

Three-Dimensional Changes of Neck Motion Following Surgery for Adolescent Congenital Muscular Torticollis: A Case Report

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Learning Point of the Article:

Three-dimensional motion analysis allows us precise evaluation of cervical range of motion for adolescent patients with congenital muscular torticollis, including changes due to surgical intervention.

Abstract

Introduction: Congenital muscular torticollis (CMT) is a common pediatric orthopedic diagnosis, but the precise change after surgery in adolescence has not been evaluated.

Case Report: A 21-year-old female with CMT received three-dimensional motion analysis for neck movement before and after surgery. Results demonstrated that the rest position remained tilted and rotated, but the active range of motion partially improved. We compared the motion with that of nine healthy controls and revealed that the patient with CMT had accompanying neck movement in an unintended direction during neck motion, which changed postoperatively.

Conclusion: Surgery for an adolescent with CMT partially improved neck movement. The patient showed different neck movement patterns with accompanying movement compared with healthy controls. However, a larger study is required to determine disease-specific movement patterns and to verify the effects of surgery on these adolescents.

Keywords: Congenital muscular torticollis, three-dimensional motion analysis, neck range of motion.

Introduction

Congenital muscular torticollis (CMT) is the third most common pediatric orthopedic diagnosis in children [1]. Benign sternocleidomastoid mass causes asymmetric posture, restricted cervical range of motion (ROM), plagiocephaly, facial asymmetry, and cranial molding. CMT resolves spontaneously in 80–90% of cases [2]; if it persists beyond 1 year of age, sternocleidomastoid muscle lengthening should be considered. Untreated CMT is rare until adolescence [3] since CMT has better treatment outcomes if administered in the youth and

shows a small change in quality of life even after surgery [4].

Accurate assessment of cervical motion is essential for evaluating the effects of CMT treatment. Torticollis was evaluated using a videotape [5,6] or goniometer [7]. Although visual estimation has acceptable reliability for some movements, the complex movement of the head and neck in all directions requires more robust assessment tools [6].

Cervical movement is difficult to evaluate because it involves multidirectional movements, such as flexion, extension, lateral bending, and rotation. Although a three-dimensional (3D)

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motion analysis device allows for detailed and accurate evaluation of neck posture and movement [8], there are no reports of CMT evaluating the effect of surgery or bracing using this analytical method. In a few reports on adolescents with CMT, the effectiveness of surgery for neck motion was described based on clinical assessment alone [9,10].

This report determined the effect of surgery on neck movement in adolescents with CMT. A detailed evaluation was conducted to check changes in resting posture and active ROM by comparing neck movements before and after surgery with those of healthy controls.

Case Report

A 21-year-old female presented with torticollis and right-sided neck and shoulder pain. She was diagnosed with right CMT in her childhood at a local hospital and received rehabilitation treatment until 18 years old. The torticollis worsened with growth, associated with right neck and shoulder pain without limitation in activities of daily living.

On examination, a hard mass was identified in the right sternocleidomastoid muscle. The right shoulder was slightly elevated, and the neck was in torticollis, tilted 10° to the right with left rotation. Facial asymmetry was also noted (Fig. 1a and b). Active neck ROM, as measured by a goniometer, revealed 60°/35°(right/left) in lateral bending and 65°/80° in rotation.

The patient received bipolar tenotomy (i.e., transection of the proximal and distal ends) of the right sternocleidomastoid muscle. Postoperatively, the patient had a polyethylene cervical collar for 5 weeks and underwent cervical ROM self-training for

1 year after surgery. Although the right neck and shoulder pain alleviated and the right neck tilting at rest has improved to 5° (Fig. 1c) and neck active ROM changed to 45°/35° in lateral bending and 70°/70° in rotation, the facial asymmetry persisted.

Three-dimensional motion analysis

We measured the neck movement of the participant using 3D motion analysis 3 times (before surgery, 6 months, and 1 year after surgery) as described in a previous study [8]. To compare neck movements, we recruited healthy controls without a history of neck disorders and measured the neck movement once.

Measurements of neck movements were obtained while the participants performed six types of movements for five trials per direction in the sitting position: flexion, extension, left and right lateral bending, and left and right rotation. For analysis, the trunk-head angle was calculated; 0° represents the head segment in the same direction as the trunk segment. The trunk-head angles in the resting position were calculated by averaging the angles before starting neck movements in all 30 trials. The active neck ROMs were the difference of trunk-head angles between the start and maximum postures. We calculated the main plane neck ROM and other plane ROMs, accompanying ROM.

We also calculated the onset timing of neck movement in each plane to follow the change in motion pattern before and after surgery. The timing of the onset was defined as the moment when the angle was equal to one-twentieth of the full ROM, and

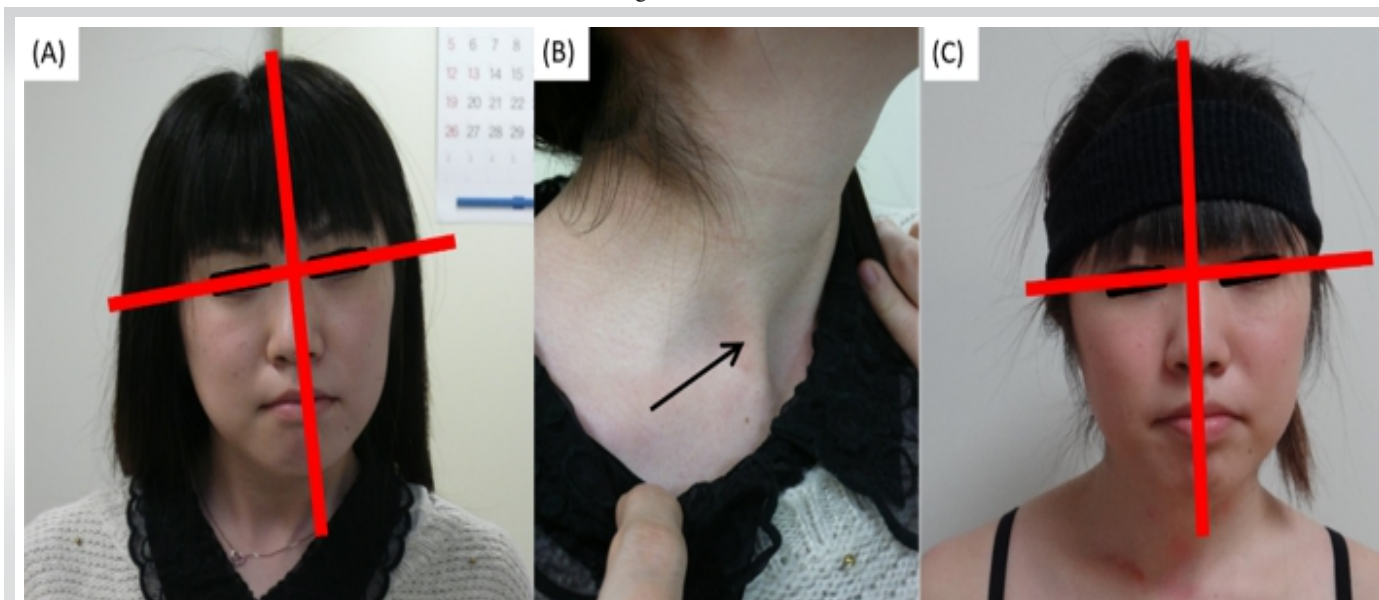


Figure 1: [A] Frontal view at initial visit: The right shoulder was slightly elevated, and the neck was in a torticollis position with right-side tilting and left rotation at rest. There was facial asymmetry. [B] Enlarged right neck at initial visit: A hard mass was noted in the right sternocleidomastoid muscle (black arrow). [C] Frontal view after surgery: The right shoulder remained elevated, and right-side tilting at rest improved.

the zero point was set at the onset time of the main movement. The onset timing of the accompanying movements was calculated by averaging five trials for each movement.

Calculations were performed using MATLAB R2024a (MathWorks, Natick, MA, U.S.A.). We performed one-way analysis of variance with a Bonferroni post hoc test, an unpaired t-test, and a paired t-test for statistics using the Statistical Package for the Social Sciences version 21 (IBM Corp., Armonk, NY, U.S.A.). The significance level was set at $P < 0.05$.

The backgrounds of the patient preoperatively and the healthy controls are shown in Table 1.

Resting position

For the resting position, the trunk-head angle was tilted to the right with left rotation. The left rotation position showed slight improvement after surgery (Table 2).

Active neck ROMs for the main direction (Table 3)

Preoperatively, the patient with CMT showed limited extension, left bending, and bilateral rotation ROM compared to healthy controls, which increased after surgery. Compared to the opposite side, the ROM for left bending was significantly limited before surgery and 6 months after surgery, and the ROM for right rotation was limited across all time points. In contrast, there was no difference between the left and right bending ROM in the healthy controls.

Neck ROM for accompanying movement (Table 3)

During flexion movements, the patient showed accompanying movement in left bending and left rotation before surgery. One year postoperatively, left bending significantly increased, whereas left rotation decreased. During extension movements, the patient showed right bending and rotation before surgery, which changed to left bending and right rotation 1 year postoperatively. In contrast healthy controls exhibited almost no accompanying lateral bending or rotation during flexion or extension.

During lateral bending, the same direction rotation was observed in both the patient and the controls, but extension accompanying movement during right bending was observed in the patient.

During rotation, contralateral lateral bending was observed in both the healthy controls and the patient, and neck flexion occurred in the healthy control, whereas extension occurred in the patient. In the patient, compared with pre-surgery, left bending during right rotation decreased significantly at 6 months postoperatively but increased again at 1 year. During left rotation, right bending decreased significantly at 6 months postoperatively.

Onset timing (Fig. 2)

The onset timing patterns in the three directions during neck movements showed large variations. For right rotation movements, the left bending onset timing was delayed at 6 months postoperatively compared to pre-surgery or 1 year after surgery.

Discussion

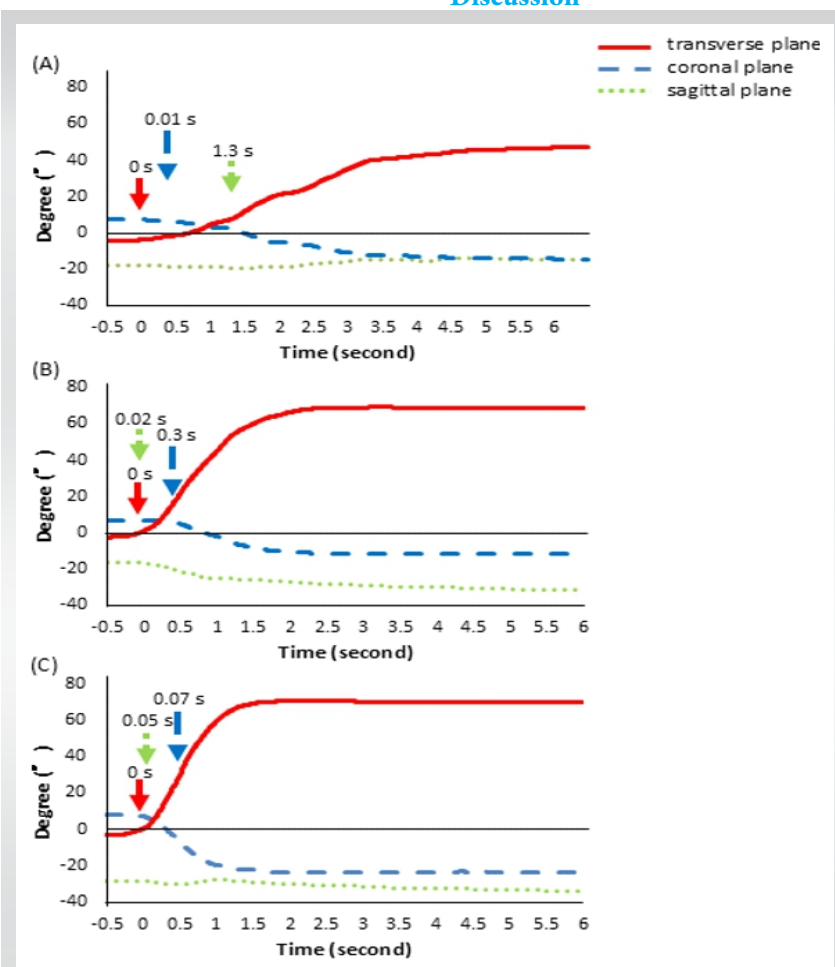


Figure 2: Change in neck range of motion (ROM) in right rotation before surgery [A] 6 months [B] and 1 year after surgery [C]. The timing of onset for each direction was defined as the moment when an angle was equal to one-twentieth of the full ROM, and the zero point was set at the onset time of the main movement. 0° represents trunk segment neutral position. Positive value means flexion for sagittal plane, right (affected side) bending for coronal plane, and right rotation for transverse plane. Arrows represents start timing of each direction.

Table 1: Background of the participants

	Patient (n=1)*	Control (n=9)
Female	1	3
Age (y.o.)	21	35.3 (9.4)
Height (cm)	158	165.4 (9.7)
Body weight (kg)	45	63.4 (12.1)
Body mass index (kg/m ²)	17.9	23.0 (2.2)
*Data at pre-surgery measurement. Control: Average (standard deviation)		

In this study, we measured the precise neck movements in the patient with CMT and confirmed that the resting posture, active neck ROM, accompanying movements, and onset timing changed after surgery. Torticollis assessment, relying on photographs or goniometers, is expected to be more precise [6]. In this study, 3D motion analysis allowed more precise ROM measurement and the evaluation of associated movements and differences in movement timing.

Surgery partially corrected the patient's preoperative resting posture, improving rotation ROM but not lateral tilting. Unilateral shortening of the sternocleidomastoid in the CMT causes ipsilateral lateral tilting and contralateral rotation, and post-operative lengthening of this muscle likely enabled the observed shift toward ipsilateral rotation [11]. Although the clinical examination suggested an improvement in affected-side tilting, precise 3D motion measurements showed no clear change. The clinical assessment was performed with the patient consciously instructed to face forward, whereas 3D motion measurements were taken between task trials and likely represented a more natural resting posture. Moreover, persistent facial asymmetry may reflect habituation to a lateral tilting position.

Even if there is no awareness of restrictions in ROM or activities of daily living, ROM limitations were observed in adolescents with CMT. CMT limits lateral bending toward the unaffected side and rotation toward the affected side [7], which is due to the shortening of the sternocleidomastoid muscle. During activities of daily living, the neck undergoes large movements: descending stairs, putting on socks, and tying shoelaces require approximately 20° of flexion; squatting requires approximately 30° of extension; shaving and face washing require roughly 25° of lateral bending; and checking behind while parking requires approximately

90° of rotation [12,13]. In this patient, restrictions on flexion-extension and lateral bending ROM were relatively small, whereas rotation was limited on both sides, which may have interfered with tasks such as looking backward. The patient reported no restriction in activities of daily living because she had ROM limitations since early childhood and had developed compensatory movements using the trunk or the rest of the body.

ROM limitations of adolescent CMT may improve with surgery in multiple directions. Even in adults, surgery for CMT improves the restriction of unaffected-side bending and affected-side rotation [14,15,16]. Surgical treatment aims to reduce side-to-side ROM asymmetry with targets such as a lateral bending ROM difference of <20° [17] and rotational ROM of <30° [18]. For the patient in this study, in addition to improvements in extension, unaffected-side bending, and affected-side rotation, restrictions on unaffected-side rotation also improved. The former three are likely to be due to lengthening of the sternocleidomastoid, and the latter might be attributed to reduced cervical muscle tension following the relief of neck pain after surgery and post-operative cervical ROM training.

The accompanying movements during neck motion observed only in the patient, which change preoperatively, might be due to multiple factors, including not only shortening of the sternocleidomastoid muscle but also the effects of sensory development. During flexion, the patient with CMT showed non-affected-side bending and non-affected-side rotation, which cannot be explained solely by shortening of the right sternocleidomastoid and its post-operative correction, as shortening of the sternocleidomastoid may cause non-affected-side bending, affected-side rotation, and improvement after surgery. Possible causes include disturbed body balance,

Table 2: Trunk-neck angle at resting position

	Patient			Control (<i>n</i> =9)
	Pre-surgery	Post-surgery		
		6 months	1 year	
Sagittal plane	−16.5° (1.6°)	−16.0° (2.7°)	−28.1° (2.8°)* [†]	−12.8° (13.3°)
Coronal plane	7.3° (1.0°)	7.0° (1.5°)	7.7° (1.2°) [†]	0.7° (2.6°)
Transverse plane	−3.9° (1.2°)	−2.2° (2.1°)*	−2.7° (1.2°)*	1.8° (3.8°)

Average (standard deviation). Trunk-head angle 0° represent the head segment is in the same direction as the trunk segment. Positive value means flexion for sagittal plane, right (affected-side) tilting for coronal plane, and right rotation for transverse plane. *Compare to pre-surgery $P < 0.05$, †Compare to 6 months after surgery $P < 0.05$

Table 3: Active neck range of motions in main direction and ranges of accompanying movement

	Patient			Control (<i>n</i> =9)
	Pre-surgery	Post-surgery		
		6 months	1 year	
Flexion				
Sagittal plane	55.8° (1.5°)	56.1° (2.5°)	57.7° (1.1°)	59.8° (8.2°)
Coronal plane	−1.7° (0.9°)	−2.2° (1.0°)	−3.2° (0.7°)	−0.6° (3.9°)
Transverse plane*	−6.1° (1.0°)	−7.5° (1.8°)	−4.4° (0.4°)†	0.1° (3.9°)
Extension				
Sagittal plane*	−61.9° (2.5°)	−72.8° (2.0°)*‡	−75.3° (2.2°)*‡	−64.5° (10.6°)
Coronal plane*	1.9° (0.7°)	−1.9° (0.4°)*‡	−6.2° (1.3°)*‡†	0.6° (3.8°)
Transverse plane*	6.3° (1.2°)	7.9° (1.3°)	9.0° (1.7°)*‡	1.7° (4.3°)
Right bending				
Sagittal plane	−19.7° (1.8°)	−14.8° (2.4°)*	−18.2° (5.1°)	−6.1° (5.3°)
Coronal plane	38.2° (1.7°)	40.5° (1.2°)	40.4° (1.9°)	36.1° (7.6°)
Transverse plane*	16.1° (2.1°)	9.8° (0.9°)*‡	25.8° (1.9°)*‡†	14.9° (10.3°)
Left bending				
Sagittal plane	4.4° (1.9°)	3.3° (3.2°)	−5.3° (1.1°)*†	−2.2° (6.4°)
Coronal plane*	−34.5° (2.1°)‡	−38.7° (1.0°)*‡†	−43.1° (2.0°)*‡†	−38.7° (6.8°)
Transverse plane*	−11.3° (1.2°)	−4.6° (2.5°)*‡	−13.1° (4.1°)†	−15.8° (6.6°)
Right rotation				
Sagittal plane*	−5.7° (2.5°)	−16.7° (2.4°)*‡	−9.7° (1.7°)†	5.7° (6.7°)
Coronal plane*	−20.3° (2.2°)	−15.7° (1.9°)*‡	−31.8° (1.1°)*‡†	−12.2° (6.0°)
Transverse plane*	57.5° (4.0°)	67.6° (3.2°)*‡	73.1° (1.5°)*‡†	63.2° (7.5°)
Left rotation				
Sagittal plane*	11.1° (1.8°)	−7.7° (2.5°)*‡	11.5° (2.3°)†	6.8° (8.6°)
Coronal plane*	18.5° (0.5°)	6.7° (1.3°)*‡	17.8° (1.2°)†	12.8° (6.4°)
Transverse plane*	−67.8° (2.6°)§	−74.5° (3.6°)*§	−79.5° (0.6°)*‡§	−71.5° (8.3°)§
Average (standard deviation). Positive value means flexion for the sagittal plane, right (affected-side) bending for the coronal plane, and right rotation for the transverse plane. Bolded data indicate range of main movement. *ANOVA shows significant difference date ‡Compare to pre-surgery <i>P</i> <0.05, †Compare to 6 months after surgery <i>P</i> <0.05, ‡Compared to right bending <i>P</i> <0.05, §Compared to right rotation <i>P</i> <0.05				

when moving body parts with restricted ROM or pain, such as compensatory movement during exercise for patients with back pain [22]. However, no studies have investigated the timing at which these compensatory movements occur. In the present study, we suspected that accompanying movements occurred to compensate for the restricted neck motion or body image. Using a 3D motion analysis system may help elucidate the mechanisms of the accompanying movements and could potentially contribute to suppressing unnecessary compensation or effectively utilizing compensatory strategies.

This study had several limitations. First, it summarizes a detailed neck motion assessment in a single adult patient with CMT; its findings may not be generalizable to other adult CMT cases. Future studies should include a larger sample. Second, we did not record muscle activity using electromyography or collect kinetic data. Therefore, muscle function was inferred only from kinematic measurements. Incorporating direct assessments of muscle activity in future studies may reveal more detailed disease and treatment-related changes.

Conclusion

Surgical intervention for CMT resulted in improved neck ROM even in adolescence. In contrast to the goniometers currently used in clinical practice, 3D motion analysis systems enable the continuous and highly precise evaluation of neck movements. With further technological advancements in motion analysis systems, clinical implementation of these technologies may allow for a more accurate assessment of therapeutic outcomes.

Clinical Message

CMT may induce different neck movement patterns compared with healthy participants, and surgery in adolescence partially improves neck ROM and abnormal neck movement patterns.

semicircular canal (vestibular) dysfunction, and visual factors. Sensory development in patients with CMT is delayed compared to healthy controls [19], and development of the semicircular canals, and thus vestibular function, is influenced by vestibular stimulation received up to adolescence [20,21]. In adults with CMT, facial asymmetry is not resolved by surgery [11]. Therefore, because this patient lived in a torticollis posture throughout adolescence, her body image, such as the perception of the midline, may differ from that of healthy individuals.

Analyzing the perioperative change in timing of neck movements may help understand the mechanisms of motor learning in patients with motor limitations. It is known that compensatory movements occur in other parts of the body

Declaration of patient consent: The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given the consent for his/ her images and other clinical information to be reported in the journal. The patient understands that his/ her names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

Conflict of interest: Nil **Source of support:** None

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