Original Article

Short-term change of tibial torsion in children with spastic cerebral palsy after selective dorsal rhizotomy

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Background: Spastic cerebral palsy (CP) is a prevalent cause of motor dysfunction in children, with patients often experiencing secondary musculoskeletal deformities, including tibial torsion. This study aimed to investigate the short-term effect of selective dorsal rhizotomy (SDR) on tibial torsion in children with spastic CP.

Methods: We conducted a retrospective review of children with spastic CP who underwent SDR at the Department of Neurosurgery, Shanghai Children's Hospital, between July 2019 and November 2022. Pre- and post-operative physical assessments were examined.

Results: A total of 148 children were included in the study. After SDR, there was a significant decrease in muscle tone in the lower limb muscle groups. Joint range of motion in the lower limbs also increased post-surgery. Bilateral transmalleolar angle (TMA) showed a significant increase after the surgery, and 21% limbs classified as internal tibial torsion before SDR changed into normal angle post-operatively. Limbs with better improvement after SDR derived from younger patients and had lower muscle tone in the hamstring muscles when compared to those that did not show improvement.

Conclusions: SDR has the potential to increase TMA in children with spastic CP. Limbs classified as internal tibial torsion are more likely to improve after SDR if they have lower muscle tone in the hamstring muscles and are derived from younger patients.

Keywords: Tibial torsion; spastic cerebral palsy (spastic CP); selective dorsal rhizotomy (SDR); spasticity; transmalleolar angle (TMA)

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Introduction

Spastic cerebral palsy (CP) is a prevalent cause of motor dysfunction in children, and its clinical presentation varies based on the degree of increased muscle tone (1). In addition to spasticity in the extremities, patients with spastic CP often experience secondary musculoskeletal deformities, including tibial torsion (2). Tibial torsion can be categorized into internal or external rotation and can have a detrimental impact on gait and overall motor function (3,4). In children with spastic CP, tibial torsion may result from abnormality of multiple lower limb muscles, such as the hip adductor, medial hamstring, and tibialis muscles (2). Timely diagnosis and treatment of tibial torsion are crucial, as persistent rotational misalignment of the lower extremity can lead to lever arm dysfunction. This dysfunction manifests as excessive rotation of the lower extremity and can cause the foot to shift outward or inward, thereby altering knee extension and ankle flexion (5).

Traditional treatments for tibial torsion primarily involve soft tissue surgeries, such as intramuscular decompression, tendon lengthening, or transfer (6). In severe cases, bone remodeling surgeries may be necessary (7-9). Selective dorsal rhizotomy (SDR) offers a promising approach by reducing spasticity in the lower extremity muscles, potentially leading to improvements in tibial torsion (10-14). However, very few studies have investigated the specific effects of SDR on tibial torsion. To address this gap, we conducted a retrospective study to investigate the impact of SDR on tibial torsion. We present this article in accordance with the STROBE reporting checklist (available at https://tp.amegroups.com/article/view/10.21037/tp-23-339/rc).

Highlight box

Key findings

- Selective dorsal rhizotomy (SDR) exhibits short-term efficacy in improving internal tibial torsion among children with spastic cerebral palsy.

What is known and what is new?

- SDR effectively reduces lower limb muscle tone in children with spastic cerebral palsy.
- Children with internal tibial torsion were observed an increase in transmalleolar angles after SDR, particularly in those with younger age (≤4.8 years old) and without severe spasticity on their hamstring pre-op (modified Ashworth Scale ≤3).

What is the implication, and what should change now?

- SDR emerges as a promising surgical intervention for children with spastic cerebral palsy, addressing the improvement of tibial torsion. This approach not only provides a conceptual framework but also offers a viable and practical method.

Methods

Inclusion criteria

We conducted a retrospective review of consecutive cases diagnosed with spastic CP who underwent lumbosacral SDR at Shanghai Children's Hospital from July 2019 to November 2022. The study cohort included patients who met the following inclusion criteria: confirmed diagnosis of CP by a multi-disciplinary team, age ranging from 3 to 18 years, no history of relevant orthopedic surgeries such as tendon lengthening or joint surgeries, good cognitive ability, and completion of both pre-operative and post-operative physical examinations performed by a single physiotherapist. Ethical approval for this study was obtained from the Ethics Committee of Shanghai Children's Hospital (approval No. 2020R069-E02). This study was conducted in accordance with the relevant guidelines and the Declaration of Helsinki (as revised in 2013). Informed consent was taken from all the patients or patients' legal guardians.

SDR procedure

All SDR surgeries were performed by a consistent team of surgeons with expertise in the procedure (15). The surgical intervention was carried out under general anesthesia. Intraoperative electromyography recordings were obtained using needle electrodes placed in specific muscle groups, including the anal sphincter, bilateral hip adductors, quadriceps, hamstrings, tibialis anterior, medial and lateral gastrocnemius, and peroneus longus. During the procedure, intraoperative neurophysiological monitoring was employed to ensure the integrity and functionality of the nervous system. To maintain the stability of the monitoring system, the minimum alveolar concentration of sevoflurane was carefully controlled and kept below 0.5, while the patient's core body temperature was maintained within the range of 36 to 37 ℃. The patient was positioned prone with the head lowered, and a single-level laminotomy was performed below the conus medullaris, typically at the L2–L3 level. This approach allowed for exposure of the cauda equina after opening the dura. The nerve roots/rootlets were electrically tested using a bipolar probe to identify the motor and sensory nerve fibers (16). Following the identification of specific dorsal roots/rootlets that met the rhizotomy protocol, partial transection was performed (17,18). Once all nerve roots/rootlets were tested and addressed, the surgical incision was meticulously closed layer by layer. This standardized surgical technique and monitoring protocol were consistently followed for all SDR procedures in the study (19).

Physical assessment before and after SDR

The motor function, muscle tone and joint range of motion of all children were assessed by one single physiotherapist before SDR. Motor function was measured by two methods, the gross motor function classification system (GMFCS) and gross motor function measure-66 (GMFM-66) (20,21). GMFCS is a five-grade classification system for determination of motor function of CP. Patients classified as the highest GMFCS level I were those who can walk without limitations, and those evaluated as the worst level V were those who needed to be dependent on humans and equipment to move. GMFM-66 is an observational clinical tool for evaluation of motor function in patients suffering from CP. The GMFM-66 scoring system is a four-point scale that consists of 66 items organized into five dimensions of gross motor function. In this system, a five-year-old child without motor disabilities achieves the maximum score of 100. To assess the muscle tone of bilateral lower extremities in all patients, the modified Ashworth Scale (mAS) was used (22,23). The mAS system includes six grades:

- ❖ Grade 0 (mAS score =0): no increase in muscle tone.
- ❖ Grade 1 (mAS score =1): slight increase in muscle tone, observed as a catch and release or minimum resistance at the end of the range of motion when the affected part is moved in flexion or extension.
- ❖ Grade 1+ (mAS score =2): slight increase in muscle tone, characterized by a catch followed by minimal resistance throughout the remaining range of movement.
- ❖ Grade 2 (mAS score =3): moderate increase in muscle tone.
- ❖ Grade 3 (mAS score =4): significant increase in muscle tone.
- ❖ Grade 4 (mAS score =5): affected part rigid in flexion or extension.

In this study, the muscles assessed included bilateral hip adductors, quadriceps femoris, hamstrings, gastrocnemius, and soleus. The target muscles, except for the quadriceps femoris, were considered muscles evaluated as mAS level 2 or higher before the SDR procedure. Two weeks after SDR, patients were discharged and received another physical examination.

Measurement and definition of tibial torsion

In this study, we employed the transmalleolar angle (TMA) as a measurement to evaluate the presence of internal/external tibial torsion in patients before undergoing SDR (22-24). To measure the TMA, the patient was positioned in a supine position, with both feet extended beyond the edge of the bed. The midpoint of the patella was marked at the center of the medial and lateral sides of the knee. Subsequently, the highest points of the inner and outer ankles were marked on both sides. With the midpoint of the patella directed upwards and the knee in a neutral position, a gravity goniometer was placed at the highest points of the inner and outer ankles on each side to accurately measure the TMA (*Figure 1*). The TMA was assessed both before and after the SDR procedure, with a larger degree indicating a greater external rotation of the lower tibial segment (foot end) in relation to the upper tibial segment (knee end). The classification of normal and internal/external tibial torsion was based on the age-matched normal range of TMA provided by the Shanghai Disabled Persons' Federation (*Table 1*). All limbs included in the study were categorized into three groups: the internal tibial torsion group, consisting of limbs with measured values below the normal range; the normal group, comprising limbs within the normal range; and the external tibial torsion group, consisting of limbs with measured values above the normal range.

Statistical analysis

SPSS 26.0 (IBM, Illinois, USA) was used for statistical analysis. All continuous data were demonstrated by mean ± standard deviation. Preoperative and postoperative comparisons were analyzed by the Wilcoxon paired rank sum test, and comparisons between groups of data were made by the student *t*-test or Mann-Whitney rank sum test as appropriate. Fisher exact test or Pearson χ^2 test was used for comparison of categorical variables. A P value less than 0.05 was considered as statistically different.

Results

A total of 148 children (113 males, 35 females) met

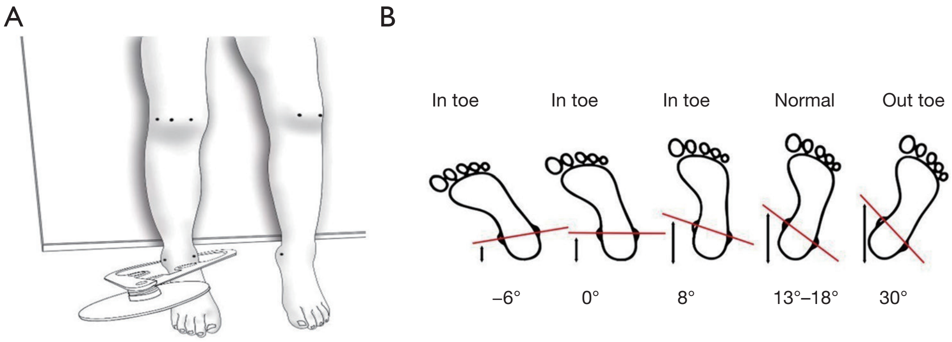

Figure 1 TMA measured by gravity goniometer. (A) TMA was measured using a gravity goniometer in the supine position after marking the medial malleolus of the tibia and lateral malleolus of the fibula while extending the knee to the coronal plane. (B) The negative value refers to the internal rotation of the tibia, whereas the positive value refers to the external rotation. TMA, transmalleolar angle.

Table 1 Normal ranges of TMA for children of all ages in the Shanghai Disabled Persons' and Federation

Age (years)	Normal range for TMA (°)
0< age <2	0< TMA <2
2≤ age <4	2≤ TMA <4
4≤ age <5	4≤ TMA <8
5≤ age <6	8≤ TMA <13
age ≥6	13≤ TMA ≤18

TMA, transmalleolar angle.

the inclusion criteria for this study. The mean age was 6.0±2.2 years, ranging from 3 to 16 years. Among them, 18 (12.2%) had hemiplegia, 106 (71.6%) had diplegia, and 24 (16.2%) had quadriplegia as their topographical subtype. Prior to the surgery, 16 (10.8%) children were classified as GMFCS level I, 50 (33.8%) as level II, 55 (37.2%) as level III, 25 (16.9%) as level IV, and 2 (1.4%) as level V. The preoperative GMFM-66 score was 62.1±11.8.

During the SDR procedure, an average of 55.9±11.6 nerve roots/rootlets were electrically stimulated, and a total of 7.2±3.2 dorsal roots/rootlets (left side: 4.1±2.3, right side: 3.1±2.1) were partially transected according to the rhizotomy protocol. Following SDR, there was a significant decrease in muscle tone in the lower extremities (refer to *Table 2*). The mAS score of bilateral adductors decreased after SDR (left side: 2.9±1.3 *vs.* 1.7±0.9, P<0.0001; right side: 2.9±1.2 *vs.* 1.7±0.8, P<0.0001). Additionally, the value of mAS scores for quadriceps decreased (left side: 0.9±1.2 *vs.* 0.1±0.4, P<0.0001; right side: 0.8±1.2 *vs.* 0.1±0.4, P<0.0001), and the muscle tone of bilateral hamstrings also exhibited a significant reduction after the operation (left side: 3.2±1.1 *vs.* 2.7±0.9, P<0.0001; right side: 3.3±1.0 *vs.* 2.8±0.8, P<0.0001). Furthermore, the mAS score of bilateral anterior tibialis decreased (left side: 0.6±0.5 *vs.* 0.3±0.5, P<0.0001; right side: 0.6±0.6 *vs.* 0.3±0.4, P<0.0001), Similarly, the mAS in bilateral gastrocnemius displayed a significant decrease (left side: 4.6±0.7 *vs.* 3.9±0.8, P<0.0001; right side: 4.8±0.5 *vs.* 4.0±0.7, P<0.0001), and the muscle tone of bilateral soleus also decreased (left side: 4.1±1.0 *vs.* 3.0±0.9, P<0.0001; right side: 4.2±0.8 *vs.* 3.1±0.9, P<0.0001).

The range of motion in three joints (hip, knee, and ankle) increased after SDR. The range of motion for bilateral hip abduction increased (left side: 74.7±12.5 *vs.* 82.3±8.6, P<0.0001; right side: 75.0±12.5 *vs.* 82.0±9.3, P<0.0001). Left ankle dorsiflexion with knee extended also showed an increase (−6.3±15.0 *vs.* 6.9±10.6, P<0.0001), and right ankle dorsiflexion with knee extended exhibited an increase as well (−6.7±14.0 *vs.* 3.9±14.8, P<0.0001). The range of motion for left ankle dorsiflexion with knee flexed increased (6.2±12.8 *vs.* 15.8±7.6, P<0.0001), and right ankle dorsiflexion with knee flexed also increased (5.5±11.8 *vs.* 14.5±7.8, P<0.0001). Additionally, bilateral TMA increased after SDR. The degree of TMA increased on the right side (3.1±2.9 *vs.* 6.0±2.1, P<0.0001) and on the left side (4.2±3.5 *vs.* 6.7±2.6, P<0.0001).

A total of 296 limbs from 148 cases were assessed in this study. Prior to the surgery, 257 (86.8%) limbs were classified as having internal tibial torsion, 35 (11.8%) were classified as normal, and 4 (1.4%) were classified as having external tibial torsion. It was observed that limbs with internal tibial torsion tended to belong to older patients compared to limbs with a normal angle (6.7±2.2 *vs.* 5.2±2.2 years old, P<0.001). The muscle tone of the tibialis

Table 2 Clinical details of patients before and after selective dorsal rhizotomy

Characteristics	Pre-operational status	Post-operational status	P value
Spasticity (modified Ashworth Scale Score)			
Hip adductors			
Left	2.9±1.3	1.7±0.9	<0.0001
Right	2.9±1.2	1.7±0.8	<0.0001
Quadriceps			
Left	0.9±1.2	0.1±0.4	<0.0001
Right	0.8±1.2	0.1±0.4	<0.0001
Hamstrings			
Left	3.2±1.1	2.7±0.9	<0.0001
Right	3.3±1.0	2.8±0.8	<0.0001
Tibialis anterior			
Left	0.6±0.5	0.3±0.5	<0.0001
Right	0.6±0.6	0.3±0.4	<0.0001
Gastrocnemius			
Left	4.6±0.7	3.9±0.8	<0.0001
Right	4.8±0.5	4.0±0.7	<0.0001
Soleus			
Left	4.1±1.0	3.0±0.9	<0.0001
Right	4.2±0.8	3.1±0.9	<0.0001
Range of motion (°)			
Hip abduction			
Left	74.7±12.5	82.3±8.6	<0.0001
Right	75.0±12.5	82.0±9.3	<0.0001
Knee flexion			
Left	150.1±4.3	151.4±3.7	<0.0001
Right	150.1±4.6	151.3±3.8	<0.05
Ankle dorsiflexion (knee extended)			
Left	–6.3±15.0	6.9±10.6	<0.0001
Right	–6.7±14.0	3.9±14.8	<0.0001
Ankle dorsiflexion (knee flexed)			
Left	6.2±12.8	15.8±7.6	<0.0001
Right	5.5±11.8	14.5±7.8	<0.0001
Tibial torsion degree			
Left	3.1±2.9	6.0±2.1	<0.0001
Right	4.2±3.5	6.7±2.6	<0.0001

Data are presented as mean ± standard deviation.

Table 3 Clinical data of all limbs after being grouped according to preoperative tibial torsion

Characteristics	Internal tibial torsion (n=257)	Normal (n=35)	External tibial torsion (n=4)
Age (years)	6.7±2.2	5.2±2.2***	5.2±3.2
Pre-op gross motor function classification system	2.6±0.9	2.7±0.9	2.8±1.3
Pre-op gross motor function measurement-66	62.2±11.7	61.4±11.8	62.0±18.5
Spasticity (modified Ashworth Scale Score)			
Hip adductors	2.9±1.2	3.0±1.3	3.0±2.0
Quadriceps	0.9±1.2	0.9±1.2	0.3±0.5
Hamstrings	3.2±1.1	3.3±1.0	3.3±1.5
Tibialis anterior	0.6±0.5	0.4±0.5*	0.3±0.5
Gastrocnemius	4.7±0.6	4.7±0.6	4.5±1.0
Soleus	4.2±0.9	3.9±0.8*	4.0±1.4
Range of motion			
Hip abduction	74.4±12.6	78.6±11.1*	68.8±11.8
Knee flexion	150.1±4.6	150.3±3.4	150.0±0.0
Ankle dorsiflexion (knee extended)	−7.2±14.6	−0.6±11.7**	−11.3±18.0
Ankle dorsiflexion (knee flexed)	5.2±12.5	10.7±9.7**	6.3±13.8
Tibial torsion degree	3.2±2.9	5.9±3.6***	9.8±7.5

Data are presented as mean ± standard deviation. *, P<0.05 compared with group classified as internal tibial torsion. **, P<0.01 compared with group classified as internal tibial torsion. ***, P<0.001 compared with group classified as internal tibial torsion.

anterior and soleus was higher in limbs with internal tibial torsion compared to those with a normal angle. Additionally, the limbs with a normal angle exhibited greater joint mobility, particularly in hip abduction and ankle dorsiflexion, when compared to limbs with internal rotation (*Table 3*).

In order to investigate the factors contributing to internal rotation of the tibia, we further examined the clinical data of 18 hemiplegic children, using the intact limbs of these patients as a control group in comparison to the affected limbs. No significant difference was found in the TMA between the intact and affected extremities, although the spasticity of muscles in the affected limbs was much higher than that of the intact limbs (*Table 4*).

The preoperative and postoperative changes in the TMA for the 296 assessed limbs are presented in *Figure 2*. Among the limbs with internal tibial torsion, 21.0% (54/257) improved and changed to a normal angle after SDR, although the other 79% (203/257) were still grouped as internal tibial torsion, 65% (166/257) of them showed an outward change in the TMA angle after SDR, indicating that the improvement of internal tibial torsion could be seen in a majority of limbs. Additionally, one limb (25.0%) with external tibial torsion improved and changed to a normal angle. When comparing the differences between the 54 improved limbs and the 203 unchanged limbs with internal tibial torsion, several observations were made. Firstly, the limbs that showed improvement tended to belong to younger patients at the time of surgery, which reached statistical significance (*Figure 3A*, P<0.0001). Furthermore, limbs with a lower preoperative mAS score for the hamstrings were more likely to improve compared to those with a higher mAS score for the hamstrings (*Figure 3B*). The change in tibial torsion after SDR was significant when compared to the preoperative status, as confirmed by a chi-square test involving all 296 limbs, with a P value less than 0.0001 (*Figure 4A*). No significant difference was observed when comparing the preoperative and postoperative statuses of the limbs in the 36 limbs of hemiplegic children (*Figure 4B*). However, when excluding these 36 limbs and considering the remaining 260 limbs, a statistically significant difference was observed (*Figure 4C*),

Table 4 Clinical data of both affected and intact limbs in patients with hemiplegia before selective dorsal rhizotomy

Characteristics	Affected limbs (n=18)	Intact limbs (n=18)	P value
Age, years	6.8±2.0		–
Gender			
Boys	26 (72.2)		–
Girls	10 (27.8)		–
Gross motor function classification system			
Level I	24 (66.7)		–
Level II	12 (33.3)		–
Level III	–		–
Level IV	–		–
Level V	–		–
Gross motor function measurement-66	78.83±5.57		–
Spasticity (modified Ashworth Scale Score)			
Hip adductors	0.9±0.7	0.3±0.6	<0.01
Quadriceps	0.0±0.0	0.0±0.0	>0.99
Hamstrings	2.1±0.9	0.7±0.7	<0.0001
Tibialis anterior	0.2±0.4	0.1±0.2	0.296
Gastrocnemius	4.9±0.2	3.2±0.9	<0.0001
Soleus	4.8±0.4	1.9±1.0	<0.0001
Range of motion			
Hip abduction	86.1±3.7	87.2±3.9	0.299
Knee flexion	151.4±2.9	151.4±2.9	>0.99
Ankle dorsiflexion (knee extended)	–16.7±12.9	12.8±5.5	<0.0001
Ankle dorsiflexion (knee flexed)	–10.3±12.3	17.2±4.3	<0.0001
Tibial torsion degree	4.4±3.3	6.2±5.5	0.301

Data are presented as mean ± standard deviation or n (%).

with a P value less than 0.0001.

Discussion

Previous study has reported an association between tibial torsion in children with CP and abnormal muscle tone in the hip adductors, hamstrings, and posterior tibial muscles, which aligns with our findings (2). Our study revealed that limbs classified as internal rotation had higher muscle tone in the soleus compared to normal limbs. Additionally, we observed an association between elevated muscle tone in the anterior tibial muscles and internal tibial rotation. In normally developing children, physiological internal tibial rotation is present at a young age and gradually resolves by 4–5 years old (24). However, children with CP appear to have difficulty in naturally correcting internal tibial rotation during development. In our cohort study, we found that limbs with internal tibial rotation tended to belong to older children. This may be attributed to the fact that younger patients were affected by spasticity for a shorter period, resulting in a relatively normal tibial angle. However, it remains unclear whether patients with a normal angle would deteriorate over time.

SDR is a safe and effective surgical approach for

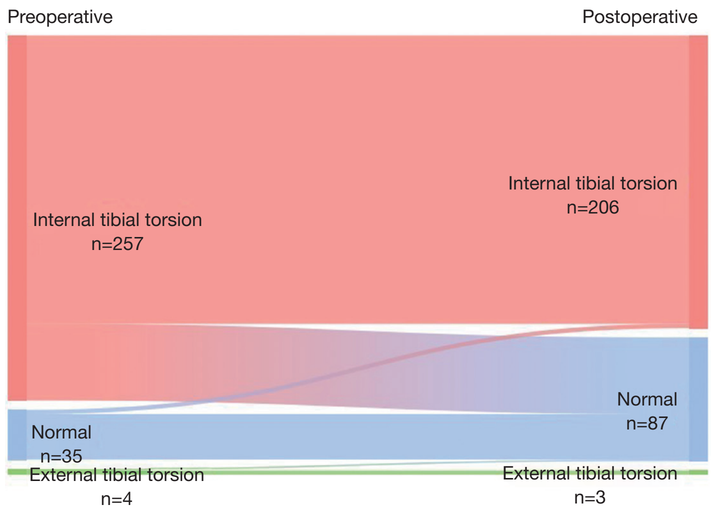

Figure 2 The change of TMA in 296 limbs after selective dorsal rhizotomy. TMA, transmalleolar angle.

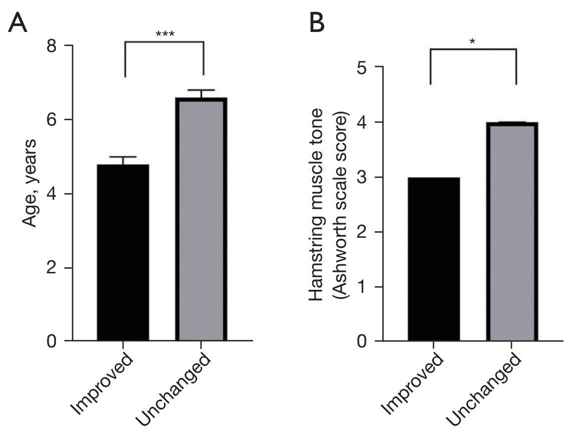

Figure 3 Comparison of factors influencing the improvement of tibial torsion in 257 limbs defined as internal tibial torsion basing on the measurement of transmalleolar angle. (A) Comparing the limbs with/without improvement after SDR from the aspect of age derivation. The limbs with improvement derived from patients with a median age of 4.8 years old, younger than those without change (6.6 years old). (B) Comparing the limbs with/without improvement after SDR from the aspect of muscle tone of hamstring. The limbs with improvement possess a lower median modified Ashworth Scale score (score 3) than those without change (median modified Ashworth Scale score 4). *, P<0.05; ***, P<0.001. SDR, selective dorsal rhizotomy.

reducing muscle spasticity in the lower limbs of children with spastic CP (25). The patients included in this study demonstrated a significant improvement in TMA after the surgery, with a statistically significant increase in values compared to the preoperative period. It is important to note that these results reflect short-term changes after surgery, excluding the influence of postoperative rehabilitation and other interventions. Based on these findings, it is reasonable to speculate that the decrease in muscle tone in the lower limbs contributed to the improvement of tibial torsion. Furthermore, it can be presumed that elevated muscle tone in the lower limbs might be a contributing factor to tibial torsion in individuals with spastic CP. However, it is important to consider that tibial torsion in this population may not solely result from spasticity. Another potential cause of this phenomenon could be the development of secondary skeletomuscular deformities due to increased muscle tone. This speculation is supported by the observation that patients with younger age and lower spasticity in the hamstrings tended to experience greater improvement in tibial torsion following SDR.

In an attempt to identify potential causes of tibial torsion, we reviewed the data of hemiplegic children, as their unaffected limbs could serve as a control group. However, we did not find any significant differences in

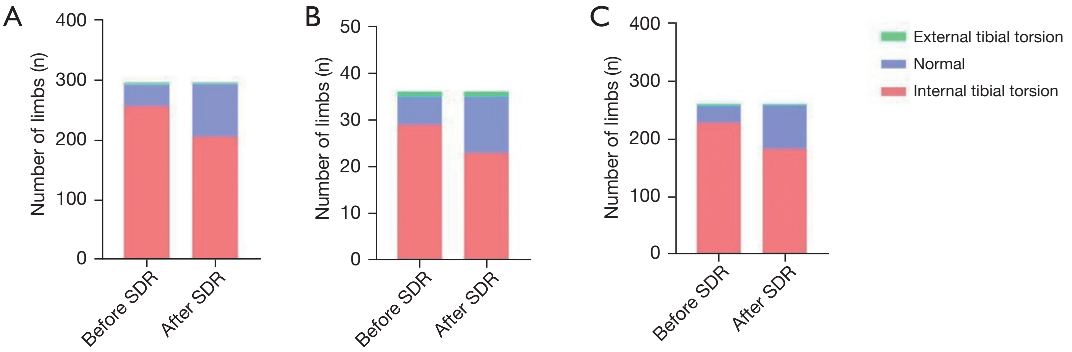

Figure 4 Comparison of the status of tibial torsion basing on transmalleolar angle before and after SDR. (A) Comparison of the status of tibial torsion before and after SDR in all 296 limbs. Before SDR, 257 were classified as internal tibial torsion, 4 external tibial torsion and 35 normal, respectively. After SDR, 206 were classified as internal tibial torsion, 3 external tibial torsion and 87 normal, respectively (P<0.001). (B) Comparison of the status of tibial torsion before and after SDR in 36 limbs from 18 hemiplegic patients. Before SDR, 29 were classified as internal tibial torsion, 1 external tibial torsion and 6 normal, respectively. After SDR, 23 were classified as internal tibial torsion, 1 external tibial torsion and 12 normal, respectively (P=0.26). (C) Comparison of the status of tibial torsion before and after SDR in 260 limbs after excluding 36 limbs from hemiplegic patients. Before SDR, 228 were classified as internal tibial torsion, 3 external tibial torsion and 29 normal, respectively. After SDR, 183 were classified as internal tibial torsion, 2 external tibial torsion and 75 normal, respectively (P<0.001). SDR, selective dorsal rhizotomy.

TMA among the 18 hemiplegic patients included in this study. It is possible that the lack of significant differences could be attributed to the limited sample size of hemiplegic patients and the compensatory mechanisms present in the intact limbs of these individuals. Further studies with larger sample sizes are warranted to better understand this issue and provide more conclusive findings.

However, we observed a single case where the tibial angle changed from normal to internal rotation after surgery. Upon further examination of this case, we found that the joint movement angles were significantly lower in comparison to the normal group, Additionally, the spasticity levels of the adductor and soleus muscles were higher than the normal level. Based on these findings, we speculate that the previously normal tibial angle may have been a result of compensatory mechanisms. Although there was improvement in muscle tone and joint range of motion following surgery, the TMA shifted into the abnormal range. It is possible that the situation may change with the implementation of a rehabilitation program.

Our findings indicate that younger patients tend to benefit more from SDR, which is consistent with previous studies demonstrating that patients below 6 years of age show better response to SDR compared to older patients (15).

Limitation

However, several limitations existed in this study. Firstly, the follow-up period was relatively short, and it remains uncertain whether the improvement in tibial torsion will be sustained in the long term. Secondly, the study was limited by the small number of cases, retrospective design, and the fact that it was conducted at a single center, which may impact the reliability of the results. Nevertheless, considering that this study aimed to preliminarily investigate the changes in tibial torsion after SDR, we believe that SDR can offer an alternative treatment option for tibial torsion in children with spastic CP. Further research is warranted to address these limitations and provide more comprehensive insights into the long-term outcomes of SDR in this population.

Conclusions

SDR can reduce muscle tone and improve joint mobility in children with spastic CP. Patients with older ages and higher spasticity in tibialis anterior and soleus are more likely to develop internal tibial torsion. SDR can improve tibial torsion in patients with spastic CP. Limbs classified as internal tibial torsion tended to improve after SDR if they presented with lower muscle tone of hamstring and derived from patients with younger age.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://tp.amegroups.com/article/view/10.21037/tp-23-339/rc

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Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://tp.amegroups.com/article/view/10.21037/tp-23-339/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. This study was conducted in accordance with the relevant guidelines and the Declaration of Helsinki (as revised in 2013). Ethical approval for this study was obtained from the Ethics Committee of Shanghai Children's Hospital (approval No. 2020R069-E02). Informed consent was taken from all the patients or patients' legal guardians.

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