Clinical Neurophysiology Practice 7 (2022) 49–50

Contents lists available at ScienceDirect

Clinical Neurophysiology Practice

journal homepage: www.elsevier.com/locate/cnp

Editorial

Emerging role of clinical neurophysiology in the diagnosis of movement disorders

The critical first step for clinical diagnostic approach for movement disorders involves identification and correct classification of a movement disorder based on phenomenology into a discrete number of categories such as tremor, jerk-like movements/myoclonus, dystonia, Parkinsonism, etc. Combined with the phenomenology and other clinical characteristics the movement disorder is initially given an axis I classification. The subsequent workup for etiological or axis II classification is guided and reliant on this critical first step. It is increasingly being recognized that there are several overlaps in this clinical classification schema and there has been a progressive change towards adopting a transdiagnostic approach, acknowledging the phenotypic and pathophysiologic differences within the different movement disorder categories. However, there are several limitations to change the current clinical practice, based solely on clinical examination.

Everlo et al. (2022) in the current edition of *Clinical Neurophysiology Practice* share the clinical experience of a large movement disorders tertiary care center, which highlights several limitations of the clinical approach and makes a compelling argument for the role of electrophysiological diagnostic aids to supplement the clinical practice of movement disorders. Using a combination of clinical examination and systematic clinical neurophysiological approach, the authors note revisions and changes between the clinical diagnostic categories of tremor and jerk-like movements/myoclonus in 37% of patients. It is important to note that their institution is world renowned for their expertise in the clinical care and research in hyperkinetic movement disorders and as such it is highly plausible that misclassification rates could be much higher in the community settings and general neurologists with limited expertise. It is indeed well known that Essential tremor (ET), one of the most common movement disorders seen in clinical practice is commonly misdiagnosed (Schrag et al., 2000; Jain et al., 2006; Iglesias-Hernandez et al., 2021). The current study being a retrospective investigation has some limitations (as also highlighted by the authors), with need for systematic prospective studies; however, the results are reliant on a large dataset ($n = 773$) and systematic diagnostic approach. I would like to highlight some limitations of the current clinical classification of the categories of tremor and jerk-like movements/myoclonus and briefly discuss the emerging role of clinical neurophysiology as an important diagnostic tool for the correct classification of these disorders. I will also discuss the current limitations which have stymied the progress and more widespread utilization of diagnostic clinical neurophysiology in the practice of movement disorders with some suggestions and efforts underway to improve its use in the future.

Myoclonus has been defined as a sudden, brief, shock-like or jerk-like movement (Caviness and Brown, 2004). The different adjectives used to describe this category of movement disorder can have different subjective interpretations. Several movements disorders such as chorea, tic disorders, dystonia, ballism, functional movements, have jerk-like phenomenology. Repetitive jerk-like movements especially at higher frequencies can be misconstrued as tremors. Furthermore, myoclonus can co-exist with other movement disorders such as dystonia or tremor disorders. Several of these clinical challenges are highlighted in this retrospective experience by Everlo et al. However, the electrophysiological definitions of these different categories of myoclonus are well defined and can be distinguished using electrophysiology (Everlo et al., 2022; Shibasaki and Hallett, 2005; Merchant et al., 2020). Electrophysiology, besides aiding the clinical diagnosis can also help localize the source of myoclonus within the nervous system, with important pathophysiological and treatment implications (Merchant et al., 2020). The diagnostic approach aided by electrophysiology can provide objective categorization of these complex disorders using a systematic approach and some simplistic diagnostic algorithms have been proposed to easily incorporate them into clinical practice (Everlo et al., 2022; Zutt et al., 2015; Zutt et al., 2018; Merchant et al., 2020).

Tremors are defined as rhythmic, oscillatory movements around a joint involving different body regions. Clinical assessment and descriptive classification (axis I) of tremor involves identifying the phenomenology and activation patterns, such as presence at rest, postural-kinetic, intentional, etc. Tremors can occur as an isolated movement disorder such as 'ET syndrome' or can occur with other movement disorders such as Parkinsonism, dystonias, etc. Arhythmic jerky movements as those noted in dystonia, cortical tremor and palatal tremor can be misconstrued and are also misclassified as tremors. There is phenotypic heterogeneity even within the defined categories of tremors, which has been emphasized in the revised consensus criteria on tremor classification by the International Parkinson and Movement Disorder Society (IPMDS) (Bhatia et al., 2018). The revised classification proposes a transdiagnostic approach towards axis I classification of tremors and introduced the term 'ET-plus' to acknowledge atypical features

☆ DOI of original article: https://doi.org/10.1016/j.cnp.2021.12.002

https://doi.org/10.1016/j.cnp.2022.01.003

and co-existence of other movement disorders in ET. The proposal has met with a lot of controversy and disagreements for many reasons, but it also introduces more complexity in the clinical diagnosis and categorization of an entity with baseline high rates of clinical misdiagnosis (Schrag et al., 2000; Jain et al., 2006; Iglesias-Hernandez et al., 2021). Tremor analysis provides objective, reproducible and reliable information about tremors and can provide useful pathophysiologic insights to guide treatment (Vial et al., 2019). Tremors can be driven by different oscillators and more than one type of tremor can co-exist in an individual. Correct diagnosis of tremor syndromes such as enhanced physiologic tremor and orthostatic tremors is based on physiologic criteria (Hassan and van Gerpen, 2016; Vial et al., 2019). Co-existence of tremor with other movement disorders such as myoclonus, dystonia is very well known and also highlighted in their paper by Everlo et al. (2022), Bhatia et al. (2018), Merchant et al. (2018), Vial et al. (2019). Utility of tremor analysis is very well established and validated for the diagnosis of functional tremors (Schwingenschuh et al., 2016).

The limitations of clinical approach and utility of electrophysiology as a useful aid in the clinical practice of movement disorders has been increasingly recognized, though its utilization has been limited. Several inter-related factors have stymied the progress on this front which need to be addressed in aggregate. Diagnostic testing for movement disorders requires a combination of EMG and EEG equipment to objectively characterize a movement disorder, which can be easily performed in an outpatient setting. However, there is very limited training in CN as part of movement disorders fellowship and it is indeed not uncommon for trainees to have no exposure in the utilization of these techniques. Similarly, though CN fellowship involves training in both EMG and EEG techniques, it is mainly limited to neuromuscular disorders and epilepsy. Currently CN testing for movement disorders is not covered by health insurance in regions such as USA, which serves as a major deterrent for private and even academic institutions to offer these tests. Having no incentive to perform these tests further dampens enthusiasm for education and training. All these reasons have resulted in lack of interest in developing standardized techniques and limited industry incentive to develop standardized equipment for performance, analysis, and interpretation of these tests. Most current institutions which offer such testing rely on research equipment which offers the required flexibility to perform testing.

There is growing interest on this subject and efforts ongoing for more widespread utilization of clinical neurophysiology for objective and correct categorization of movement disorders, to improve patient care. A task force on Clinical Neurophysiology has been appointed by the IPMDS to address these challenges using a global collaboration and consensus. Movement CN utilizes techniques spanning across different neurophysiologic domains and the International Federation of Clinical Neurophysiology (IFCN) could play a pivotal role to help in this endeavor to improve clinical care of movement disorders patients. Using an international collaboration, different challenges such as lack of education, training, resources, lack of reimbursement schemes, etc. need to be identified for the different regions across the globe. There is a need for recognizing the current state and appraise the current literature and evidence for different diagnostic CN testing tools for different movement disorder categories. A consensus on standardized methodologies for performing CN testing and defining electrophysiologic criteria for diagnosis of different movement disorder syndromes with prospective validation, will help establish the clear utility of CN testing for movement disorders. Several of these efforts are currently underway through the Task force on CN and have received enthusiastic global support. There is a lot of synergy and potential for collaborative efforts between IPMDS and IFCN in this endeavor for promoting education and improving clinical care of patients with movement disorders.

Funding sources

None.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Received 8 January 2022
Received in revised form 17 January 2022
Accepted 20 January 2022

Available online 29 January 2022