Received: 21 December 2020 | Revised: 15 February 2021 | Accepted: 18 February 2021

DOI: 10.1002/lio2.544

ORIGINAL RESEARCH

Laryngoscope Investigative Otolaryngology

Classification of vocal tremor using updated consensus-based tremor classification criteria

Vanessa Torrecillas MD[1] | Kaitlyn Dwenger BS[1,2] | Julie M. Barkmeier-Kraemer PhD, CCC-SLP[1,2]

[1]Division of Otolaryngology – Head and Neck Surgery, University of Utah, Salt Lake City, Utah, USA

[2]Department of Communication Sciences and Disorders, University of Utah, Salt Lake City, UT, USA

Correspondence
Julie M. Barkmeier-Kraemer, Division of Otolaryngology – Head and Neck Surgery, The University of Utah, 50 N Medical Drive, SOM 3C120, Salt Lake City, UT 84132, USA.
Email: julieb.kraemer@hsc.utah.edu

Funding information
National Institute on Deafness and Other Communication Disorders, Grant/Award Number: R01DC016838

Abstract

Objectives: This study characterized the clinical phenotypes of individuals with vocal tremor (VT) using tremor classification criteria published by the International Parkinson and Movement Disorder Society (IPMDS) including laryngeal features from the American Academy of Otolaryngology—Head and Neck Surgery (AAO-HNS).

Methods: VT phenotypic descriptors were extracted from participant medical records from 2017 to 2019. Clinical phenotype descriptors included the: (a) chief complaint and discipline for the first appointment, (b) demographics, (c) tremor body distribution, condition, frequency, and progression, (d) exacerbating/alleviating factors, (e) treatment approaches, and (g) neurologic comorbidities. Descriptive statistics were conducted.

Results: Of 179 meeting inclusion criteria, 2/3 were female; tremor onset affected voice (43%) or extremity (32%) and 2/3 were documented with tremor duration of 3 years or more. Those with primary VT first saw otolaryngology or speech language pathology (59%), whereas those with primary extremity/head tremor first saw neurology (36%). Documentation commonly omitted tremor clinical features such as (a) observed conditions of tremor (64%), (b) laryngeal features (64%), and (c) tremor frequency (92%). Thus, VT classification was based on comorbidity in 49% of patients (ie, essential tremor (48%), dystonia (72%), and Parkinson's disease (100%)) and 32% had inadequate documentation to classify.

Conclusion: The majority of individuals with VT were unable to be classified based on documented clinical features highlighting the need for consistent multidisciplinary assessment of tremor affecting speech structures. The primary site of tremor determined the first discipline seen. Most commonly classified VT categories included essential tremor (47%), dystonia (28%), Parkinsonism (7%), and isolated VT (19%).

Level of Evidence: 4.

KEYWORDS
essential tremor, laryngeal dystonia, Parkinson's disease, vocal tremor, voice tremor

1 | INTRODUCTION

The voice is intrinsically tied to personal identity such that impaired quality and function of the voice is associated with lower self-esteem, impaired communication, and decreased quality of life.[1-3] Vocal tremor (VT) is a common, but poorly studied neurogenic voice problem that can interfere with communication and is typically associated with other movement disorders such as essential tremor (ET), dystonia, and Parkinson's disease (PD).[4] Distinguishing clinical features of VT in isolation or associated with other movement disorders have not been elucidated from prior research. Further, prior investigation of VT has not systematically compared clinical tremor features using tremor classification criteria.

Updated consensus-based classification criteria for tremor were recently published by the International Parkinson and Movement Disorder Society (IPMDS) that broadly defined tremor as an involuntary, rhythmic oscillatory movement of a body part further classified into tremor syndromes across two clinical axes—clinical features (axis 1) and etiology (axis 2).[5] The IPMDS task force defined several tremor-specific clinical features (ie, axis 1) (see Figure 1) used to classify clinical syndromes of tremor such as essential tremor (ET), dystonia (DT), or Parkinsonism (see Figure 2).[5] This updated framework classifies individuals with ET having clinical features for less than the minimum duration of 3 years as "indeterminate tremor." Isolated vocal tremor (IVT) is classified separately, among other isolated tremors affecting individual body structures such as the palate, jaw, and head. This new classification of IVT appeared based on the rationale that the "voice" represents tremor affecting only the larynx. Unfortunately, this reclassification of isolated VT overlooks that VT could originate from any singular or combined respiratory or upper airway speech structure(s) affected by tremor. That is, isolated VT may not meet the classification requirement of an isolated tremor affecting a singular structure. Unfortunately, few publications adequately describe clinical features of VT to elucidate the characteristics necessary for tremor classification. For example, a recent literature review investigated isolated VT as a clinical variant of ET and identified only three publications that adequately characterized individuals with IVT for comparison to classification features of ET.[6]

Guidance regarding classification of tremor affecting upper airway structures was published in 2005 by the AAO-HNS Neurolaryngology Committee. This consensus document offers clinical features of "laryngeal tremor" obtained during nasoendoscopy to distinguish individuals with VT associated with ET, dystonia, or Parkinsonism (see Figure 3).[7] AAO-HNS characteristics of VT classified as ET included individuals with IVT and the observation of tremor affecting one or multiple upper airway structures regardless of task (ie, during both respiration and speech tasks). In contrast, dystonic VT (DT) (eg, spasmodic dysphonia, or laryngeal dystonia) was characterized by tremor affecting the larynx during speech production (ie, task specificity).[7] Also, DT symptoms may be reduced or eliminated during a "sensory trick" such as placement of the nasoendoscope with or without use of topical anesthesia.[7] Parkinsonism VT was defined by a comorbidity of idiopathic PD and associated with vertical laryngeal oscillation.[7]

Although these two consensus documents offer guidance regarding critical clinical features to assess in those exhibiting VT, no prior studies have systematically utilized these criteria to distinguish VT

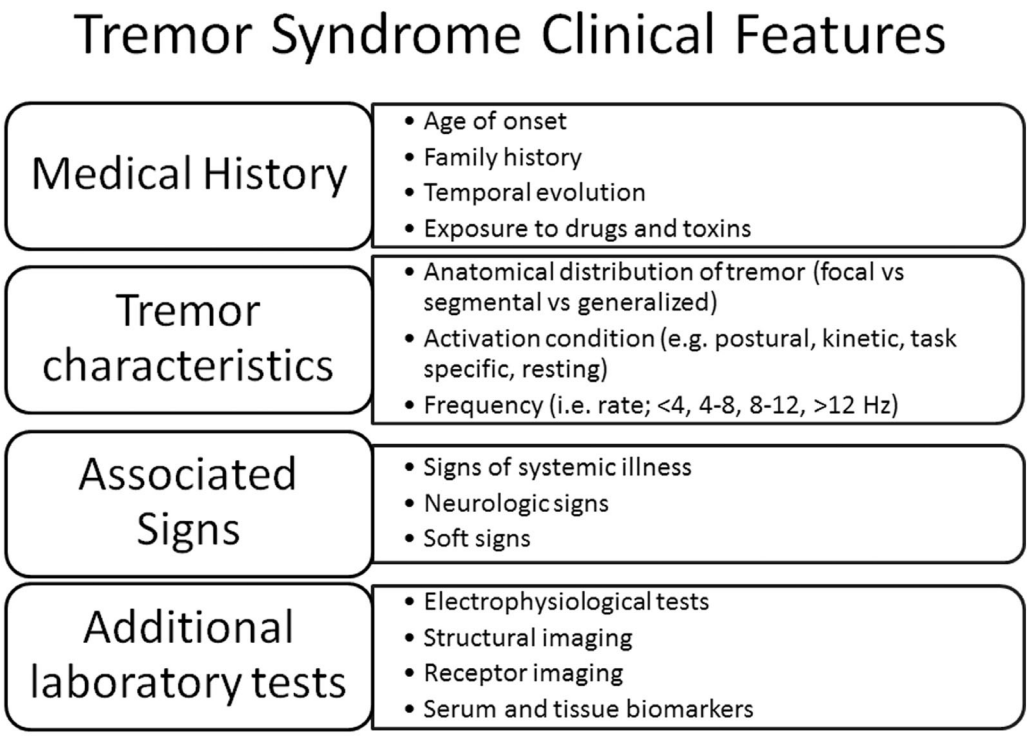


FIGURE 1 Axis 1 clinical features recommended for classification of tremor by the IPMDS

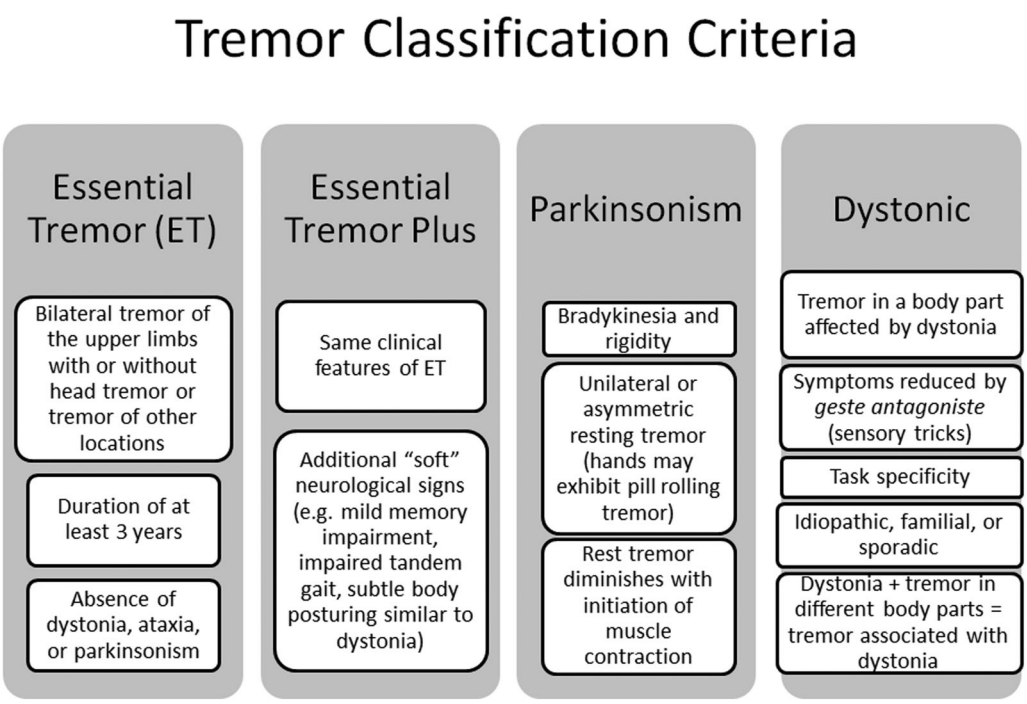


FIGURE 2 Axis 1 classification criteria for ET, Essential Tremor Plus, Dystonia, and Parkinsonian tremors

characteristics by tremor category.[6,8-10] The purpose of this study was to characterize the documented clinical phenotypes of individuals with VT using combined IPMDS and AAO-HNS tremor classification criteria. Typical medical discipline entry points, patterns of assessment, treatment and clinical phenotypic descriptors were also evaluated.

2 | MATERIALS AND METHODS

This study was approved by the University of Utah IRB (Protocol#00127836).

2.1 | Participants

Participants for this study were identified using the University of Utah (UofU) Data Warehouse and met these inclusion/exclusion criteria: (a) 18 years of age or older, (b) electronic medical record (EMR) documentation containing the phrase, "vocal tremor" or "voice tremor," (c) completed appointments within UofU outpatient clinics from 2017 to 2019, and (d) a diagnosis containing one or more of the ICD-10 CPT codes listed in Table 1. The first 300 participants meeting inclusion criteria were identified for manual inspection and EMR data extraction.

2.2 | VT clinical feature and classification procedures

The research team (VT, KD, and JBK) developed and reached consensus on operationally defined methods of data extraction. Simultaneous evaluation of EMR documentation was completed on the first five participants to reach consensus. Data extraction and classification criteria are described in Tables 2-4. Inter-rater reliability checks were randomly conducted on 15% of participants throughout data collection demonstrating ≥80% reliability across all extracted items and time points.

Final VT classification was rendered upon completion of EMR data extraction using combined tremor classification criteria from the IPMDS and AAO-HNS (see Table 4). Individuals with VT and a single related neurological diagnosis without nasoendoscopy were "*classified by comorbidity*." Those with conflicting or inadequate clinical descriptors were marked as "*inadequate information to classify*."

2.3 | Statistical analysis

Descriptive statistics were used to analyze and characterize data across all participants as well as by tremor classifications.

3 | RESULTS

3.1 | Classification rate using medical record documentation

A total of 179 individuals met initial inclusion criteria (see Figure 4); however, a total of 119 (66%) individuals demonstrated adequate EMR documentation to classify and characterize their tremor. Of these individuals, 99 (83%) completed a nasoendoscopy. That is, 55% of the total VT population meeting inclusion criteria completed

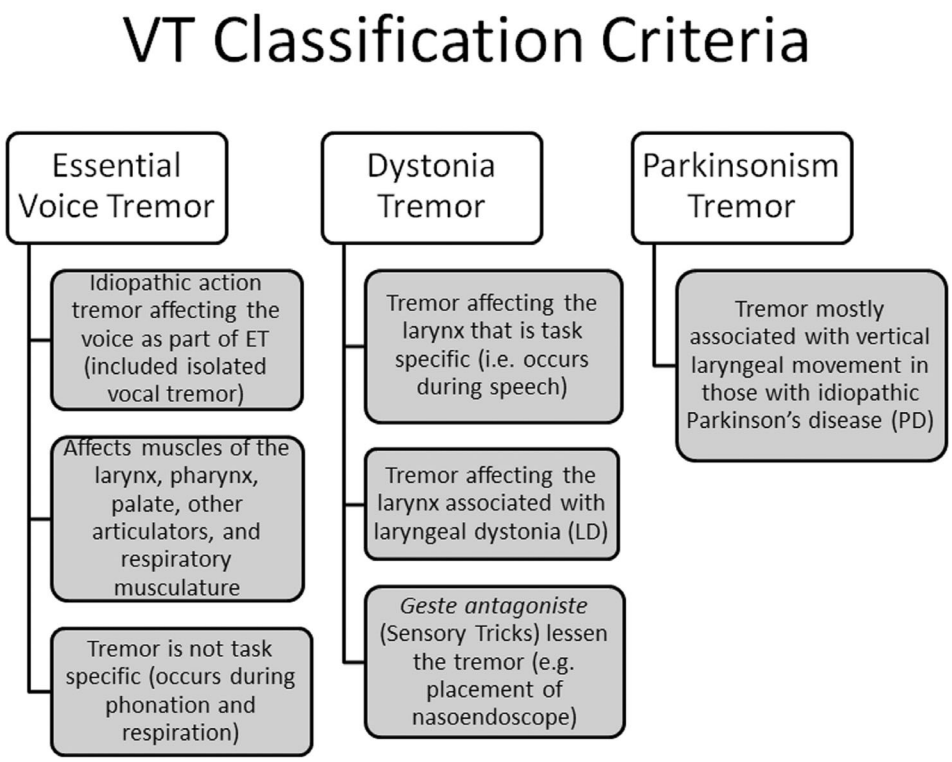


FIGURE 3 AAO-HNS Neurolaryngology Committee[7] classification criteria for VT associated with ET, dystonia, and Parkinsonism

TABLE 1 ICD-10 codes used to identify participants for consideration for inclusion in the study

ICD-10 codes	ICD-10 associated descriptors
R49.0	Dysphonia
	Vocal tremor (VT)
	Spasmodic dysphonia (SD)
	Spasmodic dysphonia + vocal tremor (SD + VT)
	Adductor spasmodic dysphonia with vocal tremor (ADSD + VT)
	Adductor spasmodic dysphonia with vocal tremor (ADSD + VT)
	Adductor spasmodic dysphonia (ADSD)
	Abductor spasmodic dysphonia (ABSD)
	Mixed spasmodic dysphonia
	Essential tremor of spasmodic dysphonia
	Dystonic tremor
G25.0	Essential tremor (ET)
G20	Idiopathic Parkinson's disease (PD)
G21.9	Secondary to Parkinson's disease
G24.9	Dystonia

nasoendoscopic evaluation. Of those classified (N = 119), eight were assigned to tremor categories with fewer than five individuals and an additional six were classified as indeterminate tremor (Figure 4). Thus, outcomes are reported on 105 individuals with VT classified as dystonia (DT), Parkinsonism (PD), essential tremor (ET), and isolated VT (IVT).

3.2 | Demographic characteristics

Detailed demographic characteristics of the total group and VT classification categories are shown in Table 5.

3.2.1 | VT classification

Of those with VT that were classified, 29 individuals (28%) were classified as DT, 7 as PD (7%), 49 as ET (47%), and 20 as IVT (19%). Within groups, the majority of those classified as DT, ET and PD were based on comorbidities rather than clinical features.

3.2.2 | Sex

The majority of participants were female (62%); similar findings occurred for all tremor categories except for ET in which nearly equal representation between males (53%) and females (47%) occurred.

3.2.3 | Age

The mean age at first evaluation was 67 years (SD = 10.6; 30-87 years). The average age at tremor onset was 52 years (SD = 12.8; 27-85 years). Those diagnosed with IVT exhibited a later average onset of tremor (67; 40-85 years) compared to other VT categories averaging 53-58 years (range = 27-78 years). The time from onset of tremor and the initial evaluation averaged 12 and 13 years in those

TABLE 2 Criteria applied to clinical features and characteristics for EMR data extraction

Demographics (age, sex, duration of disease)	Age: • *Age at first diagnosis* = first documented clinic visit – birthdate • *Age of symptom onset* = age at first diagnosis – documented duration of symptoms
Initial evaluation	Date of service: The initial appointment date for tremor despite presence/absence of accompanying notes Service/specialty: The service associated with the initial evaluation date above • If a team-based approach (eg, otolaryngology and speech), then document as both "ENT/SLP"
Presenting complaint	Primary complaint associated with the initial evaluation date above • If the primary complaint is absent in the initial evaluation, infer from the encounter notes that provide the medical history or document the reason for referral
Onset of symptoms	Years from the initial evaluation (ie, initial consult year – year documented in the clinical encounter) • If over 20 years, then document "20+" • If less than a year, then document "<1"
Progression	Relating to tremor severity or spread to other body parts over time • Yes/no as noted in the initial evaluation or primary note
Voice percent normal	The patient report of the proportion of normal their current voice is during the clinic visit (eg, 60% of their normal voice) • If a range is reported (eg, 50%-60%), then record the lower value listed
Condition of Tremor (rest, postural, and kinetic)	Determined using the history and physical examination from the first notes available from each specialty and record for any body distribution. Information regarding condition(s) under which tremor was observed could be recorded based on medical record information across the entirety of time span of tremor documentation and before or after treatment approaches if the tremor(s) evolved. Condition of VT: • Record from nasoendoscopy documentation (if present) for upper airway structures and other associated body sites. • The upper airway structures were assumed to never be observed with support against gravity. Quiet breathing posturing was recorded as tremor during postural condition and speech production was recorded as tremor during kinetic condition.
VT frequency (Hz)	This was only recorded with VT using acoustic measures rather than kinematic measures of tremor rate affecting individual structures.
Laryngeal tremor excursion	Vertical: • Documentation of "vertical bobbing of the larynx" counts Lengthwise: • Documentation of shortening and elongation of the laryngeal vestibule without views of the vocal folds counts • Documentation of shortening and elongation of the true vocal folds counts AB/ADD: • Documentation of "quasi-irregular abductor/adductor movements of the arytenoids" counts • Documentation of "phonatory breaks" associated with laryngeal tremor counts
Exacerbated by stress	Documented as per HPI and can be reported as anxiety, nervousness, etc.
Alcohol responsive	Documentation of benefit of alcohol to tremor • If patient does not drink alcohol, then document "NA" • If patient drinks alcohol with no change, then document "N" • If not documented, then document "."
Primary body site	Body site where the tremor was first observed • If documented as hand, arm, or upper extremity, then document "UL" • If isolated vocal tremor to begin with, then document "Voice" • If multiple (eg, both voice and extremity), then document "Multiple" • If any other body site, then record that body site
Body site distribution	Only documented is a body site is positive for tremor through direct observation of tremor. • If positive, then document symmetry (ie, unilateral or bilateral) • If only "upper extremity" is in the notes with no specification of hand or arm, then document both • If one note specified hand or arm and another note documents "upper extremity," the document arm and hand For VT, do not assume there is a tremor in the larynx, pharynx, etc. unless there was direct observation of tremor using nasoendoscopy. • If undocumented but the patient received Botox treatment into the larynx, then infer the larynx as a positive site of tremor.
Family history	Documented anywhere in the medical chart • If history of blepharospasm, Meige Syndrome, etc. for family members, then document positive family history for dystonia
Parkinsonism symptoms	See Table 4 for criteria

(Continues)

TABLE 2 (Continued)

Medication trial	Trialed (yes/no): • This includes any medications (not just ones that were specifically trialed for tremor) if an effect on tremor was documented Type trialed: • Beta blocker, muscle relaxant/antispasmodic, benzodiazepine, anticonvulsant, Parkinson medications, other neuropsyciatric medications (ie, other neuropsychiatric medications such as antidepressants) (see Table 3 for medication list) Benefit: • Documented if a medication was trialed and a benefit to tremor in anybody site was received
Behavioral (SLP) trial	Trialed (yes/no): • A stimulability session does not count Benefit: • Documented is there was a benefit to the VT
Procedure/surgery trial	Trialed (yes/no) Type trialed: • Botox, DBS (unilateral or bilateral), FUS, etc. Benefit: • Documented if a procedure/surgery was trialed and a benefit to tremor in anybody site was received
Disciplines seen	Neurology, ENT, SLP, and psychiatry (ie, psychiatry, neuropsychiatry or neurobehavioral specialists)
Diagnoses (primary, secondary, and other)	Diagnosis(es) given at the time of the initial evaluation and recorded in the medical record • *Primary*: first documented diagnosis • *Secondary*: second documented diagnosis • *Other*: all further documented diagnoses
Evolving diagnosis	Any diagnosis that changed over subsequent clinical evaluations • *Change in clinical phenotype*: evolving or new characteristics of tremor that effect the diagnosis • *Diagnosis for treatment (despite clinical phenotype)*: if a specialist specifically changes diagnosis to facilitate treatment recommendation

with DT and PD, respectively, whereas IVT and ET averaged 4 and 6 years, respectively.

3.2.4 | Duration of symptoms

The average duration of tremor symptoms was 10 years (SD = 7.3; <1 to 20+ years). The longest duration of symptoms occurred in those with DT (10 ± 7.3 years; <1 to 20+ years) and ET (12 ± 7.2 years; <1 = 20+ years). Those with PD and IVT showed the shortest average duration of symptoms (5 and 4 years, respectively).

3.2.5 | Family history

On average, 42% of those with VT reported a family history of tremor. The majority belonged to the ET group (59%) with ~1/3 each from the DT and PD groups. Approximately 30% of those with PD also reported a family history of PD. Family history features were unknown in 38% of those with DT and 35% of those with IVT.

3.2.6 | Exacerbated by stress

This feature was not documented or assessed in 77% of participants.

3.2.7 | Responsive to alcohol

The study location potentially influenced outcomes for this clinical feature. The majority of respondents did not consume alcohol (52%); this feature was undocumented in ~1/3 of participants and only 9% confirmed that alcohol reduced tremor symptoms.

3.2.8 | First site of tremor

The first site of tremor was reported as the voice in 100% of those with IVT and ~60% of those with DT. Those reporting tremor first in the extremities (eg, hands) were primarily classified as ET (54%) and PD (57%).

3.2.9 | Progression of tremor

On average, the majority of participants (68%) reported progression of their symptoms. However, only 1/3 of the IVT group reported progression of their tremor symptoms.

3.2.10 | Comorbidities

On average, 29% of participants were documented with anxiety and depression; approximately 33% were documented with GERD and dysphagia. Over 50% of those classified as PD were documented with

TABLE 3 Classification of medications extracted from the EMR

Medication class	Common medications
Beta blocker	Metroprolol
	Propanolol
Muscle relaxant/antispasmodic	Baclofen
	Cyclobenzaprine
Benzodiazepine	Alprazolam
	Clonazepam
	Diazepam
	Lorazepam
Anticonvulsant	Carbemazepine
	Gabapentin
	Lamotrigine
	Levetiracetam
	Oxcarbazepine
	Phenytoin
	Primidone
	Topirimate
	Valproic acid
Parkinson medications	Amantadine
	Carbidopa-Levodopa
	Entacapone
	Pramipexole
	Ropinirole
	Selegiline
Other neuropsychiatric medication	Amitryptiline
	Buproprion
	Citalopram
	Duloxetine
	Fluoxetine
	Lithium
	Mirtazapine
	Paroxetine
	Quetiapine

anxiety, depression, and dysphagia, and 43% had GERD. Over 50% of the IVT group was documented with GERD and dysphagia; DT had the fewest comorbidities.

3.3 | VT clinical features

The clinical features of body distribution, symmetry, and condition of tremor by classification category are shown in Table 6.

3.3.1 | Body distribution

As shown in Table 6 and Figure 5, the anatomical distribution of tremor affecting speech structures showed tremor of the larynx for all

TABLE 4 Criteria for medical record classification of vocal tremor (VT)

VT classification	Clinical features
Essential tremor	1. Bilateral upper limb action tremor (postural or kinetic) 2. At least 3 years' duration 3. With or without tremor in other locations 4. Speech structures exhibited oscillation during respiration and speech tasks 5. Absence of other neurological signs such as dystonia, ataxia, or parkinsonism
Inadequate information to classify	Conflicting or missing tremor features that preclude classification
Vocal tremor classified by comorbidity	Tremor observed in upper airway structures associated with a single co-existing neurologic disorder (e.g., essential tremor, dystonia, Parkinson's disease) in the absence of confirmatory nasoendoscopic examination
Dystonic tremor	1. Tremor in a body part affected by dystonia 2. May be focal or segmental 3. Tremor affecting speech structures showing task specificity 4. Sensory trick(s) are reportedly helpful in reducing symptoms 5. Clinical feature of clear phoneme specificity during speech
Isolated vocal tremor	1. Vocal tremor in the absence of tremor affecting the limbs or head 2. No known co-occurring neurologic comorbidities 3. Tremor observed in speech structures (larynx, tongue, pharynx, palate, face, jaw)
Essential plus	1. Tremor with the characteristics of ET 2. Additional neurological signs of uncertain significance such as impaired tandem gait, questionable dystonic posturing, memory impairment, or other mild neurologic signs.
Indeterminate tremor	Does not fit into an established syndrome of ET and has a duration for less than 3 years requiring further observation to clarify the tremor syndrome.
Parkinsonism	1. Tremor observed in someone with bradykinesia and rigidity 2. Documented 4-7 Hz rest tremor (pill rolling) of the hand 3. Resting tremor of the lower limb, jaw, tongue, or foot 4. Tremor may be asymmetrical and may diminish upon initiation of movement5. May be associated with a diagnosis of Parkinson's disease
Other	Tremor etiology from a neurologic condition not defined above

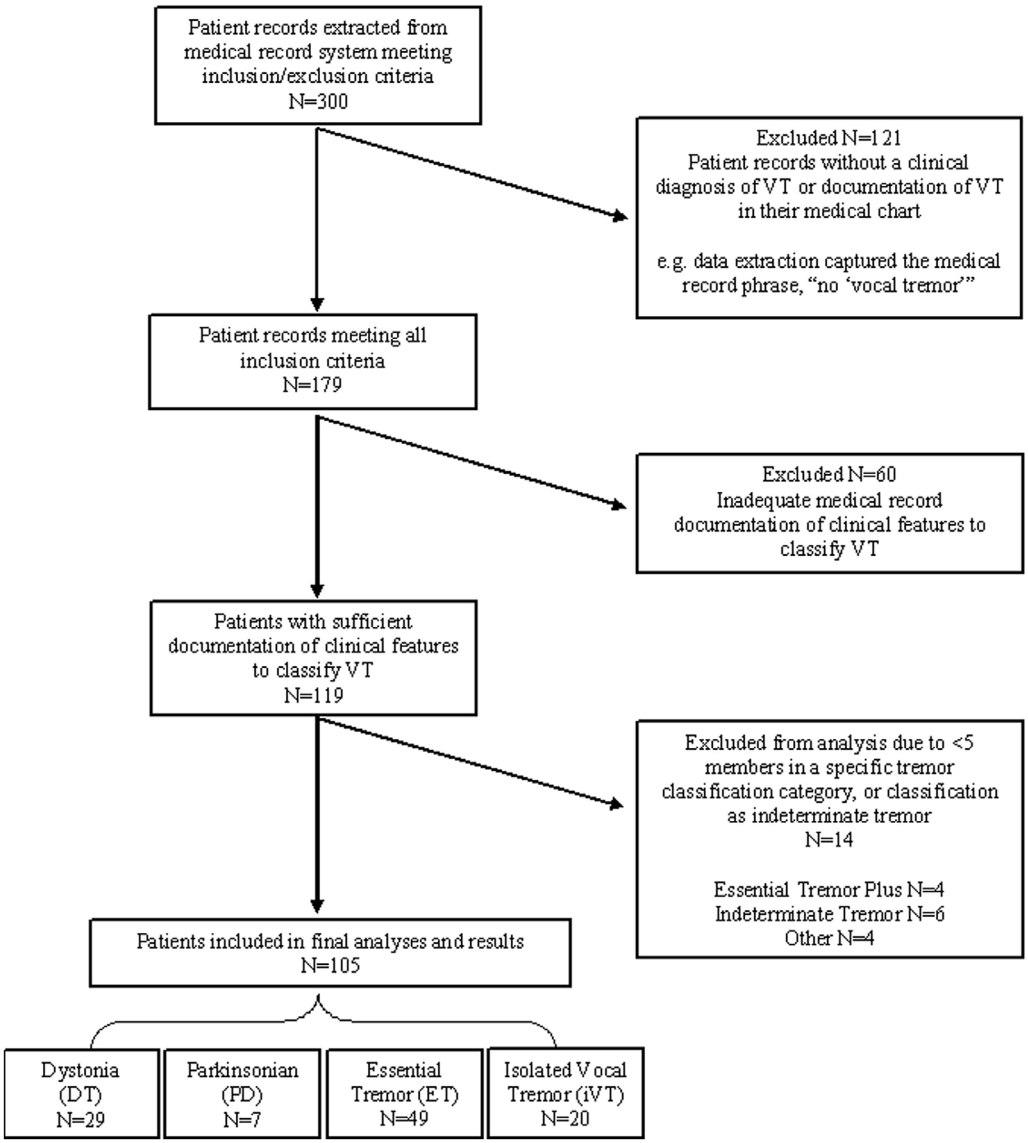


FIGURE 4 Flowchart of participant screening and inclusion evaluation for this study. Only classification categories with ≥5 individuals were included in study analyses and results. Those with indeterminate tremor were also excluded

categories of VT. The pharynx and palate were also frequently affected in those with DT, ET and IVT. The tongue, face, and jaw were less frequently documented.

3.3.2 | Tremor symmetry

Tremor symmetry across affected structures was undocumented for 56% to 100% of structures; however, those in which symmetry was documented showed bilateral tremor. Unilateral laryngeal tremor was documented in one individual classified with IVT.

Additional features of laryngeal tremor were infrequently documented. When documented, 40% to 52% of all tremor categories exhibited horizontal oscillation of the larynx (ie, abduction/adduction) (see Figure 6). Vertical oscillation of the larynx was documented in 50% of those with DT and 48% of those with ET compared to 20% and 26% of those with PD and IVT, respectively. Lengthwise oscillation (ie, anterior/posterior) oscillation was undocumented in 72% to 100% of individuals.

3.3.3 | Condition of tremor

Tremor affecting speech structures was typically judged during speech production. Across VT categories, specification of tremor assessment during respiration was not typically documented at comparable rates for the larynx (48%-80%), pharynx (84%-100%), palate (72%-89%), tongue (89%-100%), face (60%-100%), and jaw (92%-100%). The most frequent occurrence of laryngeal tremor across conditions occurred for those classified as IVT (48%) and ET (28%).

TABLE 5 Demographic characteristics overall and by VT classification

Clinical characteristics	Tremor classification				
	Dystonia N = 29	Parkinson's disease N = 7	Essential tremor N = 49	Isolated vocal tremor N = 20	Total N = 105
Classified by comorbidity (%)	21 (72%)	7 (100%)	23 (48%)	0 (0%)	51 (49%)
Gender					
Female	22 (76%)	6 (86%)	23 (47%)	14 (71%)	65 (62%)
Male	7 (24%)	1 (14%)	26 (53%)	6 (29%)	40 (38%)
Mean age at first evaluation in years (SD, range)	67 (8.3, 50-83)	71 (8.8, 63-86)	62 (12.2, 30-87)	70 (7.9, 51-80)	67 (10.6, 30-87)
Mean age at onset of tremor in years (SD, range)	53 (12.3, 27-73)	58 (10.2, 51-72)	56 (11.9, 31-78)	67 (12.6, 40-85)	52 (12.8, 27-85)
Mean duration of tremor symptoms in years (SD, range)	10 (7.3, <1-20+)	5 (3.5, 1-11)	12 (7.2, <1-20+)	4 (4.6, <1-20+)	10 (7.3, <1-20+)
Family history					
Tremor	10 (34%)	2 (29%)	29 (59%)	3 (15%)	44 (42%)
Dystonia	2 (7%)	0%	0 (0%)	1 (5%)	3 (3%)
Parkinson's disease	1 (3%)	2 (29%)	5 (10%)	0 (0%)	8 (8%)
Unknown/undocumented	11 (38%)	0%	10 (20%)	7 (35%)	28 (27%)
Exacerbated by stress (%)					
Yes	4 (14%)	3 (43%)	14 (29%)	1 (5%)	22 (21%)
Unknown/undocumented	25 (86%)	4 (57%)	33 (67%)	19 (95%)	81 (77%)
Responsive to alcohol (%)					
Yes	3 (10%)	0 (0%)	5 (10%)	1 (5%)	9 (9%)
Not applicable	13 (45%)	5 (71%)	26 (53%)	11 (55%)	55 (52%)
Unknown/undocumented	12 (41%)	2 (29%)	16 (33%)	8 (40%)	38 (36%)
First site of tremor (%)					
Voice	18 (28%)	1 (14%)	6 (12%)	20 (100%)	45 (43%)
Head	0 (0%)	1 (14%)	3 (6%)	0 (0%)	4 (4%)
Extremity	4 (14%)	4 (57%)	26 (53%)	0 (0%)	34 (32%)
Multiple	2 (7%)	0 (0%)	6 (12%)	0 (0%)	8 (8%)
Unknown/undocumented	5 (17%)	1 (14%)	8 (16%)	0 (0%)	14 (13%)
Progression (%)	16 (55%)	7 (100%)	42 (86%)	6 (30%)	71 (68%)
Comorbidities (%)					
GERD	7 (24%)	3 (43%)	15 (31%)	10 (50%)	35 (33%)
Dysphagia	5 (17%)	4 (57%)	15 (31%)	12 (60%)	36 (34%)
Dyspnea	2 (7%)	1 (14%)	5 (10%)	5 (25%)	13 (12%)
Anxiety	5 (17%)	4 (57%)	16 (33%)	5 (25%)	30 (29%)
Depression	4 (14%)	4 (57%)	15 (31%)	4 (20%)	27 (26%)
Other psychiatric illness	3 (10%)	0 (0%)	1 (2%)	0 (0%)	4 (4%)

3.3.4 | Tremor frequency

Of 105 individuals, 5 individuals had measures of VT frequency; acoustic measures were documented for 1 individual each with ET (2-4 Hz) and DT (4-5 Hz), and 3 individuals with IVT (4-10 Hz) (N = 7).

3.4 | VT clinical assessment patterns by discipline

The clinical patterns of VT care based on symptoms and discipline-specific encounters are summarized in Table 7.

3.4.1 | Primary complaint at initial encounter

Voice was the primary complaint during the first clinic visit in 61 patients (58%); extremity tremor was the primary complaint in 38 patients (36%). The majority of individuals classified as IVT (80%) and DT (83%) reported their voice as a primary concern compared to 41% of those with ET and 14% of those with PD. In addition, VT was documented in eight patients (8%) listing primary complaints other than tremor such as cough, dysphagia, weakness, or various gait or movement disorders. Those classified with PD primarily expressed concern about symptoms affecting their extremities (57%) as did those with ET (57%).

TABLE 6 VT nasoendoscopy clinical features of body distribution, symmetry, and condition by tremor category

Dystonia (DT) (N = 22)												
							Condition					
	Body distribution			Symmetry			Respiration			Speech		
Speech structure	Present	Absent	Unknown	Unilateral	Bilateral	Unknown	Present	Absent	Unknown	Present	Absent	Unknown
Larynx	21 (95%)	0 (0%)	1 (5%)	0 (0%)	7 (32%)	15 (68%)	4 (18%)	4 (18%)	14 (64%)	19 (86%)	0 (0%)	3 (14%)
Pharynx	11 (50%)	4 (18%)	7 (32%)	0 (0%)	6 (27%)	16 (73%)	0 (0%)	0 (0%)	22 (100%)	9 (41%)	0 (0%)	13 (59%)
Palate	16 (73%)	0 (0%)	6 (27%)	0 (0%)	6 (27%)	16 (73%)	2 (9%)	1 (5%)	19 (86%)	12 (55%)	0 (0%)	10 (45%)
Tongue	7 (32%)	6 (27%)	9 (41%)	0 (0%)	2 (9%)	20 (91%)	0 (0%)	1 (5%)	21 (95%)	4 (18%)	0 (0%)	18 (82%)
Face	1 (5%)	9 (41%)	12 (55%)	0 (0%)	9 (41%)	13 (59%)	0 (0%)	0 (0%)	22 (100%)	0 (0%)	0 (0%)	22 (100%)
Jaw	2 (9%)	2 (9%)	18 (82%)	0 (0%)	0 (0%)	22 (100%)	0 (0%)	0 (0%)	22 (100%)	0 (0%)	0 (0%)	22 (100%)
Parkinson's disease (PD) (N = 5)												
							Condition					
	Body distribution			Symmetry			Respiration			Speech		
Speech structure	Present	Absent	Unknown	Unilateral	Bilateral	Unknown	Present	Absent	Unknown	Present	Absent	Unknown
Larynx	5 (100%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	5 (100%)	1 (20%)	0 (0%)	4 (80%)	2 (40%)	0 (0%)	3 (60%)
Pharynx	1 (20%)	0 (0%)	4 (80%)	0 (0%)	1 (20%)	4 (80%)	0 (0%)	0 (0%)	5 (100%)	1 (20%)	0 (0%)	4 (80%)
Palate	2 (40%)	0 (0%)	3 (60%)	0 (0%)	1 (20%)	4 (80%)	1 (20%)	0 (0%)	4 (80%)	2 (40%)	0 (0%)	3 (60%)
Tongue	1 (20%)	2 (40%)	2 (40%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	5 (100%)
Face	0 (0%)	2 (40%)	3 (60%)	0 (0%)	0 (0%)	3 (60%)	0 (0%)	0 (0%)	3 (60%)	0 (0%)	0 (0%)	5 (100%)
Jaw	0 (0%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	0 (0%)	5 (100%)
Essential tremor (ET) (N = 25)												
							Condition					
	Body distribution			Symmetry			Respiration			Speech		
Speech structure	Present	Absent	Unknown	Unilateral	Bilateral	Unknown	Present	Absent	Unknown	Present	Absent	Unknown
Larynx	25 (100%)	0 (0%)	0 (0%)	0 (0%)	11 (44%)	14 (56%)	7 (28%)	3 (12%)	15 (60%)	23 (92%)	0 (0%)	2 (8%)
Pharynx	18 (72%)	4 (16%)	3 (12%)	0 (0%)	11 (44%)	14 (56%)	3 (12%)	1 (4%)	21 (84%)	14 (56%)	0 (0%)	11 (44%)
Palate	18 (72%)	4 (16%)	3 (12%)	0 (0%)	7 (28%)	18 (72%)	5 (20%)	2 (8%)	18 (72%)	15 (60%)	0 (0%)	10 (40%)
Tongue	4 (16%)	16 (64%)	5 (20%)	0 (0%)	2 (8%)	23 (92%)	2 (8%)	0 (0%)	23 (92%)	1 (4%)	0 (0%)	24 (96%)
Face	4 (16%)	15 (60%)	6 (24%)	0 (0%)	11 (44%)	14 (56%)	2 (8%)	0 (0%)	23 (92%)	1 (4%)	0 (0%)	24 (96%)
Jaw	9 (36%)	2 (8%)	14 (56%)	0 (0%)	2 (8%)	23 (92%)	2 (8%)	0 (0%)	23 (92%)	2 (8%)	0 (0%)	23 (92%)

TABLE 6 (Continued)

Isolated vocal tremor (IVT) (N = 20)										
	Body distribution			Symmetry			Condition			
							Respiration		Speech	
Speech structure	Present	Absent	Unknown	Unilateral	Bilateral	Unknown	Present	Absent	Unknown	Present	Absent	Unknown
Larynx	19 (95%)	0 (0%)	1 (5%)	1 (5%)	5 (25%)	14 (70%)	10 (50%)	1 (5%)	9 (45%)	16 (80%)	0 (0%)	4 (20%)
Pharynx	9 (45%)	7 (35%)	4 (20%)	0 (0%)	6 (30%)	14 (70%)	2 (10%)	0 (0%)	18 (90%)	6 (30%)	0 (0%)	14 (70%)
Palate	10 (50%)	5 (25%)	5 (25%)	0 (0%)	7 (35%)	13 (65%)	2 (10%)	0 (0%)	18 (90%)	10 (50%)	0 (0%)	10 (50%)
Tongue	3 (15%)	8 (40%)	9 (45%)	0 (0%)	2 (10%)	18 (90%)	2 (10%)	0 (0%)	18 (90%)	1 (5%)	0 (0%)	19 (95%)
Face	1 (5%)	9 (45%)	10 (50%)	0 (0%)	9 (45%)	11 (55%)	1 (5%)	0 (0%)	19 (95%)	0 (0%)	0 (0%)	20 (100%)
Jaw	1 (5%)	3 (15%)	16 (80%)	0 (0%)	0 (0%)	20 (100%)	0 (0%)	0 (0%)	20 (100%)	1 (5%)	0 (0%)	19 (95%)

3.4.2 | Initial evaluation by discipline

The initial evaluation was documented by otolaryngology (OTO) and/or speech-language pathology (SLP) for 69 patients (66%), neurology in 33 patients (31%), or another specialty in 3 patients (3%). Those classified with DT and IVT most commonly saw OTO or SLP first (90% and 100%), respectively. Those classified with PD presented first to neurology (86%) whereas those classified with ET presented either to OTO/SLP (45%) or neurology (49%) at nearly equal rates and corresponding with their primary complaint of voice (OTO/SLP) versus extremity tremor, or other movement disorder (neurology).

3.4.3 | Disciplines involved in care over time

The majority of individuals with VT were evaluated/treated by OTO (73%), SLP (70%), and neurology (63%). A smaller proportion was seen by psychiatry/neuropsychiatry (21%) and neuro-ophthalmology (4%). Nearly 100% of those classified as IVT and ~80% of those with DT were seen by OTO/SLP whereas the majority of those with ET (86%) and PD (100%) saw neurology compared to OTO (~50%). Those with PD were seen by SLPs 71% of the time compared to ~50% of those with ET.

3.5 | Treatment patterns

3.5.1 | Pharmaceutical

Medications were trialed in 59% of all participants (see Table 7). As shown in Figure 7, all individuals classified as PD were prescribed Parkinsonism medications. A small proportion of those with ET (22%) also trialed these medications. Beta blockers and anticonvulsants were the next most common class of medication prescribed to those in the ET (71% and 69%, respectively) and DT (24% for both) groups. A small proportion of each VT group was prescribed a benzodiazepine (5%-22%) or medications for depression, anxiety, etc. (5%-29%).

3.5.2 | Procedural/surgical treatment

Procedural or surgical intervention was trialed in 61 (58%) of participants (see Table 7). As shown in Figure 8, botulinum toxin (Botox) was used to treat 83% of those classified as DT, 35% with ET (35%), and 30% with IVT. Other surgical treatments included unilateral or bilateral deep brain stimulation (DBS) in the DT, PD, and ET groups (3%-14%) and focused ultrasound (FUS) treatment for those in the ET group (16%). Outcomes specific to VT were not documented for these therapies.

3.5.3 | Behavioral treatment

Behavioral treatment was completed in 34% of participants. The majority receiving behavioral treatment were classified as IVT (65%)

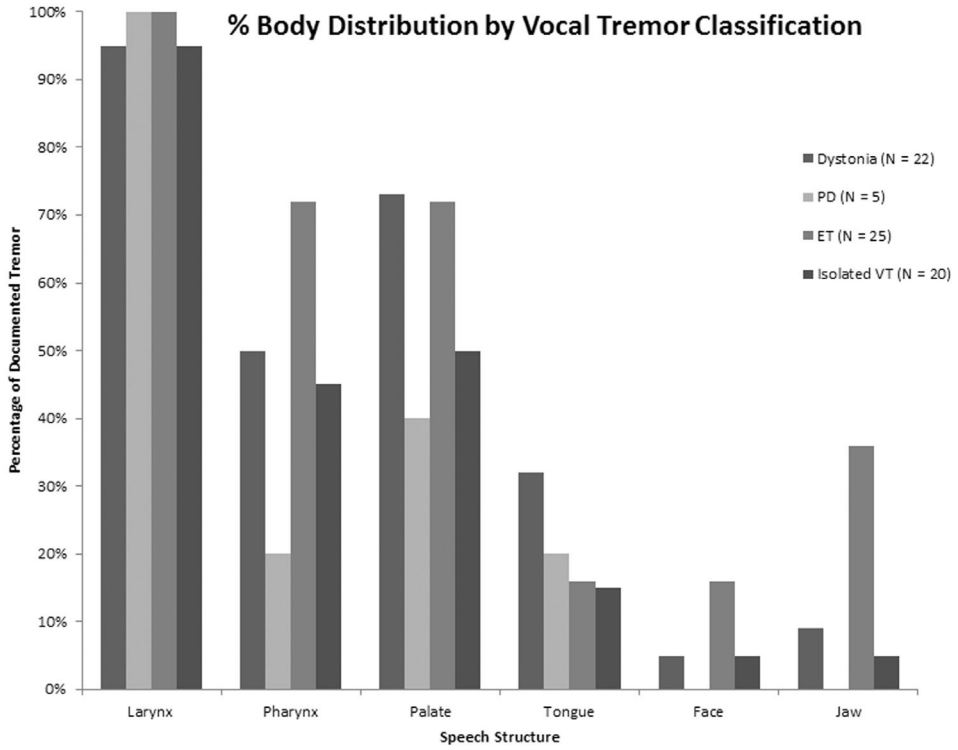


FIGURE 5 Body distribution of tremor across speech structures by classification

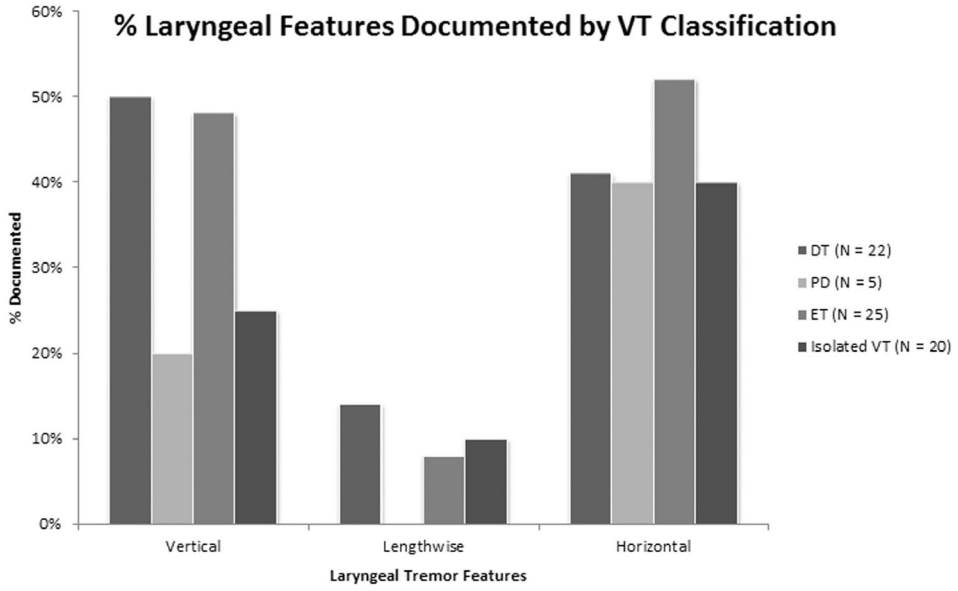


FIGURE 6 Laryngeal tremor features by VT classification

whereas 1/3 or less of the other groups received behavioral treatment.

4 | DISCUSSION

This is the first study to systematically evaluate VT clinical features using combined IPMDS and AAO-HNS tremor classification criteria. The findings of this study offer important insights regarding VT clinical features for classification in addition to clinician assessment, documentation, and treatment patterns to inform future clinical practice and research patterns.

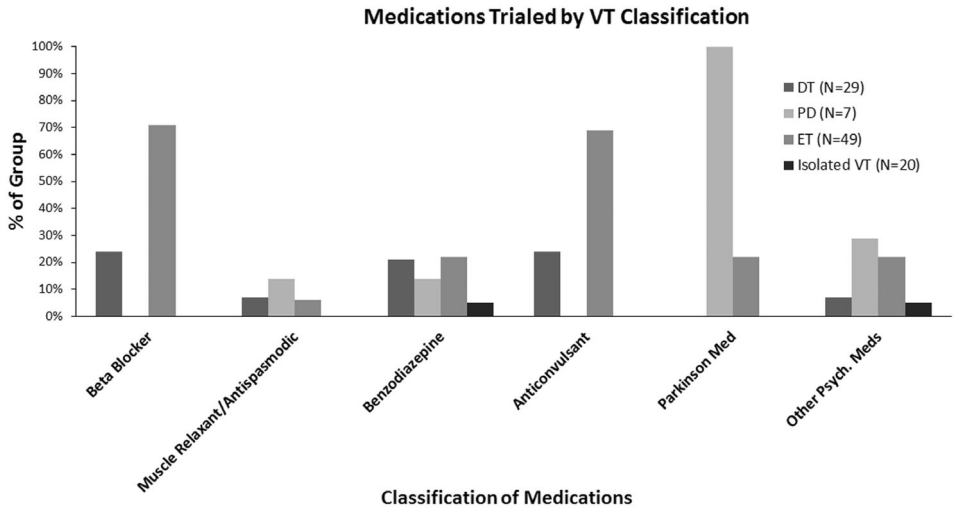
4.1 | VT documentation challenges

Notable limitations in the systematic data extraction from this regional medical center's EMR documentation elucidate inconsistencies in clinical practice and documentation patterns across disciplines that likely can be generalized to other clinic sites/regions. One third of the total

TABLE 7 Vocal tremor classifications and discipline-specific assessment and treatment patterns

Characteristic	Tremor classification				
	Dystonia N = 29	Parkinson's disease N = 7	Essential tremor N = 49	Isolated vocal tremor N = 20	Total N = 105
Primary complaint at first visit					
Voice	24 (83%)	1 (14%)	20 (41%)	16 (80%)	61 (58%)
Extremity tremor	6 (14%)	4 (57%)	28 (57%)	0 (0%)	38 (36%)
Other	1 (3%)	2 (29%)	1 (2%)	4 (20%)	8 (8%)
First specialty to assess tremor (%)					
OTO ± SLP	26 (90%)	1 (14%)	22 (45%)	20 (100%)	69 (66%)
Neurology	3 (10%)	6 (86%)	24 (49%)	0 (0%)	33 (31%)
Other	0 (0%)	0 (0%)	3 (6%)	0 (0%)	3 (3%)
All disciplines seen (%)					
OTO	26 (90%)	4 (57%)	28 (57%)	19 (95%)	77 (73%)
SLP	23 (79%)	5 (71%)	26 (53%)	19 (95%)	73 (70%)
Neurology	14 (48%)	7 (100%)	42 (86%)	3 (15%)	66 (63%)
Psych	2 (7%)	3 (43%)	15 (31%)	2 (10%)	22 (21%)
Medication trial (%)					
Yes	11 (38%)	7 (100%)	42 (86%)	2 (10%)	62 (59%)
No	15 (52%)	0 (0%)	7 (14%)	18 (90%)	40 (38%)
Speech therapy trial (%)					
Yes	10 (34%)	2 (29%)	11 (22%)	13 (65%)	36 (34%)
No	17 (59%)	5 (71%)	37 (76%)	7 (35%)	66 (63%)
Procedure/surgery trial (%)					
Yes	24 (83%)	2 (29%)	29 (59%)	6 (30%)	61 (58%)
No	5 (17%)	5 (71%)	19 (39%)	14 (70%)	43 (41%)

FIGURE 7 Medications prescribed by VT classification



number of participants could not be classified due to inadequate documentation of VT clinical features. This is likely due to less than half of all participants undergoing VT evaluation using nasoendoscopy. In addition, interpretation of nasoendoscopy exams was limited by the absence of both positive and negative findings from OTO and SLP disciplines regarding body distribution, condition of tremor, and symmetry. Consequently, half of all patients in the DT, ET, and PD groups were classified based on comorbidities rather than VT clinical features.

The likelihood that these documentation patterns generalize to other OTO and SLP clinicians is probable given that there is no accepted standard practice of VT assessment and the current VT

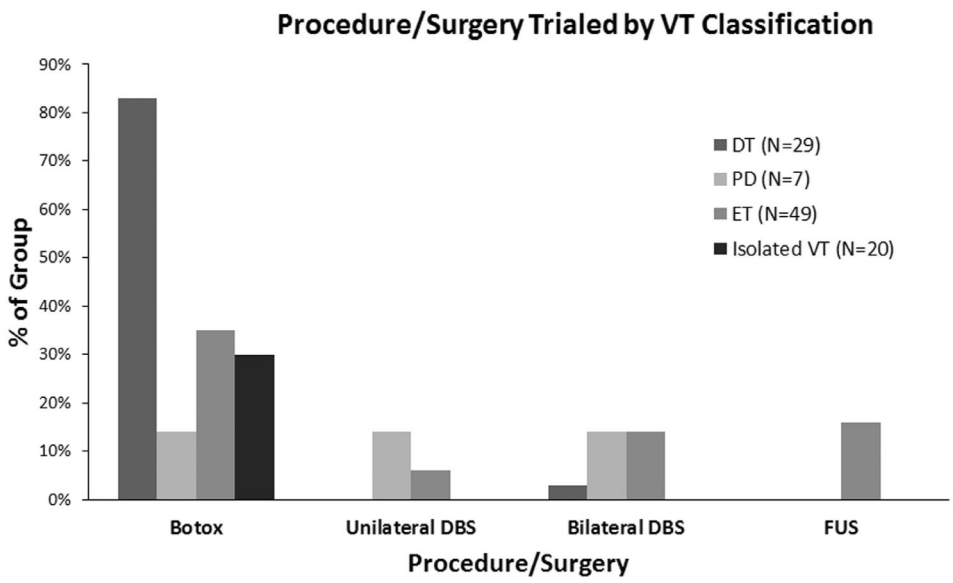


FIGURE 8 Procedure and surgical treatments trialed by VT classification

literature identifies few clinical features necessary for VT classification.[6,9,11,12] The only published vocal tremor scoring system evaluates tremor presence/absence and severity for each of the visible pharyngeal structures during nasoendoscopy.[11] In contrast, neurology clinicians evidenced consistent clinical assessment and documentation patterns of tremor. Unfortunately, participants evaluated solely by neurology did not complete imaging of upper airway structures critical to document speech structure contributions to VT. These findings underline the importance of multi-disciplinary assessment of VT by OTO, SLP, and neurology to assure that all relevant features, including the extremities, are assessed and documented for VT classification.

4.2 | VT clinical features

On average, females comprised the majority of those with VT. The only category where this was not the case was for those classified as ET in which nearly equal representation of males and females occurred. This was contrary to previously published findings for essential VT (EVT).[9,10] However, prior findings for EVT included those separately classified in this study as IVT. Those with IVT in this study exhibited a higher proportion of females similar to the DT and PD groups. The ET group showed similar male-to-female ratios as reported in the literature for ET, in general.[13-18] The IVT group was also older at onset of their tremor than the ET group by ~10 years, on average. Currently, the OTO and SLP disciplines consider IVT to be a clinical variant of ET[6-9,19] whereas the IPDMS did not find adequate evidence in the literature to combine these two groups.[5] Our findings suggest that separate classification of those with VT into IVT and ET groups is warranted until adequate evidence accumulates to support IVT as a clinical variant of ET.

Not surprisingly, the first site of tremor was commonly reported to affect extremities in those classified as ET and PD. In contrast, those classified as DT and IVT reported voice as the first site of tremor. Nearly all of those in the ET and PD groups reported progression of their tremor symptoms over time as did half of the DT group and 1/3 of those in the IVT. This finding suggests that tremor affecting extremities is more likely to progress than tremor predominantly affecting speech structures.

Laryngeal tremor was identified for all VT categories. Body distribution was best documented for the larynx, pharynx, and palate, although symmetry and condition of VT was poorly documented. Tremors of the pharynx and palate were most frequently documented in those with DT, ET, and IVT. PD also showed tremor of the palate, but the pharynx was not commonly documented. Tremor affecting the tongue, face, and jaw tremor was less frequently documented; however, it was unclear whether tremor was absent, or untested in these structures. The lack of documentation for body distribution points to the need for a systematic, multidisciplinary assessment.

On average, laryngeal tremor features were absent in over 68% of participants. When documented, unique laryngeal tremor features included consistent documentation of horizontal oscillation of the arytenoids across all VT groups with vertical oscillation mostly in those with DT and ET. IVT and PD also showed vertical oscillation in some participants; however, the AAO-HNS described vertical laryngeal tremor as a prominent feature of PD in contrast to our findings.[7] Lengthwise laryngeal tremor was less commonly documented across all VT groups.

Documentation of laryngeal tremor features may indicate optimal musculature for Botox treatment; horizontal oscillation supports treatment targeting interarytenoid musculature[20] whereas lengthwise oscillation supports injection of the thyroarytenoid (TA) musculature.[21] Vertical oscillation suggests benefit from treatment of extrinsic neck musculature.[22,23] Thus, documentation of this clinical feature is important for VT classification as well as Botox treatment planning.

Condition of tremor (ie, respiration vs speech observation) was infrequently reported resulting in difficulty judging task specificity. Task specificity is a critical clinical feature of DT in addition to

documentation of benefit from sensory tricks. The absence of documentation of these features required classification based on clinical findings of phoneme specificity with comorbid dystonia.[7] Reliance on auditory-perception of phoneme specificity of symptoms to classify DT is problematic given that VT can only be heard during voicing. Thus, VT is also best perceived during production of voiced phonemes. As such, classification of DT vs ET requires direct observation of upper airway structures during respiration and speech tasks and assessment of sensory tricks to distinguish these groups.

To classify those with VT, consistent clinical assessment of tremor affecting speech structures is needed to document positive and negative findings regarding body distribution, frequency, and condition. An example of such a speech structure tremor assessment tool is shared in the Appendix materials.

4.3 | VT and discipline-specific patterns

On average, the initial evaluation of VT was by OTO/SLP. Those classified as DT and IVT most commonly saw OTO/SLP disciplines first whereas those in the PD group saw the neurologist first. Those in the ET group were split between disciplines at the first visit corresponding to their primary complaint for voice or extremities. These findings suggest that PD and ET groups more commonly experience tremor first in their extremities.[5,18,24-26] Interestingly, voice was a primary issue for nearly half of the ET group; this may reflect that half experienced onset of tremor first in the voice, or were bothered by VT more than extremity tremor. Future investigation is needed to clarify this pattern.

4.4 | Treatment patterns

Treatment patterns differed by VT group. Overall, medication and procedure/surgery approaches were documented in approximately half of participants. Pharmaceutical treatment was most common in the PD and ET groups and in 40% of those in the DT group. The most common classes of medication prescribed for those with ET and DT included beta blockers and anticonvulsants whereas those with PD trialed Parkinsonism medications. DT and ET were most commonly recommended for procedure/surgical treatment with the most frequently used treatment being Botox injections. Speech treatment was documented in approximately 1/3 of the DT, ET, and PD groups in contrast to the majority of the IVT groups. Treatment outcomes specific to VT were not adequately documented for reporting and would be an important aspect for future investigation relative to VT groups and associated clinical features.

4.5 | Study limitations

The outcomes of this study relied on the accuracy of electronic medical record documentation to extract and characterize clinical features of those identified with vocal tremor for classification. None of the participants underwent additional clinical testing to substantiate the accuracy of documented features. Future clinical research is necessary to address missing medical record documentation of vocal tremor clinical features as well as to evaluate replicability of this study's findings.

5 | CONCLUSION

Clinical features of VT critical for classification were often absent from EMR documentation resulting in frequent classification by comorbidity, or inability to classify participants. Body distribution was commonly documented demonstrating VT most commonly affected the larynx for all groups; however, the pharynx and palate were also frequently affected whereas tongue, jaw, and face were less commonly documented. Several novel demographic findings between VT groups were found. To classify VT groups, multidisciplinary evaluation by OTO, SLP, and neurology is recommended, including consistent assessment of positive and negative findings for body distribution, frequency, and condition of tremor patterns affecting speech structures.

ACKNOWLEDGMENTS

This project was partially funded by R01DC016838 (PI: Barkmeier-Kraemer), "Physiologic correlates of vocal tremor affecting those with essential tremor."

CONFLICT OF INTEREST

V. T. has no conflicts of interest to disclose. K. D. is currently employed as a University of Utah pre-doctoral student on R01DC016838. J. B.-K. is the PI of R01DC016838 that partially supported this project; she also receives royalties from MedBridge for online courses on the topic of vocal tremor assessment and treatment. Nonfinancial conflicts include service as a scientific advisory member for the NSDA and membership in ASHA and ASHA's Special Interest Group on voice and upper airway disorders.

ORCID

Vanessa Torrecillas https://orcid.org/0000-0003-3430-9877
Julie M. Barkmeier-Kraemer https://orcid.org/0000-0002-5037-3070

BIBLIOGRAPHY

1. Hogikyan ND, Sethuraman G. Validation of an instrument to measure voice-related quality of life (V-RQOL). *J Voice*. 1999;13(4):557-569.
2. Cohen SM. Self-reported impact of dysphonia in a primary care population: an epidemiological study. *Laryngoscope*. 2010;120(10):2022-2032.
3. Verdonck-de Leeuw IM, Mahieu HF. Vocal aging and the impact on daily life: a longitudinal study. *J Voice*. 2004;18(2):193-202.
4. Woodson G. Management of neurologic disorders of the larynx. *Ann Otol Rhinol Laryngol*. 2008;117(5):317-326.
5. Bhatia KP, Bain P, Bajaj N, et al. Consensus statement on the classification of tremors. From the task force on tremor of the International Parkinson and Movement Disorder Society. *Mov Disord*. 2018;33(1):75-87.

6. Barkmeier-Kraemer JM. Isolated voice tremor: a clinical variant of essential tremor or a distinct clinical phenotype? *Tremor Other Hyperkinet Mov (N Y)*. 2020;10. https://doi.org/10.7916/tohm.v0.738.
7. Merati AL, Heman-Ackah YD, Abaza M, Altman KW, Sulica L, Belamowicz S. Common movement disorders affecting the larynx: a report from the neurolaryngology committee of the AAO-HNS. *Otolaryngol Head Neck Surg*. 2005;133(5):654-665.
8. Patel A, Frucht SJ. Isolated vocal tremor as a focal phenotype of essential tremor: a retrospective case review. *J Clin Mov Disord*. 2015;2:1-5.
9. Sulica L, Louis ED. Clinical characteristics of essential voice tremor: a study of 34 cases. *Laryngoscope*. 2010;120(3):516-528.
10. Massey EW, Paulson GW. Essential vocal tremor: clinical characteristics and response to therapy. *South Med J*. 1985;78(3):316-317.
11. Bove M, Daamen N, Rosen C, Wang CC, Sulica L, Gartner-Schmidt J. Development and validation of the vocal tremor scoring system. *Laryngoscope*. 2006;116(9):1662-1667.
12. Ludlow CL, Domangue R, Sharma D, et al. Consensus-based attributes for identifying patients with spasmodic dysphonia and other voice disorders. *JAMA Otolaryngol Head Neck Surg*. 2018;144(8):657-665.
13. Elble RJ. The essential tremor syndromes. *Curr Opin Neurol*. 2016;29(4):507-512.
14. Govert F, Deuschl G. Tremor entities and their classification: an update. *Curr Opin Neurol*. 2015;28(4):393-399.
15. Louis ED. Diagnosis and management of tremor. *Continuum (Minneap Minn)*. 2016;22(4):1143-1158.
16. Louis ED. Essential tremor: a nuanced approach to the clinical features. *Pract Neurol*. 2019;19(5):389-398.
17. Louis ED, Ottman R. How many people in the USA have essential tremor? Deriving a population estimate based on epidemiological data. *Tremor Other Hyperkinet Mov (N Y)*. 2014;4:259.
18. Romero JP, Benito-León J, Bermejo-Pareja F. The NEDICES study: recent advances in the understanding of the epidemiology of essential tremor. *Tremor Other Hyperkinet Mov (N Y)*. 2012;2. https://doi.org/10.7916/D8N58K4H.
19. Orbelo DM, Duffy JR, Hughes Borst BJ, Ekbom D, Maragos NE. Differences in botulinum toxin dosing between patients with adductor spasmodic dysphonia and essential voice tremor. *J Voice*. 2014;28(1):123-127.
20. Kendall KA, Leonard RJ. Interarytenoid muscle botox injection for treatment of adductor spasmodic dysphonia with vocal tremor. *J Voice*. 2011;25(1):114-119.
21. Blitzer A, Brin MF, Stewart CF. Botulinum toxin management of spasmodic dysphonia (laryngeal dystonia): a 12-year experience in more than 900 patients. *Laryngoscope*. 2015;125(8):1751-1757.
22. Nelson RC, Silva Merea V, Tierney WS, Milstein C, Benninger MS, Bryson PC. Laryngeal botulinum toxin injection for vocal tremor: utility of concurrent strap muscle injection. *Laryngoscope*. 2019;129(6):1433-1437.
23. Gurey LE, Sinclair CF, Blitzer A. A new paradigm for the management of essential vocal tremor with botulinum toxin. *Laryngoscope*. 2013;123(10):2497-2501.
24. Armstrong MJ, Okun MS. Diagnosis and treatment of Parkinson disease: a review. *JAMA*. 2020;323(6):548-560.
25. Gigante AF, Pellicciari R, Iliceto G, et al. Rest tremor in Parkinson's disease: body distribution and time of appearance. *J Neurol Sci*. 2017;375:215-219.
26. Pasquini J, Ceravolo R, Qamhawi Z, et al. Progression of tremor in early stages of Parkinson's disease: a clinical and neuroimaging study. *Brain*. 2018;141(3):811-821.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Torrecillas V, Dwenger K, Barkmeier-Kraemer JM. Classification of vocal tremor using updated consensus-based tremor classification criteria. *Laryngoscope Investigative Otolaryngology*. 2021;6:261–276. https://doi.org/10.1002/lio2.544