 ± 39.11 vs 62.83 ± 59.28) was greater than the adult group, and the postoperative ICIQ-SF score (6.21 ± 4.85 vs 7.75 ± 4.23) was lower than that of the adult group ($P < 0.05$).

Conclusion: HSAD can achieve good clinical effects in treating children and adults with tether syndrome. In the long run, it may benefit urinary function, especially in children.

Introduction

Tethered cord syndrome (TCS), characterized by longitudinal traction of the spinal cord leading to injury to the lumbosacral spinal cord and cauda equina. Refers to a series of neurological dysfunction syndromes with high incidence. [1]TCS is caused by the thickened filum terminal, lipomyelomeningocele, spina bifida or other congenital abnormalities.[2] Patients with TCS may present various symptoms and signs, including low back pain, gait difficulties, sensory or/and motor deficits, sphincter dysfunction.[3–6]The traditional surgical procedure for treating TCS is untethering surgery, which has been considered to be the golden standard treatment for TCS.[7–9]However, 5–50% of patients need revision surgery after untethering surgery due to unsatisfied urologic outcomes.[10–12] Moreover. Cerebrospinal fluid leakage and retethering, neurological deterioration high risk of suffering postoperative complications remains a problem hard to deal with [5, 6]. As an alternative to the treatment of TCS, spine-shortening osteotomy (SSO) reduces the tension of the spinal cord and reduces perioperative complications. On the other hand, homogeneous spinal-shortening axial decompression (HSAD) can also achieve the purpose of uniform shortening of intervertebral disc by means of uniform shortening of intervertebral disc, and good results have been achieved in the treatment of TCS [1]. In this study, although the number of cases is small, but the use of a variety of scores to evaluate the function of patients, urodynamic examination to evaluate the changes of bladder indicators, and divided into adult and child groups, for long-term follow-up, with a certain degree of scientific, the report is as follows.

Materials And Methods

Study Design and Participants

This study was a retrospective study. 50 patients with TCS who received HSAD treatment in spinal surgery of our hospital from January 2011 to September 2014 were divided into children group and adult group according to whether they were older than 18 years old or not. We are studying to explain to patients suitable for TCS diagnosis that HSAD is an unproven but potentially beneficial procedure. After discussing the pros and cons with the patient, the patient decides whether to accept surgery. The research protocol has been approved by our ethics committee. The clinical trial followed the relevant guidelines and regulations, and released an identification image obtained from the participants with informed consent. All patient data are users, including demographic characteristics, operating age, urological examination results, urodynamic examination, back or lower limb pain, neurological diseases and recorded orthopedic abnormalities. The termination grade cone, pulp size, the presence of fat in the pulp, and other related spinal cord and spinal cord abnormalities were determined by MRI scans.

The diagnostic criteria of TCS were as follows: (1) lumbar MRI showed that the position of the medullary cone was low, and the lower end of the medullary cone was lower than the L2/3 segment; (2) there were symptoms such as low back pain, dysfunction of defecation and defecation, sensorimotor disturbance of the lower extremities; (3) deformities such as meningocele, lipoma, foot deformity and skin abnormalities. The inclusion criteria of this study were as follows: (1) the diagnosis of TCS was clear, and MRI showed that the pulp cone was low and the lower end of the cone was lower than L2/3; (2) voiding dysfunction, with or without other neurological symptoms; (3) complete clinical and follow-up data, including clinical scores and urodynamic results before and after operation. Exclusion criteria: (1) TCS patients with normal cone position; (2) urinary dysfunction caused by non-TCS, such as cauda equina syndrome, urology-related diseases, and (3) incomplete clinical or follow-up data. All patients were fully informed of the expectations and adverse consequences of the surgical trial and obtained their written informed consent. During the study period, HSAD was an unproven but potentially beneficial procedure for patients diagnosed with TCS. After discussing the pros and cons, patients are advised to consider various options and decide whether to undergo surgery or continue conservative treatment. The research scheme has been approved by the ethics committee of the college. Conduct clinical trials in accordance with relevant guidelines and regulations, and obtain the informed consent of the participants.

1.2 Surgical methods and postoperative rehabilitation training (taking L2 ~ S1 as an example) patients were used as prone position, general anesthesia, routine Aner iodine disinfection and towels. After resection, a median incision was made to cut the skin, subcutaneous tissue and fascia in turn to expose the L2 ~ S1 spinous process, lamina and facet joint. Screws were placed into the pedicle of L2 ~ S1 to remove the interspinous ligament and interlaminar ligament of L5/S1. The inferior articular process of L5 was resected by osteotomy and the medial edge of superior articular process of S1 was removed. Enlarge the L5/S1 intervertebral foramen, cut open the fibrous annulus after the L5/S1 space, and remove the intervertebral disc tissue. The operative segments of L4/5, L3/4 and L2/3 were treated in the same way.

After the treatment of each intervertebral space, connect the connecting rod with bilateral screws, fix the nut, press the L2/3 ~ L5/S1 space in turn, and then lock the nut. Exploration showed that the spinous process space and intervertebral space were significantly reduced, and the nerve root and dural sac became loose and unobstructed. Saline irrigation, hemostasis, intertransverse bone grafting, layer-by-layer suture dressing and routine drainage. After operation, urination exercises were carried out regularly, urination was carried out regularly, normal micturition reflex was restored, and the recovery of bladder function was promoted.

1.3. The function was evaluated by ICI-Q-SF, JOA, Rintala score, VAS score, and Oswestry Disability Index(ODI) before operation and at the last follow-up. urodynamic examination and urinary flow parameters (including bladder safe volume, detrusor leak point pressure, bladder compliance, maximum urinary flow rate) were measured by MMS solar urodynamic examination system and bladder residual urine volume were measured by Bladder ultrasound (After urination) in our hospital before operation and in the last follow-up. Bladder compliance (ml/cm H₂O) = Δ volume (ml) / Δ pressure (cm/H₂O). Improvement rate of residual urine volume = difference / preoperative $\times$ 100%. Post-treatment score improvement rate = [(post-treatment score-pre-treatment score) / score (29-pre-treatment score)] $\times$ 100%. The highest improvement rate is 100%.

1.4 Statistical methods

SPSS21.0 statistical software was used to analyze the data. All scores, bladder compliance, bladder safety capacity, detrusor leak point pressure, bladder residual urine volume and maximum urinary flow rate were expressed in $\bar{x} \pm s$. Paired t-test was used in preoperative and final follow-up. Independent sample t-test was used in both groups ($P < 0.05$). The difference was statistically significant.

Results

the preoperative data were shown in Table 1. 21/50(42%)patients had a history of previous surgery (meningocele repair + terminal filament release in 3 cases, sacral mass resection + spinal cord release in 2 cases, sacral mass resection in 2 cases, lumbosacral composite tissue transplantation + epidural resection + spinal canal enlargement in 2 cases. Meningocele resection in 3 cases, fiber termination in 1 case, lipoma resection and thrombolysis in 2 cases, sacral coccyx lipoma resection + meningeal release + meningocele lysis in 1 case. Resection of sacral lipoma + release + meningeal repair in 3 cases, meningocele repair in 2 cases). The average operative age was (13.15 ± 1.86) years and (41.08 ± 12.06) years, and the average follow-up time was (6.50 ± 1.41) years and (6.00 ± 0.90) years in children group ($n = 26$, Female, 61.54%) and adult group ($n = 24$, Female, 58.33%), the average operative age was (13.15 ± 1.86) years and (41.08 ± 12.06) years. The clinical manifestations included indwelling catheter in 12 cases (6vs6), Stool dysfunction in 28 cases (18vs10) ($p = 0.05$), syringomyelia in 10 cases (6vs4), lipoma in 24 cases (12vs12), intramedullary cyst in 10 cases (4v6) and scoliosis in 8 cases (6vs2). The position of medullary cone was L3 in 4 cases, L4 in 4 cases, L5 in 10 cases, S1 and below in 32 cases. The scope of operation was L1-S1 ($n = 28$), L2-S1 ($n = 4$), L1-L5 ($n = 10$), L2-L5 ($n = 2$), L3-S1 ($n = 4$) and L1-L4 ($n = 2$).

The average operation time was $278.93\text{min} \pm 45.82 \text{ min}$ and $262.57 \text{ min} \pm 40.85 \text{ min}$, and the average blood loss was $768.96\text{ml} \pm 232.84 \text{ ml}$ and $708.98 \text{ ml} \pm 255.22 \text{ ml}$, respectively. Cerebrospinal fluid leakage occurred in 3 cases, which was cured by catheterization and drainage, 2 cases were treated in time because of wound infection, 1 case was removed because of lumbar discomfort caused by long segmental fixation, and the neurological function of 1 case was slightly worse than that before operation. During the follow-up period, the intertransverse bone graft fusion was good, and no internal fixation complications such as broken rod and screw prolapse were found.

Table 1
Baseline Demographic information of patient with TCS

Variable	Children group (n = 26)	Adult group (n = 24)	P Value
Age at surgery mean ± SD, y	13.15 ± 1.86	41.08 ± 12.06	0.000
Female, No. (%)	16(61.54)	14(58.33)	0.817
Average follow-up time, y	6.50 ± 1.41	6.00 ± 0.90	0.870
Duration of disease (m)	19.57 ± 5.36	22.98 ± 4.47	0.323
Indwelling catheter, No. (%)	6(23.08)	6(25.00)	0.874
Fecal incontinence, No. (%)	18(69.25)	10(41.67)	0.050
Syringomyelia, No. (%)	6(23.08)	4(16.67)	0.571
Lipoma, No. (%)	12(46.15)	12(50.00)	0.786
Intramedullary cyst, No. (%)	4(15.38)	6(25.00)	0.396
Scoliosis, No. (%)	6(23.08)	2(8.33)	0.155
Range of surgery			
L1-S1	14	14	
L2-S1	2	2	
L1-L5	6	4	
L2-L5	0	2	
Other*	4	2	
Position of conus medullaris			
L3	0	4	
L4	2	2	
L5	6	4	
S1 and below	18	14	
Operative time, minutes	278.93 ± 45.82	262.57 ± 40.85	0.750
Blood loss, mL	768.96 ± 232.84	708.98 ± 255.22	0.659
Complications (%)			
Wound infection	1(3.85)	1(4.17)	0.954
CSF leakage	2(7.69)	1(4.17)	0.600

Variable	Children group (n = 26)	Adult group (n = 24)	P Value
Neurologic deterioration	1(3.85)	0(%)	0.332
Implant complications	0	0	

Values are mean $\pm$ SD (range) or number of patients. CSF, cerebrospinal fluid.

There were significant differences in JOA score, VAS score, ICI-Q-SF score, Rintala score and Oswestry Disability Index (ODI) score before operation and at

the last follow-up in children group. ($P < 0.05$, 7.58 ± 4.87 vs 19.35 ± 3.63 , 5.54 ± 2.10 vs 3.47 ± 1.72 , 14.94 ± 4.15 vs 6.21 ± 4.85 ,

4.55 ± 2.46 vs 12.10 ± 4.74 , 67.12 ± 25.80 vs 24.17 ± 20.97 respectively).

In the adult group, The difference of JOA score, VAS score, ICI-Q-SF score, Rintala score and Oswestry Disability Index (ODI) score was also statistically significant ($P < 0.05$, 12.32 ± 4.13 vs 18.15 ± 4.17 , 4.63 ± 1.68 vs 2.98 ± 1.61 , 15.94 ± 4.17 vs 7.75 ± 4.23 , 5.88 ± 3.45 vs 11.76 ± 3.86 , 62.95 ± 22.75 vs 31.69 ± 18.83 , The difference There was significant difference in lumbar JOA improvement rate ($54.95\% \pm 14.14\%$ vs $34.95\% \pm 11.82\%$) ($P = 0.028$) and postoperative ICI-Q-SF score ($P = 0.035$) between the two groups. There was no significant difference in other scores (Table 2).

Table 2
Clinical outcomes of patients in the two groups

Variable	Children group (n = 26)	Adult group (n = 24)	P Value
JOA mean $\pm$ SD			
Pre.	7.58 $\pm$ 4.87	12.32 $\pm$ 4.13	0.153
Final FU	19.35 $\pm$ 3.63*	18.15 $\pm$ 4.17*	0.421
Improvement rate (%)	54.95 $\pm$ 14.14	34.95 $\pm$ 11.82	0.028
VAS mean $\pm$ SD			
Pre.	5.54 $\pm$ 2.10	4.63 $\pm$ 1.68	0.782
Final FU	3.47 $\pm$ 1.72*	2.98 $\pm$ 1.61*	0.623
ICIQ-SF, mean $\pm$ SD			
Pre.	14.94 $\pm$ 4.15	15.94 $\pm$ 4.17	0.531
Final FU	6.21 $\pm$ 4.85*	7.75 $\pm$ 4.23*	0.035
Rintala, mean $\pm$ SD			
Pre.	4.55 $\pm$ 2.46	5.88 $\pm$ 3.45	0.465
Final FU	12.10 $\pm$ 4.74*	11.76 $\pm$ 3.86*	0.351
ODI score, mean $\pm$ SD			
Pre.	67.12 $\pm$ 25.80	62.95 $\pm$ 22.75	0.153
Final FU	24.17 $\pm$ 20.97*	31.69 $\pm$ 18.83*	0.102

Preop, preoperative; FU, follow-up; JOA, Japanese Orthopaedic Association; VAS, visual analog scale; ICIQ-SF, International Consultation on Incontinence Questionnaire

Short Form. * Compared with preoperative, $P < 0.05$.

Table 3
Urodynamics Parameters of patients in the two groups

Variable	Children group (n = 26)	Adult group (n = 24)	P Value
Bladder safe capacity, mL			
Pre.	181.74 ± 73.25	170.59 ± 72.95	0.571
Final FU	270.27 ± 67.79*	265.23 ± 76.46*	0.159
Detrusor leak point pressures, cm H ₂ O			
Pre.	43.21 ± 11.54	44.87 ± 15.63	0.233
Final FU	30.67 ± 14.13*	33.29 ± 13.37*	0.189
Bladder compliance, mL/cm H ₂ O			
Pre.	7.70 ± 4.76	8.13 ± 5.87	0.424
Final FU	24.98 ± 10.32*	22.61 ± 11.58*	0.115
Residual urine volume, mL			
Pre.	133.92 ± 62.62	118.75 ± 99.51	0.286
Final FU	15.46 ± 29.33	55.92 ± 75.28	0.005
Improve value	118.46 ± 39.11	62.83 ± 59.28	0.032
Improvement rate (%)	0.46 ± 0.52	0.50 ± 0.46	0.161
Maximum urine flow rate, ml/s			
Pre.	3.69 ± 2.77	7.62 ± 4.25	0.081
Final FU	8.56 ± 6.84	9.02 ± 4.36	0.045
Improve value	4.87 ± 5.49	1.40 ± 1.88	0.003

(Preop, preoperative; FU, follow-up.) 64 * Compared with preoperative, P < 0.05.

Because the score is subjective evidence, it has great volatility. Therefore, urodynamic data are introduced as an objective basis.

The bladder safety capacity, detrusor leak point pressure, bladder compliance, bladder residual urine volume and maximum urinary flow rate in children were 181.74 ± 73.25vs270.27 ± 67.79,43.21 ± 11.54vs30.67 ± 14.13,7.70 ± 4.76vs24.98 ± 10.32and 133.92 ± 62.62vs15.46 ± 29.33,3.69 ± 2.77vs8.56 ± 6.84respectively before operation and the last follow-up. All the data have statistical differences (P < 0.05).

In adult group, The parameters of the safe bladder capacity (170.59 ± 72.95 vs 265.23 ± 76.46), detrusor leak point pressure (44.87 ± 15.63 vs 33.29 ± 13.37), bladder compliance (8.13 ± 5.87 vs 22.61 ± 11.58), bladder residual urine volume (118.75 ± 99.51 vs 55.92 ± 75.28) and maximum urinary flow rate (7.62 ± 4.25 vs 9.02 ± 4.36) before operation and the last follow-up were statistically significant ($P < 0.05$). The improvement of maximum urinary flow rate in the adult group was higher than that in the adult group (4.87 ± 5.49 vs 1.40 ± 1.88) ($P = 0.003$) (Fig. 1). The difference of residual urine volume in the child group (118.46 ± 39.11 vs 62.83 ± 59.28) ($P = 0.032$) (Fig. 2).

Discussion

3.1 Surgical treatment of TCS.

The effect of conservative treatment of TCS is not good. Early surgical treatment should be performed after diagnosis, and long-term follow-up should be carried out [13]. Even in order to prevent the occurrence of symptoms, surgical treatment is recommended for asymptomatic patients [14]. The surgical treatment of tethered cord syndrome can be divided into two categories: spinal cord release, terminal filament amputation and spinal shortening. The standard treatment for tethered cord syndrome has long been intradural detethering, and prophylactic detethering has generally been performed before scoliosis correction for patients with both scoliosis and tethered cord [15]. However, it brings great risk and recurrence of the nervous system, as well as limited correction of scoliosis [16]. By separating the spinal cord from the surrounding structure, releasing the tethering of the spinal cord, the lysis of the terminal filament can correct the local distortion and compression, restore the microcirculation of the injured part of the spinal cord, and promote the recovery of neurological function [17]. However, the incidence of retethering after terminal filament release can reach 5–50%, and the rate of nerve injury can reach 40% [11, 18]. Grande et al. [19] have proved that 15 ~ 25 mm thoracolumbar osteotomy can effectively reduce the tension of spinal cord, lumbosacral nerve root and terminal filum in human cadaveric experiments. Shortening spinal osteotomy is a safe and effective method for the treatment of congenital scoliosis and binding of spinal cord. It has been reported that spinal shortening osteotomy at the apical level of the thoracic spine can not only correct spinal deformity, but also release the tension of the tethered cord, thus improving neurological function [20]. Posterior vertebral osteotomy and spinal shortening can avoid the risk of intradural operation aggravating nerve injury, thus reducing complications such as nerve injury, cerebrospinal fluid leakage and retethering, but it also has some limitations. Because although the tension of spinal cord and nerve root has been alleviated to a certain extent after shortening, it is difficult to achieve the goal of complete release. Therefore, unless combined with severe spinal deformity and vertebral hypoplasia, it is not advisable to destroy the normal vertebral body, HSAD surgery as an improved treatment has been widely reported.

3.2 improvement of bladder function TCS by Surgery

Terminal filament release is not ideal for the improvement of voiding function of TCS. Although Palmer et al. [21] performed terminal filament lysis and urodynamic examination in 20 patients with TCS, it was

found that the detrusor overactivity was relieved in 50% of the patients, the sphincter function was improved in 21% of the patients, and one or more urodynamic indexes were improved in 25% of the patients. However, 8.5% of the patients still experienced deterioration of urodynamic parameters such as deterioration of compliance, increased bladder pressure, sphincter activity and loss of sensation. Most scholars believe that there is no significant improvement in lower urinary tract symptoms in patients with TCS after terminal filament lysis [22, 23]. Kokubun et al. [24] proposed a method of posterior vertebral osteotomy to shorten the spine and alleviate the longitudinal traction of the spinal cord. Safain et al. In this cadaveric experiment, SPO did not cause a significant decrease in tension, while both PSO and VCR showed a significant response [19]. Repeated untethering surgeries seem to have a positive effect on the patient's weakness and a negative effect on pain. The longer the follow-up, the more likely are improvements in pain, weakness, and paresthesia. Bladder dysfunction is not expected to improve over time [25]. Nakashima [26] retrospective study found that posterior osteotomy shortening was better than terminal filament release in improving bladder function, especially in difficult cases. Although SSO is a safe and effective technique for patients with TCS, especially in more challenging situations such as complex deformities or revision surgery. However, there is a large heterogeneity in the evaluation of motor function and the improvement rate of urinary and fecal dysfunction [27]. Therefore, the operation of spinal shortening is improved in this paper. the uniform shortening of intervertebral disc can also achieve the purpose of shortening. The last follow-up has obvious effect on the improvement of defecation and defecation function, which can be regarded as an alternative surgical method.

3. 3 Analysis of the reasons for the functional improvement of TCS by HSAD.

HOU et al believe that HSAD operation is a safe and effective surgical method for TCS, which can directly decompress the spinal cord. This operation can restore normal tension on the spinal cord, and improve neurologic and urologic symptoms [28]. Many studies were conducted in pediatric patients who had worsening symptoms many years after previous untethering surgery performed in infancy. In children, there is an imbalance between the growth column of the spine and the spinal cord, resulting in stretching and increasing spinal cord tension. Abnormal extension of the spinal cord wire reduces blood flow, followed by mitochondrial deterioration of oxidative metabolism and electrophysiological injury [29]. Shortening the spinal column seems to represent a safe and effective option for the traditional removal of spinal cord embolism for tethered cord syndrome [4]. The JOA score ranges from preoperative to final follow-up. The recovery rate of the two groups is significantly different. Children with HSAD have significantly improved urodynamic indicators than adults. HSAD is restoring neurological function and defecation function. Whether routine tethering surgery or orthopedic surgery to treat patients with spinal deformities can significantly reduce pain. However, only a small number of patients experienced sensory changes and improvement in sphincter problems [30]. Children are repeatedly tethered, and the symptoms can be attributed to a mismatch between the growth and prolongation of the spine and spinal cord. In adults, although the growth tends to be stable, the intervertebral disc degenerates naturally. Symptoms are thought to result from daily exercise and chronic tension at the distal end of the spinal cord. Activity can lead to neurogenic pain, motor and sensory nervous system defects, and deterioration of bladder function. The author believes that with the growth of children, the spinal cord grows gradually,

and the growth of the spine is limited by internal fixation, which leads to the further reduction of the axial tension of the spinal cord. For adults, this operation slows down the traction of the distal active spinal cord after fixation. Removal of a part of the intervertebral disc in each segment and uniform compression restored the lumbar curvature and the natural height of the intervertebral disc corresponding to the lower spinal cord. The scope of the operation was shortened by multi-segmental compression, and each nerve root outlet on both sides was completely decompressed, and some of the nerve roots were also decompressed. Intraoperative electrophysiological monitoring can prevent excessive reduction and injury of spine and nerve root and ensure the safety of operation. An indicator of postoperative shortening: cerebrospinal fluid flow, spinal cord pulsation and relaxation of the dural sac. Postoperative imaging examination showed that the length of the spine was significantly shortened and the tension of the spinal cord decreased. During the last follow-up, urinary function improved [19]. Because the spinal cord and spine of children are in dynamic balance, the operation creates a relaxed environment for the development of spinal cord and nerve roots without traction, the cerebrospinal fluid beats well, the peripheral blood circulates well, and the nerve cells of children are highly constructible. therefore, the defecation function and urodynamic data of children are better than those of adults. However, whether the improvement of its function is natural development, or whether the operation itself brings more advantages, it still needs to be further studied in the future.

The symptoms of tethered syndrome are accompanied by an increase in height and aggravate during growth. It is speculated that various reasons lead to the high tension of the terminal filament of the fixed cauda equina, the untimely rise of the cone, and a series of problems caused by the normal development of the spine. It is well known that Laminoplasty is more effective for lordotic alignment cases than for kyphotic cases of myelopathy [31]. Although the main purpose of cervical laminoplasty is decompression of the spinal cord, the tension of the spinal cord influences recovery. The posterior shift of the spinal cord was observed to be insufficient in the kyphotic aligned spine after posterior decompression [31]. Lumbar lordosis increases when symptoms worsen in children with Lipomyelomeningocele [32–34]. Therefore, there is also a drift in the low cone of the lumbar vertebrae. We believe that the long segment fixation of the operation can restore the normal physiological curvature of the lumbar spine, and the outlet of the nerve root is unobstructed and loosened thoroughly during the operation, and the lumbar spinal cord is uniformly decompressed in the axial direction. MRI showed that the spinal cord and cauda equina tightened in a bowstring state close to the posterior structure of the spine, while the low spinal cord and Conus moved forward and relaxed after operation. Finally, mild to moderate scoliosis can be corrected by excision of intervertebral disc and posterior column structure.

3.4 Analysis of complications of TCS by HSAD.

About half of patients in this study had previous surgery or spina bifida, with more sequelae. Abnormal soft tissue scar coverage of the posterior dura mater of the lumbar spine and congenital spinal deformities can increase the complexity and time of the operation. Lee et al [9] reported their experience in 60 patients who underwent reoperation, with a wound-related complication rate of 22% (CSF leakage, infection, meningitis) and neurological deterioration in 2 patients. But up to 90% of patients improved.

Selcuki et al [35] reported that the tethered cord of adults has an improvement rate of 95% and 40%. However, for patients with cystic cysts (dermoid, epidermoid or neural nerve cyst or lipomas), clinical deterioration occurred within 10 years. Therefore, it can be seen that "the benefits of the second operation are limited" and "revision surgery should be performed in patients with complex diseases under abnormal circumstances." HSAD operation only shortens the intervertebral disc to avoid some of the complications of spinal osteotomy, which is effective and safe. The clinical effect of short-term follow-up is satisfactory [36]. It can also significantly improve the neurological function of reoperation patients with tethered cord syndrome [37]. Sofuoglu [38] et al reported 23 cases of tethered cord surgery in adults. The incidence of complications was 26% in surgical wounds (cerebrospinal fluid leakage and infection). Therefore, tethering surgery is complex and has serious complications. In this study, surgery was planned based on the symptoms highlighted by adequate neurological examinations, magnetic resonance imaging, and urodynamic examinations. During the operation, there is no need to open the dura mater and peel off the scar tissue that adheres to the dura mater, but only on both sides, which is a repetitive action of routine operation and is safe in theory. And long-term follow-up found that the incidence of spinal internal fixation failure and pseudoarthrosis was not high. Although long segmental fixation led to a certain loss of spinal motion, it significantly improved the defecation and defecation function of children.

Limitations

First, there is no statistical difference in the duration of the course of symptoms in patients. In addition, the patients developed dysfunction of urine and feces and affected their lives, and randomly selected the timing of surgical treatment. Finally, the efficacy score and objective data were evaluated by three double-blind neurosurgeons. Therefore, this research is reasonable. However, it was only initially found that the operation has excellent efficacy for TCS patients, and basic mechanism studies are needed to confirm whether children are better than adults. There are still some flaws. The number of cases is too small. Some cases were too old and had a long history, and there were differences in the recovery of sphincter function.

Conclusions

HSAD is an effective surgical method for the treatment of tether syndrome in adults and children. It may benefit urinary function in the long term, especially in children.

Abbreviations

HSAD Homogeneous Spinal Cord Shortening and Axial Decompression

VAS Visual analog scale

ICIQ-SF International Consultation on Incontinence Questionnaire Short Form

SPSS: Statistical Package for the Social Sciences

JOA: Japanese Orthopedic Association Score

FU: follow-up

ODI: Oswestry Disability Index

TCS: Tethered cord syndrome

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are not publicly available due to feasibility but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

Shunmin Wang designed the study, carried out most of the data analysis, and wrote the manuscript; Jian Zhu, Kaiqiang Sun and Rongzi Chen should be considered as co-first authors. The authors read and approved the final manuscript.

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Figures

Figure 1

Improve value of maximum urine flow rate

Improve value of residual urine volume

Figure 2

Improve value of residual urine volume