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Original Article

Effect of minimally invasive sternocleidomastoid release on muscle regeneration in children with congenital muscular torticollis

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Abstract: Objective: To investigate the clinical efficacy of minimally invasive small-incision sternocleidomastoid (SCM) muscle release in the treatment of congenital muscular torticollis (CMT) in children and its regulatory effect on abnormal regeneration of the SCM muscle. Methods: A retrospective analysis was conducted on 178 children with CMT who underwent minimally invasive small-incision SCM release at Qinghai Provincial Women and Children's Hospital from January 2022 to December 2024. All children completed a 12-month follow-up. Clinical efficacy scores, SCM muscle thickness, and echogenicity were measured preoperatively, 1, 6, and 12 months postoperatively. The excellent and good rate of clinical efficacy was statistically analyzed, and changes in ultrasound indicators and postoperative complication rate were statistically analyzed to evaluate the therapeutic effect and safety of the surgery. Results: The total clinical efficacy score at each postoperative time point was significantly higher than that before surgery ($P<0.001$), with the excellent efficacy rate reaching 77.53% at 12 months postoperatively. The thickness and echogenicity of the SCM muscle showed a continuous downward trend at each postoperative time point, compared with preoperative values (all $P<0.001$). Ten mild complications occurred postoperatively, with a total complication rate of 5.62%. All symptoms were relieved after symptomatic treatment, and no serious adverse events occurred. Conclusion: Minimally invasive small-incision SCM release is clinically effective in the treatment of children with CMT. It can effectively improve cervical motor function and craniofacial appearance, inhibit abnormal SCM muscle regeneration, and has high safety and few complications. For children with CMT who fail to respond to conservative treatment, this procedure is an ideal surgical treatment option and has good clinical application value.

Keywords: Congenital muscular torticollis, minimally invasive surgery, sternocleidomastoid muscle release, muscle regeneration, muscle Echo intensity, children

Introduction

Congenital muscular torticollis (CMT) is a common musculoskeletal deformity. The core pathological feature of this disease is unilateral fibrosis and contracture of the sternocleidomastoid (SCM) muscle, which causes the head to tilt to the affected side and the face to rotate to the healthy side [1]. If timely and effective early intervention is not carried out, the child will gradually develop secondary deformities such as facial asymmetry and cervical scoliosis, which can seriously damage the child's physical and mental health [2, 3]. For children with mild contracture, conservative treatment is often used in clinical practice, such as manual stretching and physical therapy. However, for children who do not respond to conservative treatment, have large fibrotic masses, or have severe contracture, surgery is the key treatment option [4, 5]. Although the conventional open surgery can effectively release contracted tissues, it has many drawbacks, including long surgical incisions, large trauma, and obvious postoperative scars. Moreover, there is currently no systematic monitoring method for postoperative muscle regeneration [6, 7]. With the development of minimally invasive surgical techniques, minimally invasive small-incision SCM muscle release has been widely used due to its advantages such as small trauma, rapid recovery, and inconspicuous scarring [8, 9]. However, long-term follow-up studies on postoperative muscle regeneration in CMT children who have undergone this procedure are still relatively scarce in China. This study retrospectively analyzed the clinical data of 178 CMT children who underwent small-incision SCM muscle release surgery to observe postoperative muscle regeneration, aiming to provide clinical evidence for optimizing the surgical treatment of this disease.

Information and methodology

General data

This retrospective study analyzed the clinical data of 178 children with CMT who underwent minimally invasive SCM muscle release at Qinghai Provincial Women and Children's Hospital from January 2022 to December 2024.

Inclusion criteria: (1) age <18 years; (2) medical history and physical examination meeting the diagnostic criteria for congenital SCM muscular torticollis [10]; (3) persistent head tilt, with limited neck rotation and lateral flexion angles >15°; (4) ineffective conservative treatment (treatment duration at least 6 months), and first surgical treatment; (5) ultrasound examination confirming SCM muscle lesions of different locations and degrees, excluding torticollis caused by other etiologies. Exclusion criteria: (1) concomitant congenital anomalies (e.g., congenital hip dislocation, scoliosis); (2) history of neck surgery; (3) spasmodic torticollis due to central nervous system diseases or cervical spine deformity, as well as strabismic torticollis, postural torticollis, and postoperative recurrent muscular torticollis; (4) contraindications to surgery such as coagulation disorders or active infections; (5) incomplete follow-up data. This study was approved by the Ethics Committee of Qinghai Provincial Women and Children's Hospital (Approval No.: 2025QHFELLW10).

Surgical procedure

All children underwent surgery performed by the same senior chief physician team under general anesthesia using minimally invasive small incision SCM muscle release. The child was placed in a supine position with the shoulders elevated and the head turned to the healthy side to fully expose the sternal and clavicular ends of the SCM muscle on the affected side. The surface landmarks of the sternum, clavicle, neurovascular tissues, and endoscopic operating ports were identified by palpation and marked. Two operating ports were designed: one located 5 cm below the sternoclavicular joint and 1.5 cm medial to the sternoclavicular joint on the affected side; the other located 5 cm below the midline of the sternum. After routine skin disinfection, sterile saline was injected subcutaneously. Each operating port was opened layer by layer using an electrocautery knife, making a 3 mm transverse incision, sequentially cutting the skin, subcutaneous tissue, and platysma muscle. The SCM muscle was bluntly dissected to expose its sternal and clavicular heads. The tissue was lifted with hemostatic forceps, and the muscle bundles at the sternal and clavicular ends were dissected and severed using microscissors or electrocoagulation instruments. The upper muscle belly was fully released until neck rotation and lateral flexion were restored to normal, ensuring complete release of the contracted muscles. During the release procedure, strict avoidance of injury to adjacent blood vessels and nerves (such as the external jugular vein and accessory nerve) was maintained. Active bleeding was promptly treated, and electrocoagulation was used to achieve thorough hemostasis. After complete hemostasis, absorbable sutures were used to suture the skin and subcutaneous tissue layer by layer, and the incision was covered with sterile gauze and pressure-bandaged. Throughout the surgery, vital signs such as blood pressure, blood oxygen saturation, and heart rate were closely monitored.

Postoperative management and rehabilitation

A cervical brace (neck collar) was worn for 2-3 weeks post-surgery to maintain a neutral or slightly lateral tilt of the neck, protecting the released neck muscles and promoting wound healing. Prophylactic antibiotics were administered for 3 days post-surgery, and analgesics were given to patients experiencing significant pain. The incision dressing was changed 24-48 hours post-surgery, and the wound was observed for healing, keeping it dry and clean. After discharge, patients underwent a 12-month long-term follow-up through outpatient visits and telephone follow-ups. Under the guidance of a rehabilitation therapist, all children underwent at least 6 months of systematic active and passive neck exercises, including lateral flexion of the healthy neck and rotation of the affected neck.

Observation indicators and data collection

(1) General data such as gender, age at surgery, affected side, surgical time, and incision length were collected.

(2) Clinical efficacy data at four time points was collected: preoperative (T0), 1 month postoperative (T1), 6 months postoperative (T2), and 12 months postoperative (T3). The 1999 revised Cheng and Tang rating scales were used to evaluate surgical efficacy from seven dimensions: degree of limitation of head and neck rotation, lateral flexion angle, craniofacial deformity, cervical appearance, scar formation, head deviation, and physician subjective evaluation [11]. The scores for each dimension were divided into four levels. Excellent: 3 points, rotation/lateral flexion angle ≤5°, no muscle contracture, no obvious scarring; Good: 2 points, rotation/lateral flexion angle 6°-10°, no severe neck contracture, only fine linear scarring; Fair: 1 point, rotation/lateral flexion angle 10°-15°, slight clavicular end contracture affecting movement, linear scarring visible; Poor: 0 point, rotation/lateral flexion angle >15°, severe sternal end contracture restricting movement, accompanied by hypertrophic scarring.

Craniofacial deformity, head tilt, and subjective scores were graded based on severity. The total score range is 0-21 points, serving as a comprehensive prognostic assessment indicator; a higher score indicates better recovery. Total score grading criteria: Excellent 17-21 points, Good 12-16 points, Fair 7-11 points, Poor <7 points.

(3) The same ultrasound physician measured the maximum cross-sectional thickness of the lower and middle segments of the bilateral SCM muscles under contracted and relaxed states at time points T0, T1, T2, and T3, and calculated the difference in muscle thickness between the two sides. The GE Voluson E8 high-frequency ultrasound system with a 7-10 MHz linear array probe, was used to complete the examination using the musculoskeletal mode. During the examination, the child was placed in a supine position with the neck relaxed, the shoulders elevated by 5-10 cm, and the head fixed in a neutral position to ensure standardized image acquisition. Transverse and longitudinal scans were performed along the SCM muscle, and the thickest part of the muscle in the transverse section was measured [12, 13].

(4) Muscle echo intensity was detected using a GE Voluson E8 high-frequency ultrasound system equipped with a 7-18 MHz SP 10-16-D high-frequency linear array probe. Instrument parameter settings: fixed gain 50-60 dB, detection depth 2-3 cm, dynamic range 70-80 dB, focal point located in the middle of the SCM muscle, frame rate ≥30 fps. Automatic gain control, color Doppler, and image optimization filtering functions were turned off. All examination operations were performed by the same ultrasound physician who had received standardized training, and the examination time points and patient positioning standards were consistent with those for muscle thickness detection. The probe was placed along the longitudinal axis of the SCM muscle, and three clear, artifact-free images were taken from the mid-section of the muscle belly. Within each image, three non-overlapping regions of interest (ROIs), each 2-3 mm in size and completely located within the muscle parenchyma, were selected. The average echo intensity of each ROI was calculated using workstation software (range 0-255). After removing outliers, the mean of the remaining data was used as the final detection result. Quality control was strictly performed according to the requirements shown in **Figure 1**.

(5) Postoperative complications were statistically analyzed and recorded, including incision infection, hematoma, permanent nerve injury, transient hoarseness, massive hemorrhage, and hypertrophic scarring.

Statistical analysis

Data analysis was performed using SPSS 25.0 software. Normally distributed continuous data are presented as mean ± standard deviation ($\overline{x}$ ± sd), and categorical data were expressed as percentages (%). Repeated measures ANOVA was used to compare the differences in clinical efficacy scores and muscle thickness at different time points, with a significance level of α = 0.05. When the differences between groups were statistically significant, pairwise comparisons were performed using the least significant difference method, and the P values were

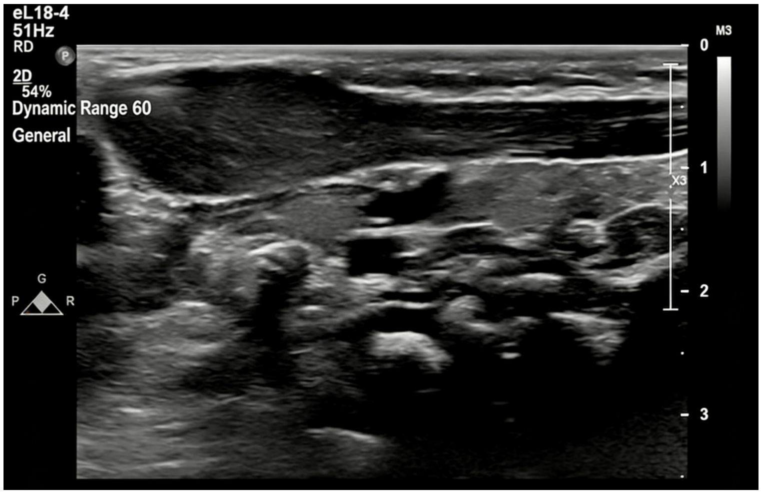

Figure 1. Typical preoperative longitudinal ultrasound image of the affected sternocleidomastoid muscle in a pediatric patient with congenital muscular torticollis, showing characteristic pathological changes including muscle thickening and increased echo intensity suggestive of interstitial fibrosis. Imaging was performed using a GE Voluson E8 system with a 7-18 MHz high-frequency linear probe.

Table 1. General information and surgical details of congenital muscular torticollischildren (n/%, $\overline{x}$ ± sd)

Item	n/$\overline{x}$ ± sd
Gender	
Male	98 (55.06)
Female	80 (44.94)
Age at surgery (years)	6.29 ± 2.30
Affected side	
Left	93 (52.25)
Right	85 (47.75)
Operative time (min)	92.83 ± 17.24
Type of condition	
Torticollis	59 (33.15)
Clavicular head contracture	65 (36.52)
Sternal head contracture	41 (23.03)
Bilateral head contracture	13 (7.30)

adjusted for multiple comparisons using the Bonferroni correction (α = 0.05/6 = 0.0083). Statistical significance was defined as adjusted P<0.0083.

Results

General and surgical data of CMT children

All 178 children with CMT enrolled in the study successfully underwent surgery, with no cases requiring conversion to open surgery. Intraoperative blood loss was minimal, and none of the children required blood transfusions. The operation time ranged from 60 to 131 min, and the children's ages ranged from 3 to 15 years. Further details are presented in **Table 1**.

Comparison of clinical efficacy scores across time points

The results of the 178 children at four time points (T0-T3) showed that all individual scores (limited head and neck rotation, lateral flexion angle, craniofacial deformity, cervical appearance, scarring, head tilt, and physician's subjective assessment) and the total score significantly improved postoperatively, showing a continuous upward trend (P<0.001).

Repeated-measures ANOVA indicated statistically significant differences across time points for all domains (all *P*<0.001, **Table 2**). Pairwise comparisons revealed statistically significant differences between all-time point pairs (all unadjusted P<0.001). After Bonferroni correction for multiple comparisons (α = 0.0083), all differences remained statistically significant (**Table 3**).

Comparison of excellent and good clinical efficacy rates across time points

Following minimally invasive SCM release, the excellent and good clinical efficacy rates gradually increased with the extension of follow-up time. Specifically, the excellent and good rate was 1.68% 1 month postoperatively, 35.95% 6 months postoperatively, and reached 77.53% 12 months postoperatively (**Table 4**).

Comparison of muscle thickness across time points

Data from T0 to T3 showed that muscle thickness in the children continuously decreased over time. Repeated-measures ANOVA confirmed that the differences in muscle thickness at different time points were statistically significant (P<0.001, **Table 5**). Pairwise comparisons

Table 2. Comparison of clinical efficacy scores in CMT children across different time points (n = 178, $\bar{x}$ ± sd)

Time	Head/neck rotation limitation	Lateral flexion angle	Craniofacial deformity	Cervical appearance	Scar	Head tilt	Clinician's subjective assessment	Total score
T0	1.32±0.55	1.21±0.47	1.20±0.47	1.28±0.50	1.20±0.47	1.20±0.47	1.21±0.47	8.50±3.16
T1	1.71±0.49	1.70±0.49	1.60±0.52	1.61±0.51	1.58±0.53	1.71±0.49	1.63±0.52	11.54±3.14
T2	2.27±0.44	2.31±0.46	2.38±0.49	2.40±0.49	2.23±0.42	2.27±0.45	2.34±0.47	16.20±2.62
T3	2.60±0.60	2.75±0.44	2.78±0.41	2.86±0.35	2.71±0.46	2.70±0.46	2.78±0.41	19.28±2.67
F	259.177	623.502	711.316	802.123	588.769	611.402	626.498	770.040
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Note: T0, preoperative; T1, 1 month postoperative; T2, 6 months postoperative; T3, 12 months postoperative. CMT, congenital muscular torticollis.

Table 3. Pairwise comparisons of clinical efficacy total scores between different time points

Comparison group	Mean difference	Standard error	*t*	*P*	95% confidence interval
T0 vs. T1	3.039	0.227	13.39	<0.001	2.687-3.481
T0 vs. T2	7.697	0.215	35.80	<0.001	7.272-8.121
T0 vs. T3	10.781	0.251	42.95	<0.001	10.286-11.276
T1 vs. T2	4.657	0.206	22.61	<0.001	4.251-5.064
T1 vs. T3	7.742	0.217	35.68	<0.001	7.314-8.169
T2 vs. T3	3.084	0.201	15.34	<0.001	2.687-3.481

Note: T0, preoperative; T1, 1 month postoperative; T2, 6 months postoperative; T3, 12 months postoperative.

Table 4. Excellent clinical efficacy rate in CMT children at different time points (n = 178, %)

Time point	Clinical efficacy			x^2	*P*
	Fair	Good	Excellent		
1 month postoperatively	78 (43.82)	97 (54.49)	3 (1.69)	325.678	<0.001
6 months postoperatively	0 (0.00)	114 (64.04)	64 (35.96)		
12 months postoperatively	0 (0.00)	40 (22.47)	138 (77.53)		

CMT, congenital muscular torticollis.

Table 5. Comparison of muscle thickness in CMT children across different time points (n = 178, $\bar{x}$ ± sd)

Time point	T0	T1	T2	T3	*F*	*P*
Muscle thickness (mm)	4.40±0.72	4.25±0.52	4.09±0.39	3.90±0.28	37.883	<0.001

Note: T0, preoperative; T1, 1 month postoperative; T2, 6 months postoperative; T3, 12 months postoperative. CMT, congenital muscular torticollis.

showed that all pairwise differences between time points were statistically significant (unadjusted P<0.05 for all pairs). After Bonferroni correction (α = 0.0083), all comparisons remained statistically significant (**Table 6**).

Comparison of muscle echo intensity across time points

The results showed that the echoic intensity of the muscles in CMT children continuously decreased over time. Repeated measures ANOVA was used to statistically analyze the muscle echogenicity at the four time points. The results showed that the differences in the indicators at each time point were statistically significant (F = 25.343, P<0.001), as detailed in **Table 7**. Further pairwise comparisons revealed statistically significant differences between each time point (all unadjusted P<0.001). After applying Bonferroni correction for six comparisons, all differences remained statistically

Table 6. Pairwise comparisons of muscle thickness between different time points

Comparison group	Mean difference	Standard error	*t*	*P*	95% confidence interval
T0 vs. T1	0.159	0.050	3.18	0.002	0.0061-0.258
T0 vs. T2	0.313	0.055	5.69	<0.001	0.204-0.422
T0 vs. T3	0.506	0.055	9.20	<0.001	0.398-0.615
T1 vs. T2	0.153	0.038	4.03	<0.001	0.079-0.228
T1 vs. T3	0.347	0.041	8.46	<0.001	0.266-0.428
T2 vs. T3	0.194	0.029	6.69	<0.001	0.137-0.250

Note: T0, preoperative; T1, 1 month postoperative; T2, 6 months postoperative; T3, 12 months postoperative.

Table 7. Comparison of muscle echo intensity in CMT children at different time points (n = 178, $\bar{x} \pm$ sd)

Time point	T0	T1	T2	T3	*F*	*P*
Muscle echo intensity	85.68±3.43	80.61±1.89	77.92±3.06	75.48±1.75	25.343	<0.001

Note: T0, preoperative; T1, 1 month postoperative; T2, 6 months postoperative; T3, 12 months postoperative. CMT, congenital muscular torticollis.

Table 8. Pairwise comparison of muscle echo intensity in CMT children at different time points

Comparison group	Mean difference	Standard error	*t*	*P*	95% confidence interval
T0 vs. T1	5.073	0.157	32.31	<0.001	4.763-5.383
T0 vs. T2	7.764	0.145	53.54	<0.001	7.479-8.049
T0 vs. T3	10.202	0.165	61.83	<0.001	9.877-10.527
T1 vs. T2	2.691	0.114	23.60	<0.001	2.467-2.915
T1 vs. T3	5.129	0.051	100.57	<0.001	5.029-5.230
T2 vs. T3	2.438	0.104	23.44	<0.001	2.234-2.643

Note: T0, preoperative; T1, 1 month postoperative; T2, 6 months postoperative; T3, 12 months postoperative. CMT, congenital muscular torticollis.

Table 9. Incidence of postoperative complications in children with CMT (n, %)

Complication	Mild incision redness/swelling	Minor subcutaneous hematoma	Transient hoarseness	Mild scarring hyperplasia
Number of cases	3 (1.69)	3 (1.69)	2 (1.12)	2 (1.12)

Note: CMT, congenital muscular torticollis.

significant at the adjusted α level of 0.0083 (**Table 8**).

Postoperative complications

Postoperative complications included mild incision redness and swelling in 3 cases (healed after dressing changes), small subcutaneous hematoma in 3 cases (spontaneously resolved), transient hoarseness in 2 cases (spontaneously resolved), and mild hypertrophic scarring in 2 cases. The overall complication rate was 5.62%. No serious adverse complications such as permanent nerve damage, massive hemorrhage, or severe incision infection occurred in any of the children (**Table 9**).

Discussion

This retrospective study evaluated the effect of minimally invasive SCM muscle release on muscle regeneration in 178 children with CMT through a 12-month follow-up. This procedure significantly improved neck motor function and craniofacial appearance (excellent efficacy rate of 77.53% at 12 months postoperatively). It inhibited abnormal SCM muscle regeneration by reducing muscle thickness and echogenicity, with both indicators showing a sustained and significant decrease. The procedure was safe, with a total complication rate of 5.62% and no serious adverse events. These results are consistent with those of Wang et al. [8] and Saugat et al. [14]. All three studies demonstrated the significant efficacy of minimally invasive SCM muscle release for CMT, with sustained postoperative functional improvement, fully demonstrating the core advantage of minimal tissue trauma associated with this minimally invasive procedure.

This study differs from previous studies in several key design aspects: 1) The 12-month follow-up period in this study is longer than the 6-month period in Wang et al.'s study, which is more conducive to assessing the long-term stability of muscle regeneration [8]. 2) Saugat et al. used unilateral release, while this study adopted bilateral SCM muscle release, resulting in more thorough muscle release [14]. 3) This study included 178 children aged 3-15 years, a larger sample size, leading to stronger extrapolation compared to Wang et al.'s 96 cases [8] and Saugat et al.'s 82 cases [14]. 4) Unlike single functional scoring assessments, this study combined functional scores with ultrasound indicators (muscle thickness, echo intensity) to objectively quantify muscle fibrosis and regeneration. These differences are important reasons for the differences in efficacy data: the excellent efficacy rate at 12 months post-surgery in this study was higher (77.53%, compared to 65.6% in Wang et al.'s [8], and 68.3% in Saugat et al.'s [14]), which is likely due to the longer follow-up period and the bilateral release technique. Furthermore, the finding of a sustained decrease in muscle echogenicity discovered in this study was not reported in the other two studies, providing new evidence for the mechanism by which minimally invasive surgery inhibits abnormal CMT muscle regeneration.

The study found that the clinical efficacy scores of children at all time points before and after surgery significantly improved, with overall efficacy superior to preoperative levels. The excellent and good rate gradually increased 1 month postoperatively, reaching 77.53% at 12 months, indicating that this surgical procedure can effectively improve neck function and appearance in CMT children, and the efficacy continued to improve over time. This conclusion is in line with the research findings of Wang and Saugat, et al. [8, 14]. The reason for this is that minimally invasive surgery causes less trauma and minimal damage to surrounding tissues, creating a favorable local repair environment and promoting functional recovery [15]. Simultaneously, postoperative cervical collar immobilization and regular active and passive neck rehabilitation training can enhance muscle strength and limb coordination, further optimizing muscle strengthening, quadrant rotation, cervical lateral flexion and head posture control [16, 17]. Notably, the improvement in cervical appearance and craniofacial deformity was particularly significant in these children. This is closely related to the inconspicuous scarring after small incision surgery and the formation of fine linear scars after healing. Only 2 cases of mild hypertrophic scarring were observed in the study, and these did not affect normal neck movement, fully demonstrating the dual advantages of minimally invasive surgery in both aesthetics and functional preservation [18]. Moreover, early relief of abnormal muscle tension can prevent further progression of craniofacial deformities; after muscle stress returns to normal, mild craniofacial deformities can be gradually corrected with natural growth and development. This is the core reason for the significant improvement in craniofacial appearance scores in children 6-12 months after surgery [19, 20].

Endomyosarcoma collagen deposition, interstitial fibrosis caused by fibroblast migration into myocytes, and muscle atrophy are the core pathological changes in CMT. The key to treating this condition with minimally invasive small-incision SCM muscle release is to thoroughly release contracted muscle tissue while avoiding excessive stimulation of abnormal muscle regeneration to prevent recurrence [21]. Previous studies have confirmed that muscle thickness and echogenicity can serve as reliable indicators for assessing the degree of muscle fibrosis in children with CMT [13, 22]. The results of high-frequency ultrasound dynamic monitoring in this study demonstrated that the difference in thickness between the two SCM muscles at each postoperative time point was significantly reduced compared to preoperative values, and steadily decreased over time; muscle echogenicity also decreased significantly postoperatively, showing a continuous decreasing trend. The synchronous changes in these two indicators fully demonstrate that minimally invasive small-incision SCM muscle release can effectively block the abnormal regeneration and fibrosis process of muscle. The results indicate that this procedure does not induce abnormal muscle healing or secondary contractures; on the contrary, it can promote progressive atrophy of muscle fibers after release, reducing the degree of muscle fibrosis. The surgical principle is that the endoscopic-assisted small-incision technique can fully expose the clavicular and sternal ends of the SCM muscle, completely sever the contracted diseased tissue, and minimize damage to surrounding normal muscles and fascia, thus reducing the risk of abnormal muscle regeneration from the source [23, 24]. Moreover, abnormal adhesion between postoperative scar tissue and muscle tissue is a major contributing factor to postoperative muscle dysfunction and recurrence. This study showed good wound healing after the small incision procedure, resulting in infection-free, smooth, and delicate scar tissue. This effectively reduced adhesion between the scar and surrounding muscles, creating conditions for muscle function repair and regeneration prevention [25, 26]. Histological analysis revealed a gradual decrease in muscle echogenicity, indicating that the muscle tissue was repairing towards a normal physiological structure, and the degree of fibrosis was continuously reduced, further supporting the efficacy of this surgical technique in inhibiting pathological abnormal muscle repair [27].

The overall postoperative complication rate in this study was 5.62% and all of which were mild complications, fully demonstrating the excellent safety of this minimally invasive procedure. This advantage is closely related to the surgical technique [28]. The small incision design reduces damage to the skin and subcutaneous tissue, lowering the risk of wound infection and hypertrophic scarring. Intraoperative endoscopic visualization, combined with precise anatomical manipulation, allows for clear identification of important anatomical structures such as the external jugular vein and accessory nerve, avoiding vascular and nerve damage. Precise endoscopic electrocoagulation hemostasis minimizes intraoperative bleeding and the risk of postoperative hematoma formation [29-31]. Two cases of transient hoarseness in this study were considered to be related to a brief cough reflex in CMT, and both symptoms resolved spontaneously, further validating the safety of this surgical procedure in terms of neuroprotection and precise operation. Children's neck tissues are delicate and rich in neurovascular structures; minimally invasive surgery is precise and causes minimal damage, minimizing adverse effects on children's growth and development, and is suitable for the physiological characteristics of children [32].

Compared to similar studies [33-35], this study has several advantages: 1) Most related studies in China have a follow-up period of less than 6 months, making it impossible to observe the medium- and long-term changes in muscle structure. This study's 12-month follow-up period provides more comprehensive medium- and long-term clinical data. 2) It breaks through the limitations of traditional single-function scoring assessments, combining ultrasound detection of muscle thickness and echo intensity to evaluate muscle regeneration from both morphological and histological dimensions, resulting in more complete and objective research data; 3) While ensuring treatment effectiveness, it comprehensively evaluates the overall value of minimally invasive surgery in terms of cosmetic appearance, rapid postoperative recovery, and low complication rate, providing a new reference for clinical treatment planning.

Nevertheless, certain limitations still exist. First, it is a single-center retrospective study, which may introduce selection bias. Second, it did not include a control group undergoing traditional open surgery during the same period, making it impossible to directly compare the efficacy, muscle regeneration and complication differences between the two surgical methods. Finally, the longest follow-up period was only 12 months, and the long-term evolution of muscle structure still requires longer follow-up to verify. Future research directions should cover: 1) conducting multicenter randomized controlled trials to compare the long-term efficacy of minimally invasive techniques versus open surgery for muscle regeneration; 2) extending the follow-up period to 3-5 years to clarify the long-term stability of muscle structure; and 3) combining multimodal detection methods such as electromyography to further explore the deep mechanisms of postoperative muscle function and structural repair.

Conclusion

Minimally invasive SCM release is a safe and effective therapeutic approach for children with CMT who fail to respond to conservative treatment. This procedure can significantly improve cervical motor function and craniofacial appearance, effectively inhibiting abnormal SCM muscle regeneration by reducing muscle thickness and echogenicity, while also offering advantages such as minimal surgical trauma, inconspicuous postoperative scarring, and a low complication rate. This surgical procedure can serve as an important surgical option for CMT children, and it has favorable clinical application value and prospects for promotion in medical institutions with the necessary surgical capabilities.

Disclosure of conflict of interest

None.

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