

CLINICAL INVESTIGATIVE STUDY **OPEN ACCESS**

SPECT Cerebral Perfusion Patterns in Isolated Cervical Dystonia

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ABSTRACT

Background and Purpose: Isolated cervical dystonia is characterized by sustained or intermittent neck movements caused by involuntary muscle contractions, resulting in abnormal movements or postures of cervical areas. We measured altered regional cerebral blood flow (rCBF) in patients with idiopathic cervical dystonia compared to healthy controls and explored the correlation between dystonia severity and rCBF patterns.

Methods: A total of 38 patients with isolated cervical dystonia and 29 healthy controls were recruited. All subjects underwent Toronto Western Spasmodic Torticollis Rating Scale (TWSTRS) and Tc-99m HMPAO SPECT; TWSTRS was used to assess the severity of dystonia. rCBF was compared between groups using voxel-wise statistical analyses. Associations between rCBF in significant clusters and TWSTRS scores were examined using linear regression.

Results: Compared with controls, patients with cervical dystonia exhibited reduced rCBF in brain regions implicated in sensory processing, motor control, and higher cognitive functions, including the left middle temporal gyrus, right postcentral gyrus, right lingual gyrus, left precuneus, right temporal pole, right middle cingulate gyrus, and right anterior cingulate gyrus. Although reduced rCBF was observed in seven regions, only the right temporal pole showed a significant correlation with TWSTRS motor scores. Reduced rCBF in the right temporal pole negatively correlated with higher TWSTRS scores in dystonia patients.

Conclusion: The negative correlation between reduced rCBF in the right temporal pole and increased TWSTRS scores highlights a potential association between altered cerebral perfusion and dystonic symptom severity. Understanding these alterations could offer insights into the neurobiological basis of cervical dystonia, aiding targeted therapeutic interventions.

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1 | Introduction

Isolated cervical dystonia is characterized by sustained or intermittent neck movements caused by involuntary muscle contractions, resulting in abnormal movements or postures of cervical areas [1]. Although the symptomatology of idiopathic cervical dystonia is well-documented, the pathophysiology remains poorly understood. According to the new consensus issued by the International Parkinson and Movement Disorder Society Dystonia Study Group, specific testing tools are not available for the diagnosis of cervical dystonia. The gold standard for diagnosis relies on patient history, clinical features, and phenomenology [2].

Neuroimaging has emerged as a critical technique that can provide insights into the underlying neural mechanisms contributing to idiopathic cervical dystonia to determine the complex pathophysiology of this enigmatic disorder. To date, functional neuroimaging investigations for cervical dystonia have predominantly been conducted using F-18 fluorodeoxyglucose PET (FDG-PET) uptake in the 1990s or, more recently, functional MRI (fMRI). The results of these studies showed functional changes in various cortical and subcortical regions of the brain and established that idiopathic cervical dystonia is a large-scale network disorder [3].

Brain perfusion SPECT is a valuable imaging technique used in the assessment and diagnosis of various neurological disorders [4]. This technique gathers functional information regarding regional cerebral blood flow (rCBF), yielding novel insights not provided by fMRI and FDG-PET. fMRI is based on blood oxygen level-dependent signals, reflecting indirect metabolic activity, while FDG-PET measures glucose metabolism [5, 6]. In contrast, perfusion SPECT can evaluate actual changes in cerebral blood flow, which may be useful in the evaluation of pathophysiological conditions where blood flow plays a crucial role [4, 7]. Brain perfusion SPECT also helps in treatment monitoring [4] and contributes to our understanding of disease pathophysiology [8], which can better inform both patient care and research endeavors in neurology.

In general, neuroimaging modalities each carry distinct advantages and limitations. Although fMRI offers high spatial and temporal resolution for mapping neural activity, it is primarily suited for research rather than direct diagnostic applications, and its accessibility remains limited. Advanced MRI-based perfusion techniques such as arterial spin labeling MRI and dynamic susceptibility contrast MRI enable quantitative CBF measurements with high spatial resolution, yet their clinical adoption is limited by technical complexity and limited availability in routine practice [9–11]. FDG-PET provides valuable information but is relatively expensive, and availability varies across medical institutions. Perfusion CT, which measures brain blood perfusion using iodine contrast, is primarily utilized in acute stroke settings and has limited anatomical coverage, making it less suitable for the evaluation of chronic neurological diseases [12]. Perfusion SPECT is a more economical and widely accessible option in most countries [5]. Direct measurement of cerebral blood flow and operational advantages with SPECT provide unique and complementary insights into brain function [13]. This consider-

ation underscores the practical significance of perfusion SPECT imaging in the present study given the broader accessibility and cost-effectiveness of this modality.

Although various potential causes have been associated with isolated cervical dystonia, an unexplored area in research is the relationship between rCBF and idiopathic cervical dystonia. Altered patterns in rCBF might provide insights into the potential association between dysfunctional brain regions and the severity of dystonic symptoms in idiopathic cervical dystonia patients. Therefore, changes in brain perfusion in patients with isolated cervical dystonia were evaluated in the present study.

2 | Methods

2.1 | Participants

A total of 38 patients with isolated cervical dystonia and 29 healthy control participants were recruited for this study. All patients were diagnosed with isolated cervical dystonia by experienced neurologists according to diagnostic criteria proposed by the International Parkinson and Movement Disorder Society Dystonia Study Group. Dystonia not accompanied by other movement disorders (except tremor) or additional neurological or medical features was also required for diagnosis. Only patients exhibiting laterocollis were selected for our study, but the direction of laterocollis was not considered. None of the patients had received any prior treatment at the time of diagnosis. Exclusion criteria were other neurological or psychiatric disorders, cerebral lesions other than small vessel disease, cognitive impairment, and family history of dystonia.

The severity of dystonia was evaluated using the Toronto Western Spasmodic Torticollis Rating Scale (TWSTRS) score that consists of three subscales for severity, disability, and pain. The total score is calculated as the sum of the three subscores and ranges from 0 to 85, with higher scores indicating greater severity.

The Institutional Review Board approved this study, and informed consent was obtained from all participants.

2.2 | SPECT Acquisition and Analysis

Brain SPECT scans were performed using a dual-headed gamma camera (Discovery NM630; GE Healthcare, Milwaukee, WI, USA) equipped with a low-energy fan-beam collimator. Before the scans, participants were injected with 555–740 MBq of technetium-99m hexamethylpropylene amine oxime (Tc-99m HMPAO) and rested for 40 min. During scanning, subjects were in a supine position with their eyes open.

Images were acquired as the camera rotated for a total of 720° with intervals of 6° at a rate of 12 s per frame. Reconstruction of continuous transaxial images was conducted with the following parameters: voxel size = $1.95 \times 1.95 \times 2.08$ mm³, matrix = 128×128 mm², field of view = 250×250 mm², and 20% symmetric energy window at 140 keV. To reduce noise, the standard ordered subset expectation maximization algorithm (6 iterations and 10 subsets)

TABLE 1 | Demographic and clinical characteristics of study participants.

Characteristics	Dystonia (<i>n</i> = 38)	Control (<i>n</i> = 29)	Test
Age (years)	52.9 ± 10.2	55.8 ± 9.2	$t = 0.78, p = 0.44$
Sex (male/female)	18/20	12/17	$p = 0.27$
Toronto Western Spasmodic Torticollis Rating Scale	43.9 ± 11.0	—	—

Note: Data are presented as mean ± standard deviation or *n* (number of patients).

with a Butterworth filter (cutoff frequency = 0.5 cycles/pixel, power = 10) was used.

Preprocessing and statistical analysis of the SPECT data were performed using Statistical Parametric Mapping 12 (Wellcome Centre for Human Neuroimaging, London, UK, <https://www.fil.ion.ucl.ac.uk/spm/software/spm12/>). First, the images were spatially normalized to the standard SPECT template. Then, the images were resliced with a voxel size of $2.0 \times 2.0 \times 2.0$ mm³ and smoothed with a 12-mm full-width at half-maximum Gaussian kernel. Proportional scaling was applied using the overall mean as a reference value, and the global rCBF was scaled to 50 mL/dL/min.

2.3 | Statistical Analysis

Differences in age and sex were assessed between the dystonia patients and healthy controls using independent *t*-test and Fisher's exact test, respectively.

The rCBF was compared between the two groups using voxel-wise two-sample *t*-test analysis with age and sex as covariates. The voxel-level significance threshold was set at $p < 0.001$ with a cluster-level threshold of 50 voxels.

For significant clusters, associations between the mean rCBF values and TWSTRS scores were examined using multiple linear regression after adjusting for age and sex.

A *p*-value of < 0.05 (two-tailed) was considered statistically significant. Statistical analysis was performed with STATA version 17 (StataCorp., College Station, TX, USA, <https://www.stata.com/>).

3 | Results

A total of 38 patients with isolated cervical dystonia and 29 healthy control participants were included in this analysis. The demographic and clinical characteristics are shown in Table 1. Significant differences in age and sex were not observed between the two groups.

Results of the SPECT image analysis are shown in Table 2 and Figure 1. Figure 1 is arranged into 25 slices (5×5) to clearly display meaningful areas. There were no areas where rCBF was increased in isolated cervical dystonia patients compared to controls. However, compared with controls, patients with isolated cervical dystonia showed lower rCBF in the left middle temporal

gyrus ($t = -5.00, p < 0.001$), right postcentral gyrus ($t = -4.67, p < 0.001$), right lingual gyrus ($t = -4.46, p < 0.001$), left precuneus ($t = -4.22, p < 0.001$), right temporal pole ($t = -4.04, p < 0.001$), right middle cingulate gyrus ($t = -3.95, p < 0.001$), and right anterior cingulate gyrus ($t = -3.75, p < 0.001$).

Among the significant clusters, rCBF in the right temporal pole cluster was negatively associated with TWSTRS scores in patients with isolated cervical dystonia ($\beta = -0.41, p = 0.03$; Figure 2). No significant associations were found between TWSTRS scores and rCBF in other clusters.

4 | Discussion

In the present study, rCBF patterns in individuals diagnosed with isolated cervical dystonia and healthy control subjects were analyzed. Based on SPECT imaging results, distinct differences in rCBF distribution between the two groups were identified. In patients with isolated cervical dystonia, notable reductions in rCBF were detected within specific brain regions, including the left middle temporal lobe, right postcentral gyrus, right lingual gyrus, left precuneus, right temporal pole, right anterior, and middle cingulate.

In recent functional neuroimaging studies using fMRI, isolated cervical dystonia was shown to be a network disorder encompassing multiple brain regions; however, the exact pathophysiology remains unknown [3, 14]. Functional connectivity measured by fMRI and rCBF provides distinct yet complementary neurophysiological information about brain activity, and some correlations between the two have been reported. In the present study, a decrease in rCBF within the postcentral gyrus, precuneus, lingual gyrus, and middle temporal gyrus was observed in patients with isolated cervical dystonia. These regions showing decreased rCBF have also been identified as areas with altered functional patterns in previous fMRI studies of cervical dystonia [14–17]. In particular, the precuneus is a core region of the default-mode network and maintains self-referential activity, monitoring the self and surrounding environment and environmental positioning [18, 19]. Similar to the present study, hypoactivation within the precuneus possibly interfered with the default-mode network function for posture control or led to abnormal contraction of cervical muscle tissue in cervical dystonia in a previous study [19]. However, further studies are needed to clarify this finding. Previous fMRI studies have reported increased connectivity in the anterior cingulate and paracingulate gyri, whereas our study found decreased rCBF in these same regions [14, 20]. Previous structural MRI studies in cervical dystonia have identified gray

TABLE 2 | Brain regions with significant group differences in regional cerebral blood flow.

Brain regions	Cluster size (voxels)	<i>t</i>	<i>z</i>	<i>p</i> -value	Coordinates
Dystonia > Control					
None					
Dystonia < Control					
L middle temporal gyrus	338	−5.00	−4.42	<0.001	−50, −26, −8
R postcentral gyrus	100	−4.67	−4.17	<0.001	36, −32, 34
R lingual gyrus	83	−4.46	−4.02	<0.001	32, −52, 4
L precuneus	76	−4.22	−3.84	<0.001	−22, −56, 14
R temporal pole	67	−4.04	−3.70	<0.001	48, 6, −12
R middle cingulate gyrus	86	−3.95	−3.63	<0.001	12, −6, 34
R anterior cingulate gyrus	70	−3.75	−3.47	<0.001	2, 30, 14

Note: Cluster size = minimum number of contiguous voxels required to define a significant region of interest; L = left; R = right.

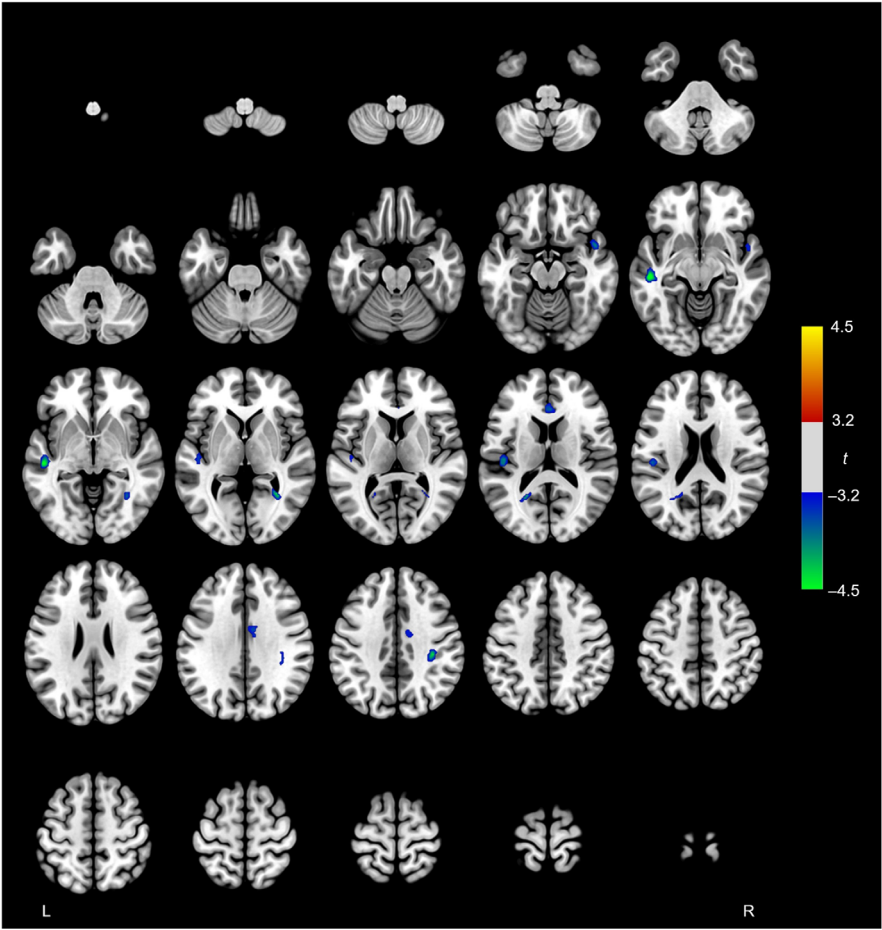


FIGURE 1 | Higher (red-yellow) or lower regional cerebral blood flow (blue-green) in cervical dystonia patients versus healthy controls. Images are shown in neurological convention. The detailed cluster information is shown in Table 2. R, right; L, left.

matter atrophy in the bilateral median cingulate/paracingulate gyri, which may be associated with the observed rCBF reduction in these regions [19]. Because pain, depression, and anxiety are frequently reported in patients with cervical dystonia, we also hypothesized that abnormal functional and structural changes within these brain regions may be associated with the impaired processing of negative emotions such as depression, dystonia-

related pain, and abnormal sensorimotor function in patients with cervical dystonia as suggested in a previous study [20].

While the significance of these findings remains to be fully established, the brain regions identified in this study might contribute to our understanding of cervical dystonia pathophysiology. The postcentral gyrus is a region that receives sensory

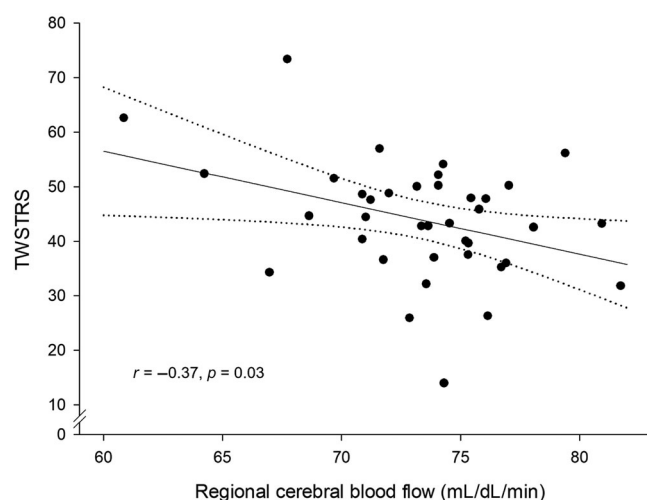


FIGURE 2 | A significant negative correlation between regional cerebral blood flow in the right temporal pole cluster and the Toronto Western Spasmodic Torticollis Rating Scale (TWSTRS) scores in patients with cervical dystonia after adjusting for age and sex ($\beta = -0.41$, $p = 0.03$). The solid line indicates the regression line, and the dashed lines represent 95% confidence intervals. mL/dL/min, the amount of blood flow in milliliters (mL) passing through 1 deciliter (dL) of tissue per minute (min).

afferents from thalamocortical projections for somatosensory processing [16, 17]. The lingual gyrus is known for its role in visual processing necessary for orientation and direction of stimuli [21], and the left middle temporal gyrus is important for understanding visual and auditory messages and semantic memory processing [22]. The anterior cingulate serves as a regulatory mechanism for processing information across various networks, functioning as a component of the executive attention network that oversees the regulation of both cognitive and emotional controls [23].

In particular, a negative correlation was found between rCBF in the right temporal pole and the severity of dystonic symptoms measured using the TWSTRS. The temporal pole plays a role in heterogeneity in many high-order brain functions, such as multimodal sensory integration, semantic memory, social cognition, and emotional processing [24]. In a systematic review in which non-motor symptoms were examined, dystonia patients showed a higher prevalence of depression and anxiety (ranging from approximately 25% to 50%) than individuals without dystonia [25–27]. A correlation between mood symptoms and disease severity has been demonstrated in several studies [28–30]. Although the temporal pole in cervical dystonia has not been investigated in a functional neuroimaging study, decreased gray matter volume in the temporal pole and precuneus in patients with idiopathic dystonia has been identified in structural imaging studies [31, 32]. Therefore, the involvement of the temporal pole in symptom severity indicates its potential as a crucial area in the pathophysiology of idiopathic cervical dystonia.

Although the results showed an association between changes in rCBF and the severity of dystonic symptoms, the precise mechanisms driving these perfusion changes remain elusive. Whether the observed perfusion alterations are a direct consequence of cervical dystonia, the symptoms associated with the

condition, or the disease itself remains unclear. Additionally, our study did not systematically record the direction of laterocollis (right or left) in the patient cohort. Given the focus on cerebral laterality in our findings, future studies should explore whether asymmetric perfusion patterns correlate with the clinical laterality of dystonic symptoms. Future research should focus on elucidating the specific neurobiological mechanisms underlying these alterations in brain perfusion and their direct influence on the clinical manifestations of cervical dystonia. In addition, results of longitudinal studies may offer insights into the gradual progression of perfusion changes and their correlation with disease advancement.

In conclusion, this study demonstrates distinct rCBF alterations in patients with isolated cervical dystonia, particularly in brain regions associated with sensory processing, motor control, and emotional regulation. The negative correlation between reduced rCBF in the right temporal pole and increased severity of dystonic symptoms suggests that altered perfusion in specific brain areas may contribute to symptom manifestation. These findings provide valuable insights into the neurobiological basis of cervical dystonia. However, further research is needed to clarify the mechanisms underlying these perfusion changes and their implications for disease progression and treatment strategies.

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The authors have nothing to report.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1. J. Jankovic, S. Leder, D. Warner, and K. Schwartz, "Cervical Dystonia: Clinical Findings and Associated Movement Disorders," *Neurology* 41, no. 7 (1991): 1088–1091.
2. A. Albanese, K. P. Bhatia, F. Cardoso, et al., "Isolated Cervical Dystonia: Diagnosis and Classification," *Movement Disorders* 38, no. 8 (2023): 1367–1378.
3. G. Battistella, P. Termsarasab, R. A. Ramdhani, S. Fuertinger, and K. Simonyan, "Isolated Focal Dystonia as a Disorder of Large-Scale Functional Networks," *Cerebral Cortex* 27, no. 2 (2017): 1203–1215.
4. A. M. Catafau, "Brain SPECT in Clinical Practice. Part I: Perfusion," *Journal of Nuclear Medicine* 42, no. 2 (2001): 259–271.
5. C. M. Davison and J. T. O'Brien, "A Comparison of FDG-PET and Blood Flow SPECT in the Diagnosis of Neurodegenerative Dementias: A Systematic Review," *International Journal of Geriatric Psychiatry* 29, no. 6 (2014): 551–561.
6. S. Amemiya, H. Takao, Y. Watanabe, et al., "Reliability and Sensitivity to Altered Hemodynamics Measured With Resting-State fMRI Metrics: Comparison With (123)I-IMP SPECT," *Neuroimage* 263 (2022): 119654.
7. S. Thobois, S. Prange, C. Scheiber, and E. Broussolle, "What a Neurologist Should Know About PET and SPECT Functional Imaging for Parkinsonism: A Practical Perspective," *Parkinsonism & Related Disorders* 59 (2019): 93–100.
8. J. M. Nicolás, A. M. Catafau, R. Estruch, et al., "Regional Cerebral Blood Flow-SPECT in Chronic Alcoholism: Relation to Neuropsychological Testing," *Journal of Nuclear Medicine* 34, no. 9 (1993): 1452–1459.

9. D. C. Alsop, J. A. Detre, X. Golay, et al., "Recommended Implementation of Arterial Spin-Labeled Perfusion MRI for Clinical Applications: A Consensus of the ISMRM Perfusion Study Group and the European Consortium for ASL in Dementia," *Magnetic Resonance in Medicine* 73, no. 1 (2015): 102–116.
10. E. S. Bayraktar, G. Duygulu, Y. K. Çetinoğlu, M. F. Gelal, M. Apaydın, and H. Ellidokuz, "Comparison of ASL and DSC Perfusion Methods in the Evaluation of Response to Treatment in Patients With a History of Treatment for Malignant Brain Tumor," *BMC Medical Imaging* 24, no. 1 (2024): 70.
11. J. M. Pollock, H. Tan, R. A. Kraft, C. T. Whitlow, J. H. Burdette, and J. A. Maldjian, "Arterial Spin-Labeled MR Perfusion Imaging: Clinical Applications," *Magnetic Resonance Imaging Clinics of North America* 17, no. 2 (2009): 315–338.
12. A. Zimny, M. Sasiadek, J. Leszek, A. Czarnecka, E. Trypka, and A. Kiejna, "Does Perfusion CT Enable Differentiating Alzheimer's Disease From Vascular Dementia and Mixed Dementia? A Preliminary Report," *Journal of the Neurological Sciences* 257, no. 1–2 (2007): 114–120.
13. L. Knutsson, S. Börjesson, E. M. Larsson, et al., "Absolute Quantification of Cerebral Blood Flow in Normal Volunteers: Correlation Between Xe-133 SPECT and Dynamic Susceptibility Contrast MRI," *Journal of Magnetic Resonance Imaging* 26, no. 4 (2007): 913–920.
14. C. C. Delnooz, J. W. Pasman, C. F. Beckmann, and B. P. van de Warrenburg, "Task-Free Functional MRI in Cervical Dystonia Reveals Multi-Network Changes That Partially Normalize With Botulinum Toxin," *PLoS ONE* 8, no. 5 (2013): e62877.
15. R. G. Burciu, C. W. Hess, S. A. Coombes, et al., "Functional Activity of the Sensorimotor Cortex and Cerebellum Relates to Cervical Dystonia Symptoms," *Human Brain Mapping* 38, no. 9 (2017): 4563–4573.
16. W. Jiang, Y. Lei, J. Wei, et al., "Alterations of Interhemispheric Functional Connectivity and Degree Centrality in Cervical Dystonia: A Resting-State fMRI Study," *Neural Plasticity* 2019 (2019): 7349894.
17. Z. Li, C. N. Prudente, R. Stilla, K. Sathian, H. A. Jinnah, and X. Hu, "Alterations of Resting-State fMRI Measurements in Individuals With Cervical Dystonia," *Human Brain Mapping* 38, no. 8 (2017): 4098–4108.
18. L. Feng, D. Yin, X. Wang, et al., "Brain Connectivity Abnormalities and Treatment-Induced Restorations in Patients With Cervical Dystonia," *European Journal of Neurology* 28, no. 5 (2021): 1537–1547.
19. X. Huang, M. Zhang, B. Li, H. Shang, and J. Yang, "Structural and Functional Brain Abnormalities in Idiopathic Cervical Dystonia: A Multimodal Meta-Analysis," *Parkinsonism & Related Disorders* 103 (2022): 153–165.
20. S. Wei, C. Lu, X. Chen, et al., "Abnormal Regional Homogeneity and Its Relationship With Symptom Severity in Cervical Dystonia: A Rest State fMRI Study," *BMC Neurology* 21, no. 1 (2021): 55.
21. A. H. Palejwala, N. B. Dadario, I. M. Young, et al., "Anatomy and White Matter Connections of the Lingual Gyrus and Cuneus," *World neurosurgery* 151 (2021): e426–e437.
22. R. G. Briggs, O. Tanglay, N. B. Dadario, et al., "The Unique Fiber Anatomy of Middle Temporal Gyrus Default Mode Connectivity," *Operative Neurosurgery* 21, no. 1 (2021): E8–E14.
23. M. I. Posner, M. K. Rothbart, B. E. Sheese, and Y. Tang, "The Anterior Cingulate Gyrus and the Mechanism of Self-Regulation," *Cognitive, Affective & Behavioral Neuroscience* 7, no. 4 (2007): 391–395.
24. B. Herlin, V. Navarro, and S. Dupont, "The Temporal Pole: From Anatomy to Function—A Literature Appraisal," *Journal of Chemical Neuroanatomy* 113 (2021): 101925.
25. J. Yang, N. Shao, W. Song, et al., "Nonmotor Symptoms in Primary Adult-Onset Cervical Dystonia and Blepharospasm," *Brain and Behavior* 7, no. 2 (2017): e00592.
26. M. Stamelou, M. J. Edwards, M. Hallett, and K. P. Bhatia, "The Non-Motor Syndrome of Primary Dystonia: Clinical and Pathophysiological Implications," *Brain* 135, no. Pt 6 (2012): 1668–1681.
27. D. J. Kuyper, V. Parra, S. Aerts, M. S. Okun, and B. M. Kluger, "Nonmotor Manifestations of Dystonia: A Systematic Review," *Movement Disorders* 26, no. 7 (2011): 1206–1217.
28. D. Naber, D. R. Weinberger, M. Bullinger, M. Polsby, and T. N. Chase, "Personality Variables, Neurological and Psychopathological Symptoms in Patients Suffering From Spasmodic Torticollis," *Comprehensive Psychiatry* 29, no. 2 (1988): 182–187.
29. L. Lewis, A. Butler, and M. Jahanshahi, "Depression in Focal, Segmental and Generalized Dystonia," *Journal of Neurology* 255, no. 11 (2008): 1750–1755.
30. C. E. Scheidt, F. Heinen, T. Nickel, et al., "Spasmodic Torticollis—A Multicentre Study on Behavioural Aspects IV: Psychopathology," *Behavioural Neurology* 9, no. 2 (1996): 97–103.
31. X. Huang, J. Lin, H. Shang, and J. Yang, "Voxel-Based Meta-Analysis of Gray Matter Abnormalities in Idiopathic Dystonia," *Journal of Neurology* 269, no. 6 (2022): 2862–2873.
32. C. C. Piccinin, L. G. Piovesana, M. C. Santos, et al., "Diffuse Decreased Gray Matter in Patients With Idiopathic Craniocervical Dystonia: A Voxel-Based Morphometry Study," *Frontiers in Neurology* 5 (2014): 283.