RESEARCH ARTICLE

Polyelectromyography Under Propofol to Differentiate Functional from Idiopathic Dystonia: A Pilot Study

CME

Roberto Eleopra, MD,[1*] Fabio Paio, MD,[1,2] Sara Rinaldo, MSc,[1] Carla Carozzi, MD,[3] Amanda Oriana, MD,[3] Grazia Devigili, MD, PhD,[1] Luigi Michele Romito, MD, PhD,[1] Roberto Cilia, MD,[1] Nico Golfrè Andreasi, MD,[1] Gianfranco Gaudiano, MD,[1] Marta Corradi, BSc,[1] Antonio Emanuele Elia, MD, PhD,[1] Fabiana Colucci, MD, PhD,[1] Arianna Braccia, MD,[1] Roberta Telese, MD,[1] Michele Tinazzi, MD, PhD,[2] Marco Gemma, MD,[3] and Valentina Leta, MD, PhD[1,4]

ABSTRACT: Background: Functional dystonia (FD) is one of the most diagnostically challenging functional movement disorders. Phenomenological features often lack specificity, as many are also observed in idiopathic dystonia (ID) and validated biomarkers to distinguish FD from ID are currently unavailable

Objective: To investigate potential differences in muscle activity between ID and FD patients using polyelectromyography (PEMG) under anesthesia.

Methods: We consecutively enrolled 10 patients with FD and 17 with ID according to the current diagnostic criteria who underwent continuous PEMG before, during, and after propofol infusion. Sedation levels were monitored by electroencephalography and bispectral index and stratified via the Observer's Assessment of Alertness/Sedation Scale (OASS). PEMG recordings were performed under five definite scenarios: alert, mild and deep sedation, and partial and full recovery of consciousness status. Presence/absence of EMG activity was evaluated across these stages, and changes from baseline patterns were analyzed.

Results: During mild sedation, EMG activity persisted in all ID (100%) and in 9 (90%) FD patients. During deep sedation, EMG activity persisted in 9 (53%) ID patients and was absent in all FD patients (100%) ($P = 0.01$). During partial recovery of consciousness, EMG activity was present in all (100%) ID and only in 1 (10%) FD patients ($P < 0.001$). At full recovery, a different muscular activation pattern from baseline was observed in 7 (70%) FD and only in 1 (6%) ID patients ($P = 0.001$)

Conclusions: EMG silence during deep sedation and partial recovery may serve as a neurophysiological marker of FD. A muscular activation pattern differing from baseline may represent a neurophysiological clue for incongruence © 2025 The Author(s). *Movement Disorders* published by Wiley Periodicals LLC on behalf of International Parkinson and Movement Disorder Society.

Key Words: functional dystonia; idiopathic dystonia; inconsistency; incongruence; differential diagnosis; propofol

Functional dystonia (FD) is one of the most common and diagnostically challenging presentations within the spectrum of functional movement disorders (FMDs).[1] FMDs are characterized by abnormal movements occurring in the absence of structural neurological damage and are typically defined by clinical inconsistency and incongruence.[2,3] A neurobiological model of FMDs has been proposed, involving impaired sense of agency (SA), abnormal expectations, and maladaptive attentional mechanisms.[4-6] Supporting this model, functional neuroimaging studies have demonstrated altered connectivity between the sensorimotor cortex and regions

[1]Parkinson and Movement Disorders Unit, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan, Italy; [2]Neurology Section, Department of Neurosciences, Biomedicine, and Movement Sciences, University of Verona, Verona, Italy; [3]Department of Neuroanesthesia and Intensive Care, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan, Italy; [4]Department of Basic and Clinical Neuroscience, King's College London, Institute of Psychiatry, Psychology and Neuroscience, The Maurice Wohl Clinical Neuroscience Institute, London, UK

***Correspondence to:** Dr. R. Eleopra, Fondazione IRCCS Istituto Neurologico "Carlo Besta", Department of Clinical Neurosciences, Parkinson and Movement Disorders Unit, Via Celoria 11, 20133 Milano, Italy. E-mail: roberto.eleopra@istituto-besta.it

R. Eleopra and F. Paio contributed equally to this article as first authors.

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such as the right temporoparietal junction,[7,8] which is involved in distinguishing self-generated from external stimuli,[9] in FMD patients. Resting-state functional imaging has further revealed reduced connectivity between the primary motor cortex and regions involved in motor planning, emotional regulation, and the SA in patients with FD, thus supporting the hypothesis that FD may result from disrupted integration within higher-order networks.[10]

Among FMDs, FD presents a unique diagnostic challenge due to its frequent clinical resemblance to ID, which may itself exhibit unusual or atypical clinical pictures.[11] While certain features such as abrupt onset, fixed postures at rest, or resistance to passive manipulation may raise suspicion of FD,[12] similar findings can occasionally be observed in ID. Moreover, clinical variability, typically considered a hallmark of FMDs, may also occur in ID.[11,13] This substantial phenomenological overlap often necessitates expert assessment, as no single clinical feature allows for a reliable distinction. Clues such as suggestibility or motor incongruence may be helpful but require experienced clinical interpretation.[14,15]

Unlike other FMDs such as functional tremor or myoclonus,[16] neurophysiological testing in FD has limited diagnostic value. Reported findings have been inconsistent, with some studies highlighting overlapping abnormalities between FD and ID,[17-19] and others suggesting group-level differences.[20-22] However, these results remain difficult to interpret at the individual level and lack applicability in clinical practice.

Given these limitations, earlier attempts to explore diagnostic responses under sedation have regained interest in recent years. Anesthetic techniques have historical roots in psychiatry and have occasionally been used to assess conversion disorders; however, their diagnostic utility remains anecdotal due to methodological shortcomings.[23-25] Early work, including therapeutic sedation trials and observations by Fahn in two patients, suggested that deep anesthesia can reveal functional components of movement disorders, aiding both diagnosis and patient insight.[26] Building on this, Stone and colleagues used therapeutic sedation in 11 patients with severe functional neurological disorders as an adjuvant strategy to demonstrate symptom reversibility.[27]

From a pathophysiological perspective, ID is underpinned by dysfunction in a distributed motor network involving the basal ganglia, thalamus, cerebellum, and somatosensory cortex.[28-30] In contrast, FD is thought to result from altered top-down modulation of voluntary movements.[6,11] Based on these differences, we hypothesized that targeted disruption of cortical activity (eg, via sedation with propofol[31]), could differentially affect motor output in the two conditions, potentially unmasking functional features in FD.

This pilot study aimed to investigate whether polyelectromyography (PEMG), recorded across defined stages of propofol-induced sedation and recovery, could provide objective biomarkers to support the differential diagnosis between FD and ID.

METHODS

Study Population

From October 2019 to May 2023, we enrolled 17 consecutive patients diagnosed with ID according to the International Parkinson and Movement Disorder Society (MDS) criteria,[33] and 10 consecutive patients with clinically definite FD according to the Gupta and Lang criteria,[32] emphasizing inconsistency and incongruence on repeated assessments (eg, variable cervical rotation angles and distraction effects), together with suggestive—but not exclusive—features (acute onset, waxing-and-waning course, fixed postures). The final diagnosis was independently confirmed by two experts in full consensus. Patients were recruited at the Parkinson and Movement Disorders Unit, Department of Clinical Neurosciences, Fondazione IRCCS Istituto Neurologico Carlo Besta, Milan, Italy. Diagnoses were confirmed by two independent movement disorders experts.

Exclusion criteria were: (1) age below 18 years; (2) inherited or acquired form of dystonia; (3) evidence of degeneration or structural lesions of central nervous system; (4) clinically relevant cognitive impairment (Mini-Mental State Examination [MMSE] score < 24) interfering with the ability to provide an informed consent; (5) presence of other concomitant neurological diseases; and (6) presence of risk for anesthesiologic complications (American Society of Anesthesiology [ASA] score > 2).

The study was authorized by the local ethics committee, and all patients gave written consent prior to the study procedures in accordance with the Declaration of Helsinki.

Study Procedures

Sociodemographics and clinical data were collected for each subject, including age, sex, years of education, body distribution of dystonia (focal, segmental, generalized), type of onset (acute—within days—or progressive), presence of fixed posture, disease duration, history of a trigger event (trauma or stressful event), response to botulinum toxin treatment, presence of pain, depression (measured by the Beck Depression Inventory-II [BDI-II]), and anxiety (measured by the State–Trait Anxiety Inventory [STAI]).

The neurophysiological protocol consisted of continuous multichannel electromyography (EMG) recording from both symptomatic and non-symptomatic muscles,

with the dystonic muscles groups always being documented, according to a semi-standardized protocol (Appendix S1). Monopolar needle electrodes were placed in muscle belly at a maximum inter-electrode distance of 3 cm and secured with adhesive tape to ensure stability and prevent dislocation.

All recordings were performed using a NIM-EclipseTM E4 (Medtronic, Minneapolis, MN, USA) and carried out in a secure setting routinely dedicated to magnetic resonance imaging (MRI) sedation, prior to the scan, as part of standard clinical practice. An experienced anesthesiologist administered 1% propofol, through a peripheral vein, via a target-controlled infusion pump (Fresenius Kabi, Agila, France) using the Schnider pharmacokinetic model,[34] in accordance with the institutional sedation protocol. Starting from an effect-site concentration (Ce) of 1.5 μg/ml, propofol was gradually increased by 0.5 μg/ml until loss of consciousness. Peripheral oxygen saturation and electrocardiogram were continuously monitored throughout the procedure. Consciousness level was assessed using the Observer's Assessment of Alertness/Sedation Scale (OASS)[35] as shown in Figure 1. The Bispectral Index (BIS; BIS™ Quatro sensor, software version 3.5, Medtronic) and electroencephalography (EEG) were continuously recorded, allowing adequate equilibration time at each dose step—approximately 2 min per step—to capture the full pharmacokinetic/pharmacodynamic effects of propofol.[36] The BIS monitor acquires frontal EEG signals via four electrodes placed on the forehead,[37] and processes them to provide a numerical index ranging from 0 (complete suppression of brain activity) to 100 (fully awake). BIS values are typically maintained from 40 to 60 to prevent intraoperative awareness under general anesthesia (eg, during surgeries).[38-40] The EEG was recorded from eight needle electrodes placed according to the international 10–20 system. Details on the technical setup for the EMG, BIS, and EEG recordings are provided in Appendix S1.

Considering the degree of clinical response (the cornerstone of the evaluation) and the BIS values, five scenarios were defined in accordance with the stages of propofol infusion as summarized in Figure 2: (1) alert stage before starting the propofol infusion (OASS = 5, BIS >55); (2) mild sedation at the start of the propofol infusion (OASS <5 and >1, BIS >55); (3) deep sedation with propofol infusion ongoing (OASS = 1, BIS ≤55); (4) partial recovery of consciousness at the end of the propofol infusion (OASS >1 and <5, BIS >55); and (5) full recovery of consciousness, at the end of the procedure, once the effects of propofol had worn off (OASS = 5, BIS >55).

EMG activity was assessed continuously for at least 2 min for each of these stages. In the alert stage, burst duration (<200 ms vs. >200 ms) and presence of agonist–antagonist co-contraction were evaluated. In addition, intra-epoch variability of EMG activity was qualitatively assessed by inspecting whether the most active muscle(s) remained consistent or changed over the course of the same recording epoch. For the mild sedation, deep sedation, and partial recovery of consciousness stages, the presence of muscular activity was evaluated and defined as EMG signals persisting for more than 50% of the epoch, in at least one muscle, and assessed with a sensitivity threshold of 100 μV. In the full recovery of consciousness stage, the muscular pattern activation (eg, most active muscle[s]) was qualitatively compared with the baseline. Neurophysiological assessment was conducted by a neurophysiologist blinded to the diagnostic status of the subject (ie, FD or ID). All EMG analyses were initially scored online during acquisition and subsequently reviewed offline to ensure consistency. Analyses were entirely visual-based, referring to 200-ms sweeps within each 2-min epoch, according to prespecified qualitative

Responsiveness	Speech	Facial Expression	Eyes	Composite Score
Responds readily to name spoken in a normal tone	Normal	Normal	Clear, no ptosis	**5** (alert)
Lethargic response to name spoken in a normal tone	Mild slowing or thickening	Mild relaxation	Glazed or mild ptosis (less than half the eye)	**4**
Responds only after name is called loudly or repeatedly	Slurring or prominent slowing	Marked relaxation (slacked jaw)	Glazed or marked ptosis (half the eye or more)	**3**
Responds only after mild prodding or shaking	Few recognizable words			**2**
Does not respond to mild prodding or shaking				**1** (sleep)

FIG. 1. Full grading of the Observer's Assessment of Alertness/Sedation Scale (OASS) used to stratify patients by level of consciousness.

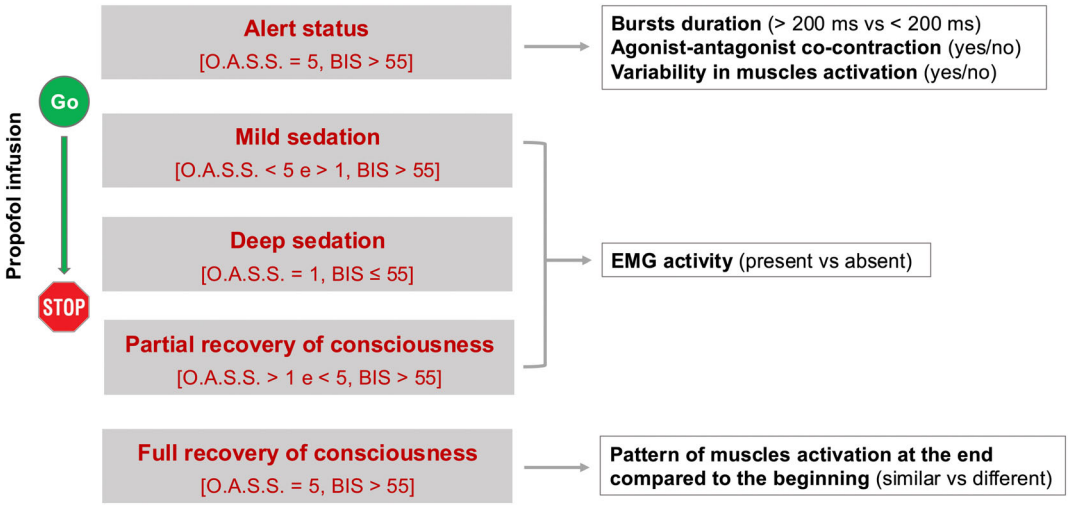

FIG. 2. Summary of the five experimental conditions assessed, and the corresponding neurophysiological features evaluated at each stage. Electromyography (EMG) activity was considered present if it persisted for more than 50% of the analyzed epoch in at least one muscle, with a sensitivity threshold of 100 μV. OASS, Observer's Assessment of Alertness/Sedation Scale; BIS, Bispectral Index. [Color figure can be viewed at wileyonlinelibrary.com]

criteria (Appendix S1). All patients were off benzodiazepines, baclofen, and anticholinergics for at least 24 hr, and free from botulinum treatment for a minimum of 4 months.

Statistical Analysis

Statistical analyses and graphical representations were performed using the R statistical software (version 4.5.0, R Foundation for Statistical Computing, Vienna, Austria). A cross-sectional analysis was conducted. Normality of continuous variables was assessed using the Shapiro–Wilk test. Between-group comparisons were evaluated using appropriate statistical tests: unpaired Student's *t*-test or Mann–Whitney U test for continuous variables (based on distribution) and Fisher's exact test for categorical variables. Sensitivity, specificity, and predictive values were calculated using the Wilson/Brown method and are reported with 95% confidence intervals (CIs). *P*-values<0.05 were considered statistically significant.

RESULTS

The sociodemographics and clinical data of the consecutively recruited 10 patients with FD and 17 patients with ID are summarized in Table 1. The two groups did not significantly differ in terms of sex distribution ($P = 0.45$). FD patients were significantly younger at the time of assessment compared with ID patients ($P = 0.03$); however, no significant difference was found in age at onset ($P = 0.06$), and the two groups were similar in terms of disease duration ($P = 0.78$). As expected, an acute onset was more frequently observed in FD (n = 5, 50%) than in ID patients (n = 1, 6%) ($P = 0.02$). No significant group differences were detected for any of the other clinical features, including fixed posture, body distribution of dystonia, presence of a trigger event, response to botulinum toxin treatment, pain, anxiety, depression and years of education. Full clinical comparisons are summarised in Table 2.

The EMG montage was bilateral in all patients but one, with an average number of 10.6 ± 2.9 (range 5–16) muscles recorded. The total average dose of propofol administered was 2.5 ± 0.9 mg/kg (range 1.2–4.5) with no significant group differences (FD: mean 2.6 ± 1.0 mg/kg, median 2.4 interquartile range [IQR] 1.84–2.9; ID: mean 2.4 ± 0.9 mg/kg, median 2.3, IQR 1.8–2.9; $P = 0.88$). No significant differences were also observed for the Ce at loss of consciousness (FD: mean 3.9 ± 0.6 μg/ml, range 3–5; ID: mean 3.7 ± 0.6 μg/ml, range 2.5–4.5; $P = 0.28$). Mean protocol duration, from the beginning of the recording to the end, was 19.4 ± 3.8 min (range 14–28). In addition, preparation of the setting (EMG montage, BIS/EEG placement, intravenous access) required an additional 15–20 min on average. No complications occurred, and all procedures were well tolerated.

At the baseline (alert stage), EMG activity from symptomatic muscles exhibited a mixed tonic-phasic pattern in all patients, except for 2 ID patients (11%) and 1 FD patient (10%) in whom the prevalent pattern was phasic ($P = 1.00$). Bursts duration was prolonged (>200 ms) in all ID patients (100%) and in 8 FD patients (80%) ($P = 0.13$). Agonist and antagonist co-contractions were observed in 8 of 16 ID patients (50%) and in 4 FD patients (40%) ($P = 0.70$) (Fig. 3A). Intra-epoch variability in EMG activity from symptomatic muscles during alert stage was common in FD (n = 8, 80%), but rare in those with ID (n = 1, 6%) ($P < 0.001$) (Fig. 3B). During mild sedation, EMG activity tended to decrease in amplitude but persisted in

TABLE 1 *Demographic, historical, and clinical characteristics of subjects with functional dystonia and idiopathic dystonia*

Patient	Gender	Age (years)	Body distribution	Fixed posture	Onset	Age at onset (years)	Disease duration (months)	Trigger (trauma or stressful event)	Response to BoTN	Pain	Depression[†]	Anxiety[‡]	Education (years)
Functional dystonia													
1	F	18	Focal (UL)	Y	Acute	17	5	N	/	Y	–	–	13
2	F	47	Generalized (cervical + axial + UL + LL)	N	Acute	33	122	No	/	N	N	N	10
3	F	34	Generalized (cervical + axial + UL + LL)	N	Progressive	10	281	N	/	Y	Y	Y	13
4	M	68	Focal (cervical)	N	Progressive	65	31	N	/	Y	N	N	5
5	M	46	Segmental (cervical + axial + UL)	N	Progressive	41	57	N	N	N	N	N	13
6	F	28	Generalized (cervical + axial + UL + LL)	Y	Acute	5	284	N	/	N	N	N	13
7	F	35	Focal (cervical)	Y	Progressive	35	6	Y (stressful)	Y	N	Y	Y	16
8	F	19	Focal (cervical)	N	Progressive	13	73	Y (stressful)	Y	Y	N	N	13
9	M	37	Segmental (cervical + UL)	N	Acute	15	264	Y (stressful)	/	N	N	N	17
10	F	57	Segmental (craniocervical)	N	Acute	55	18	N	/	N	N	N	13
Idiopathic dystonia													
1	M	67	Focal (cervical)	N	Progressive	64	30	Y (trauma)	N	Y	N	N	7
2	F	48	Focal (oromandibolar)	Y	Progressive	47	17	N	Y	N	–	–	13
3	F	36	Segmental (cervical + axial)	Y	Progressive	34	14	N	Y	Y	N	Y	13
4	M	52	Segmental (cervical + axial)	N	Progressive	48	51	N	Y	Y	N	N	10
5	M	52	Focal (cervical)	N	Progressive	28	234	N	Y	N	N	N	13
6	M	33	Generalized (cervical + axial + UL)	N	Progressive	20	44	N	/	N	Y	Y	15
7	M	29	Generalized (craniocervical + axial + UL)	N	Progressive	24	42	N	/	N	–	N	8
8	F	32	Generalized (cervical + axial + UL + LL)	Y	Progressive	19	174	N	Y	N	N	Y	8
9	F	52	Segmental (cervical + oromandibular)	N	Progressive	47	57	N	Y	Y	Y	Y	18
10	F	75	Segmental (craniocervical)	N	Progressive	40	417	N	Y	N	Y	Y	17
11	F	61	Focal (cervical)	N	Progressive	56	59	N	N	N	N	N	17
12	M	51	Segmental (cervical + axial)	Y	Progressive	36	186	N	Y	Y	–	–	17
13	M	49	Generalized (cervical + axial + UL + LL)	N	Progressive	23	312	N	Y	Y	Y	N	13
14	M	79	Segmental (cervical + axial)	N	Progressive	77	32	N	N	N	N	N	17

(Continues)

TABLE 1 *Continued*

Patient	Gender	Age (years)	Body distribution	Fixed posture	Onset	Age at onset (years)	Disease duration (months)	Trigger (trauma or stressful event)	Response to BoTN	Pain	Depression†	Anxiety‡	Education (years)
15	F	61	Focal (oromandibular)	N	Acute	59	22	Y (stressful)	N	Y	Y	Y	17
16	F	73	Segmental (craniocervical + UL)	N	Progressive	48	300	N	/	N	N	Y	13
17	F	51	Focal (cervical)	N	Progressive	47	53	Y (stressful)	Y	N	N	Y	8

†"Yes" = abnormal score (>13) on the Beck Depression Inventory-II (BDI-II).
‡"Yes" = abnormal score (>40) on the State–Trait Anxiety Inventory (STAI).
Abbreviations: BoTN, botulinum toxin; F, female; UL, upper limb; Y, yes; N, no; LL, lower limb; /, botulinum toxin treatment not previously tested; –, missing data; M, male.

at least one muscle in all patients among the two groups, except for 1 patient with FD (10%) ($P = 0.37$) (Fig. 3C). During deep sedation, EMG activity was recorded in 9 patients with ID (53%) but in none of the FD patients ($P = 0.01$) (Fig. 3D). At this stage, with patients completely unconscious and propofol infusion still ongoing, passive manipulation by the examiner disclosed partial tendon retractions at the neck level in three subjects diagnosed with ID (18%) and none in FD patients. The electrical silence during the deep sedation showed a 100% sensitivity (95% CI 0.69–1) and a 53% (95% CI 0.28–0.77) specificity in detecting FD with a low positive predictive value (PPV) (56%; 95% CI 0.31–0.78) but a high negative predictive value (NPV) (100%; 95% CI 0.66–1). During partial recovery of consciousness, EMG activity was found in all patients with ID (n = 17, 100%) but recorded in only 1 FD patient (10%) ($P < 0.001$) (Fig. 3E). Under this condition, electrical silence had slightly lower sensitivity (90%, 95% CI 0.55–1) but increased specificity (100%; 95% CI 0.8–1), with a PPV of 100% (95% CI 0.66–1) and NPV of 94% (95% CI 0.73–1). Finally, during full recovery of consciousness, a different pattern of muscle activation compared with the baseline was observed in 7 patients with FD (70%) and in only 1 ID patient (6%) ($P = 0.001$) (Fig. 3F). No sustained clinical improvement or deterioration was observed at the end of the protocol.

A post-hoc analysis within the ID group, comparing subjects with persistent EMG activity and those who exhibited electrical silence during deep sedation, revealed no significant differences in the variables listed in Table S1, except for a higher mean Ce at loss of consciousness in the electrically silent group ($P < 0.01$). In addition, subjects with persistent EMG activity showed a trend toward longer disease duration ($P = 0.05$).

DISCUSSION

To the best of our knowledge, this is the first study to evaluate the role for PEMG under propofol anesthesia in differentiating FD from ID. Our results suggest that EMG electrical silence observed during deep sedation—and more notably during the partial recovery of consciousness—may serve as a valuable neurophysiological biomarker of FD. The absence of muscle activity in these states may reflect a disruption of the voluntary motor drive, which is a hallmark of FMDs.[6] Furthermore, the emergence of distinct muscle recruitment patterns post-propofol administration, when compared with baseline pre-infusion EMG activity, may constitute a neurophysiological biomarker of functional incongruence.

This study builds upon a growing body of research dedicated to identifying neurophysiological biomarkers

TABLE 2 *Clinical and demographic differences between subjects with functional and idiopathic dystonia*

Parameter	FD	ID	*P*-value
Gender (M/F)	3/7	8/9	0.45
Age (years), median (IQR)	38.9 (25.8–49.5)	53.0 (42.0–64.0)	**0.03****
Age at onset (years), mean (±SD; min–max)	28.9 (±20.3; 5–65)	42.2 (±16.5; 19–77)	0.06*
Disease duration (months), mean (±SD; min–max)	114.1 (±117.3; 5–284)	120.2 (±126.0; 14–417)	0.78*
Distribution (generalized/total)	3/10	4/17	>0.99
Onset (acute/total)	5/10	1/17	**0.02**
Fixed posture (yes/total)	3/10	4/17	>0.99
Trauma or stressful event (yes/total)	3/10	3/17	0.64
BoTN response (yes/total)	2/3	10/14	>0.99
Pain (yes/total)	4/10	7/17	>0.99
Depression[†] (yes/total)	2/9	5/14	0.66
Anxiety[‡] (yes/total)	2/9	8/15	0.21
Scolarity (years), median (IQR)	12.6 (12.3–13.8)	13.2 (9–17)	0.56**

[†]"Yes" = abnormal score (>13) on the Beck Depression Inventory-II (BDI-II).
[‡]"Yes" = abnormal score (>40) on the State–Trait Anxiety Inventory (STAI).
*Parametric distribution (Student's *t*-test for unpaired data).
**Nonparametric distribution (Mann–Whitney U test).
[a]Bold type denotes statistical significance.
Abbreviations: BoTN, botulinum toxin; F, female; FD, functional dystonia; ID, idiopathic dystonia; IQR, interquartile range (25% and 75% percentiles); M, male; min, minimum; max, maximum; SD, standard deviation.

that may aid in the differential diagnosis of FD versus ID, to address the current gap in objective diagnostic tools reflected in the "laboratory-supported" category of the Gupta and Lang criteria.[32] Previous neurophysiological studies have reported overlapping abnormalities in FD and ID, including reduced cortical inhibition (long and short interval intracortical inhibition, cortical silent period), spinal inhibition (cutaneous silent period)[17,18] and an impaired processing of somatosensory inputs.[19] While these findings have advanced our understanding of shared dysfunctions, they do not currently offer clinically applicable markers for differential diagnosis. Nonetheless, some studies have pointed to subtle neurophysiological differences. Berardelli and colleagues found the R2 component of the blink reflex recovery cycle to be abnormally enhanced in patients with blepharospasm and oromandibular dystonia.[41] Based on this assumption, Schwingenschuh et al. assessed this parameter to successfully distinguish functional from "organic" blepharospasm.[21] Similarly, a marked reduction in post-excitatory inhibition after transcranial magnetic stimulation has been found in patients with hemifacial spasm, and not those with functional spasms or healthy controls.[42] However, these findings remain preliminary and require validation in larger cohorts and across other dystonia phenotypes (ie, cervical), to establish broader generalizability and diagnostic utility across the clinical spectrum. Other explored measures, including assessments of associative plasticity[43] and sensory temporal discrimination,[19] have shown differences between FD and ID, but are limited by technical constraints and poor clinical applicability.[44] Cortical plasticity and reaction times are influenced by cognitive and personality factors,[45,46] and temporal discrimination relies on self-report, thus presenting a major intrinsic limitation. Additionally, intra-individual variability adds further complexity.[44] The relationship between sensory processing and FD has also been explored through the lens of pain perception. Morgante et al. reported increased pain tolerance in patients with fixed FD, despite an equal tactile and pain threshold compared with "organic" dystonia and healthy subjects.[22] A more recent study using laser-evoked potentials and a conditioning protocol has demonstrated impaired descending inhibitory control in FMDs.[47] However, in this study, there were only two patients with predominant FD, and the controls were limited to healthy subjects, limiting generalizability. Building on this body of work, our study introduced a novel protocol focused on muscular activity—the final common pathway shared by both FD and ID—and applied one of the most widely available neurophysiological tools, PEMG, in the context of controlled anesthesia. Some previous studies attempted to assess dystonia during sleep, as the most physiological condition of "sedation", with discordant results. Two

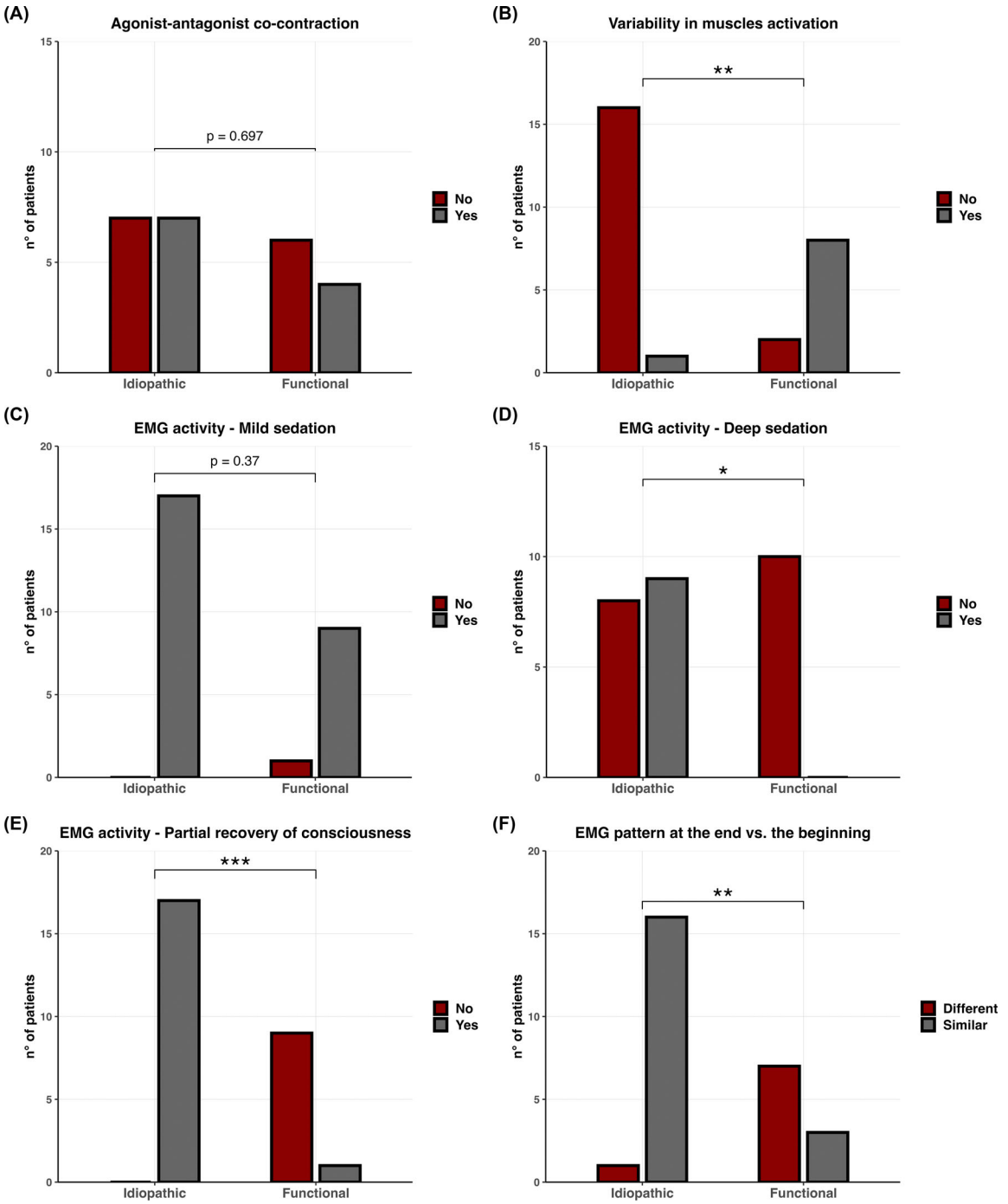

FIG. 3. Histograms comparing idiopathic dystonia and functional dystonia patients across the five stages: alert status (panels A–B), mild sedation (panel C), deep sedation (panel D), partial recovery of consciousness (panel E), and final assessment after full recovery (panel F). EMG, electromyography. [Color figure can be viewed at wileyonlinelibrary.com]

early studies conducted in the 1990s showed how EMG activity gradually decreases during sleep in patients with cranial dystonia, without disappearing and maintaining the same EMG features as in waking.[48,49] In contrast, a more recent study on cervical dystonia found complete suppression of EMG activity during all sleep stages, with values significantly lower than controls.[50] Although conducted under a different condition—sleep—these studies also differ substantially from our protocol in terms of methodological approach. In all the abovementioned studies, EMG recordings were obtained using surface electrodes, without direct monitoring of consciousness levels. By contrast, our protocol employed needle EMG recordings under pharmacologically controlled sedation, with real-time EEG and BIS monitoring to define and verify each stage of

consciousness. This allowed for a consistent and reproducible assessment of muscular activity across clearly delineated sedation and recovery phases. Propofol was selected due to its widespread use at our institution and its favorable pharmacokinetic/pharmacodynamic profile. Indeed, after a short infusion, as in our study, its clinical effects dissipate within minutes due to rapid redistribution into peripheral tissues.[36]

This setup enabled us to systematically evaluate EMG features in both FD and ID throughout the sedation protocol. During the alert condition, a tonic EMG pattern with prolonged bursts, involuntary activation of contiguous muscles, and frequent co-contraction of agonist and antagonist muscles was commonly observed, particularly in patients with ID. These features are well established in the literature as typical of ID.[51-54] However, they were also present in several FD cases, limiting their diagnostic specificity. The only feature that appeared to distinguish the two groups at this stage was the presence of intra- and inter-muscular variability in EMG activity, which was markedly more frequent in FD. This finding is consistent with the clinical observation of variability as a core feature of FMDs. During mild sedation, EMG activity persisted in at least one muscle in all patients, except for one with FD (10%). More pronounced and statistically significant differences emerged during deep sedation: no FD patients exhibited EMG activity at this stage, while persistent activity was recorded in more than half of the ID group (n = 9, 53%). This contrast was even more evident during partial recovery of consciousness—when propofol infusion was suspended but full arousal had not yet returned—as all ID patients (100%) showed a re-emergence of muscle activity, while 9 of 10 FD patients (90%) remained electrically silent. This pattern of electrical silence during deep sedation demonstrated excellent sensitivity (100%) but only moderate specificity (56%) for identifying FD. In contrast, the partial recovery phase offered improved diagnostic accuracy, with both PPV and specificity reaching 100%. This may represent potentially the most discriminative phase to distinguish FD from ID, as transitional states can unmask the differences in how muscle activity is modulated. Finally, at full recovery, a discrepancy in muscle activation compared with baseline (alert stage) was observed in most FD patients (n = 7, 70%), while nearly all ID patients (n = 16, 94%) resumed the same baseline activation pattern. This neurophysiological feature may reflect clinical functional incongruence and serve as an additional diagnostic clue. Taken together, these findings suggest that while variability at baseline may offer some indication, it is the differential response to propofol sedation that provides a more robust and reproducible means of distinguishing between FD and ID.

Although the purpose of this study was not to investigate pathophysiological mechanisms underlying the two conditions, the differing responses to propofol sedation allow for some speculation. Low-dose sedation primarily affects cortical structures, sparing deeper brain regions.[31] Neuroimaging studies have shown that propofol disrupts cortical networks such as the default mode network, motor, and salience networks[55]—areas implicated in FMDs.[7,9,56,57] This supports the idea that FD may originate from dysfunction in higher-order cortical regions, making it more sensitive to cortical disruption by sedation. In contrast, ID likely involves deeper and more distributed network "nodes",[28,30] potentially explaining its relative resistance to propofol, particularly during recovery of consciousness.

This pilot study has some limitations, including the small sample size and the lack of quantitative EMG analysis, particularly for assessing variability at baseline. To mitigate these aspects, a standardized protocol with five defined experimental conditions was implemented to ensure reproducibility. While initial results are promising, larger multicenter studies are needed for validation. We acknowledge that our cohort was restricted to clinically definitive cases of FD and ID, which constrains the external validity of our findings. Future studies should extend inclusion to patients with more ambiguous or uncertain diagnostic profiles, as they may stand to benefit most from the proposed diagnostic biomarkers in real-world clinical settings. Moreover, systematic genetic testing was not performed as part of the study protocol, although most ID patients had previously undergone investigations of varying extent, as part of their standard clinical care, without a confirmed genetic diagnosis. Importantly, the use of PEMG under sedation requires specialized expertise and resources, limiting its use in routine clinical practice. Instead, it may serve as a valuable diagnostic tool in selected, complex cases, and also to map active muscles in patients unresponsive to botulinum toxin or to distinguish true tendon retractions in ID, particularly when evaluating candidates for advanced therapies such as deep brain stimulation.

CONCLUSIONS

This is the first study to propose a diagnostic role for PEMG under propofol anesthesia in distinguishing FD from ID. Although relatively invasive, our protocol proved safe and preliminary results suggest that the presence of EMG electrical silence during deep sedation—and even more prominently during the partial recovery phase—may represent a reliable neurophysiological biomarker of FD. Additionally, the EMG variability during the alert condition and the appearance of different muscle recruitment patterns following propofol administration, relative to baseline EMG

activity, may offer further objective evidence of functional inconsistency and incongruence, respectively.

Author Roles: (1) Research Project: A. Conception, B. Organization, C. Execution; (2) Data: A. Collection, B. Curation, C. Analysis; (3) Statistical Analysis: A. Design, B. Execution; (4) Manuscript: A. Writing of the First Draft, B. Review and Critique.
R.E.: 1A, 1B, 1C, 2B, 2C, 3A, 3B, 4B.
F.P.: 1A, 1C, 2A, 2B, 2C, 3A, 3B, 4A, 4B.
S.R.: 1B, 1C, 2A, 2B, 4B.
C.C.: 1B, 1C, 2A, 2B, 4B.
A.O.: 1B, 1C, 2A, 2B, 4B.
G.D.: 1B, 1C, 2C, 4B.
L.M.R.: 1B, 1C, 2C, 4B.
R.C.: 1B, 1C, 2C, 4B.
N.G.A.: 1B, 1C, 2C, 4B.
G.G.: 1B, 1C, 2C, 4B.
M.C.: 1B, 1C, 2C, 4B.
A.E.E.: 1B, 1C, 2C, 4B.
F.C.: 1B, 1C, 2C, 4B.
A.B.: 1B, 1C, 2C, 4B.
R.T.: 1B, 1C, 2C, 4B.
M.T.: 1A, 2C, 4B.
M.G.: 1A, 2C, 4B.
V.L.: 1A, 1B, 2B, 2B, 2C, 3A, 4A, 4B.

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Data Availability Statement

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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Supporting Data

Additional Supporting Information may be found in the online version of this article at the publisher's web-site.