Manual Quantitative Assessment of Amplitude and Sleep Stage Distribution of Excessive Fragmentary Myoclonus

Romy Hoque, M.D.; David E. McCarty, M.D.; Andrew L. Chesson Jr., M.D., F.A.A.S.M.

Department of Neurology, Division of Sleep Medicine, Louisiana State University School of Medicine, Shreveport, LA

Introduction: Excessive fragmentary myoclonus (EFM) consists of brief, asynchronous, twitch-like movements appearing asymmetrically in sleep. The new AASM *Manual for the Scoring of Sleep and Associated Events* identifies some EFM scoring criteria but does not provide amplitude criteria for scoring EFM. Older observational series have used 50 μ Vs. We report data from various amplitude criteria using blinded comparisons.

Methods: EFMs were analyzed on the polysomnograms of 8 patients (7 men and 1 woman, mean age 57 years, range: 47-79) using a standardized protocol for sensitivity, tonus threshold, impedance, amplitude measurements, and sleep stage. The first 20 minutes each of wake, Stage 1-2, SWS, and REM were analyzed. EFMs ≥ 25 , ≥ 40 , and ≥ 50 microvolts (μ Vs) in negative deflection above the baseline were counted in tibialis anterior muscle electromyography (EMG) channels bilaterally.

Results: The mean EFM Index per minute for wake, regardless of impedance, was: 7.19 ± 5.90 for ≥ 25 μ V amplitude; 2.43 ± 2.02 for ≥ 40 μ Vs; and 2.08 ± 2.23 for ≥ 50 μ Vs. For

sleep stages, the EFM index by stage and amplitude criteria used for measurements were: Stage 1-2: 7.38 ± 5.79 for ≥ 25 μ Vs; 3.13 ± 3.33 for ≥ 40 μ Vs; and 2.36 ± 2.66 for ≥ 50 μ Vs; SWS: 10.05 ± 8.04 for ≥ 25 μ Vs; 2.71 ± 3.13 for ≥ 40 μ Vs; and 1.38 ± 1.92 for ≥ 50 μ Vs; Total REM: 15.96 ± 11.32 for ≥ 25 μ Vs; 6.32 ± 4.25 for ≥ 40 μ Vs; and 3.94 ± 3.73 for ≥ 50 μ Vs; Phasic REM: 19.69 ± 15.45 for ≥ 25 μ Vs; 8.63 ± 7.06 for ≥ 40 μ Vs; and 5.52 ± 6.44 for ≥ 50 μ Vs; Non-phasic REM: 13.93 ± 11.31 for ≥ 25 μ Vs; 5.16 ± 3.57 for ≥ 40 μ Vs; and 3.20 ± 2.92 for ≥ 50 μ Vs.

Conclusion: EFM rates increase with SWS and total REM with the highest EFM rates occurring during phasic REM. EFM rates were increased across all sleep stages when impedance was > 30 K Ω .

Keywords: Excessive fragmentary myoclonus, amplitude criteria, sleep stage

Citation: Hoque R; McCarty DE; Chesson Jr AL. Manual quantitative assessment of amplitude and sleep stage distribution of excessive fragmentary Myoclonus. *J Clin Sleep Med* 2013;9(1):39-45.

Excessive fragmentary myoclonus (EFM) was first described by Dagnino et al. in an observational study of 18 patients.¹ In the 2007 American Academy of Sleep Medicine (AASM) *Scoring Manual for Sleep and Associated Events*, EFM is described as a benign movement phenomenon.² The characteristic electromyogram (EMG) pattern for recommended scoring is burst duration of 150 msec, presence in at least 20 minutes of NREM sleep, and a rate of 5 EMG EFM potentials per minute. The AASM scoring manual does not address sleep stage distribution of EFM or define amplitude criteria for scoring. Older observational series used 50 microvolts (μ V).^{3,4}

This observational study was to assess functionality of use and identify potential enhancements to the AASM scoring manual EFM criteria that may aid sleep medicine clinicians, sleep medicine technologists, and clinical electrophysiologic research. Previous studies of EFMs have not used scoring manual criteria. In this study using the AASM scoring guidelines, we manually analyzed the polysomnograms (PSGs) of 8 consecutive patients with obvious EFM to assess EFM amplitude and sleep stage distribution. We also analyzed the effect of electrode impedance on EFM frequency.

BRIEF SUMMARY

Current Knowledge/Study Rationale: This observational study was to assess functionality of use and identify potential enhancements to the AASM scoring manual EFM criteria. We manually analyzed the PSGs of 8 consecutive patients with obvious EFM to assess: EFM amplitude; EFM sleep stage distribution; and impedance effect on EFM frequency.

Study Impact: Our proposed additions to the standardized AASM definition of EFM may allow for more extensive research into the physiologic and clinical associations of this phenomenon in the future.

METHODS

PSGs were acquired using the Alice Sleepware version 2.5.11 platform (Respironics, Murrysville, PA) according to the following the AASM scoring manual guidelines: left and right frontal, central and occipital electroencephalogram (EEG) leads referenced to the opposite ear; bilateral oculogram, submental EMG; bilateral tibialis anterior muscle electromyography (EMG); and cardiorespiratory recordings consisting of nasal pressure monitoring, nasal-oral thermistors, abdominal, and chest effort; pulse oximetry from the digit; and electrocardiogram. In accordance

Figure 1—Overlaid reference lines placed at 25 μ V and 50 μ V were used to make manual measurements of excessive fragmentary myoclonus potential amplitudes

Similar reference lines were used at 40 μ V.

with AASM scoring manual technical specifications, surface EMG electrodes were placed 2-3 cm apart longitudinally and symmetrically on the middle of the tibialis anterior muscles bilaterally. Both legs were monitored on separate channels.

This was an observational study of 8 consecutive patients collected over a 6-month period meeting scoring manual criteria for EFM on PSG. Scoring manual criteria for EFM requires ≥ 20 min of NREM sleep with recorded EFMs at a rate of ≥ 5 EMG EFM potentials per minute. In the scoring manual criteria for periodic limb movements in sleep (PLMS), a stable resting EMG in relaxed tibialis anterior muscle is defined as a deflection above baseline $< 5 \mu$ V. There are no such explicitly stated criteria for EFM in the scoring manual. The inclusion criterion for our study was that obvious EFMs were noted throughout the course of the night and the EMG rest amplitude at the start of the recording was $< 2 \mu$ V. In all 8 recordings evaluated, the end-of-night calibrations showed EMG rest amplitudes $< 2 \mu$ V. Leg movements clearly associated with sleep disordered breathing were excluded.

The scoring manual definition for PLMS defines the end of a LM event as a period lasting 0.5 seconds during which the EMG does not exceed 2μ V. There are no such explicitly stated criteria for EFM in the scoring manual. Minimal duration between individual EFM potential is also not defined in the AASM scoring manual. Scorers used a subjective determination of visual distinctiveness in determining individual EFM potentials.

Reflecting requirement of ≥ 20 min of NREM sleep with EFM in the scoring manual definition of EFM, the first scored 20 min each of wake, stage 1-2, slow wave sleep (SWS), and REM sleep were analyzed for each patient. EMG potentials of 150 msec were included in the manual analysis. The study designer and primary scorer (RH) is board certified in sleep medicine and was trained using the AASM scoring manual criteria by one of the manual's authors (AC). A similarly trained board certified secondary scorer's (DM) repeat scoring of three patient PSGs were assessed to determine reproducibility of the scoring method in polysomnograms with all 4 stages of sleep

(N1, N2, SWS, and REM). The κ statistic calculations were used to assess statistically significant differences between the 2 scorers. For the κ statistic, the p-value calculated was for testing the null hypothesis of no agreement; a p-value < 0.05 rejects the null hypothesis and indicates significant agreement between the 2 scorers.

The number of EMG potentials with amplitude above the baseline $\geq 25 \mu$ V, 40μ V, and 50μ V were counted for the first 20 min each of wake, NREM stage 1-2, SWS, and REM. Superimposed reference lines placed at 25μ V, 40μ V, and 50μ V were used to make these manual measurements (**Figure 1**). REM epochs were further analyzed by breaking down each epoch into phasic and non-phasic REM segments. Extraocular motion (EOM) was noted in the oculogram channels. The phasic-REM period was defined as starting with the first EOM in the series and ended 5 sec after the last EOM. REM that did not meet phasic criteria was designated as non-phasic REM.

Impedance was also assessed. The software platform used had an impedance cutoff for the leg EMG channels of $30 \text{ K}\Omega$. Each epoch was labeled as either having leg channel impedance $> 30 \text{ K}\Omega$ or $< 30 \text{ K}\Omega$. Epoch impedance was considered $> 30 \text{ K}\Omega$ if ≥ 15 sec of the epoch had an impedance value $\geq 30 \text{ K}\Omega$.

EFM rates were calculated using the following equation:

$$\text{EFM rate} = \frac{\text{Total number of EMG potentials} \leq 150 \text{ msec}}{\text{Total time in minutes for sleep stage}} \quad (\text{EFMs per minute})$$

EFM rates were calculated for wake, NREM stage 1-2, SWS, total REM, phasic REM, and non-phasic REM.

RESULTS

Demographics

Records of 8 consecutive patients with EFMs were collected over a 6-month period, reviewed to confirm the diagnosis of EFM by the scoring manual criteria, and evaluated (**Table 1**). Mean age was 57 years (range: 47–79); 7 patients were men. Wake and stage 1-2 were evaluated for 8/8 patients. SWS and/or REM were present in 7 of the 8 patients. Three recordings were successful positive airway pressure titration studies. Two recordings showed mild obstructive sleep apnea (OSA) with total sleep time (TST) respiratory disturbances indices (RDI) of 6.5 and 9, respectively. One recording showed moderate OSA with a TST RDI of 19.

Bilateral EFMs Regardless of Impedance

EFM rate for potentials $\geq 25 \mu$ V increased from wake into stage 1-2, SWS, and REM (**Table 2**). EFM rates progressively decreased in all stages with the utilization of higher amplitude criteria. Total REM, phasic REM, and non-phasic REM all had higher rates across all amplitude criteria. Phasic REM had a higher EFM rate across all amplitude criteria than either non-phasic REM or total REM.

Interestingly, with the 40μ V and the 50μ V amplitude criteria, EFMs occurred less often in SWS than wake, stages 1-2, and total REM.

Table 1—Demographics, comorbidity, medication, and polysomnography data

Patient, age, sex	Diagnostic RDI	Comorbidities	Medications	Sleep Stages		2° scorer	Final PSG Diagnosis
				REM	SWS		
1, 66, M	3.4	None	Amitriptyline	+	-	-	Normal
2, 47, M	NA	CHF, Atrial fibrillation, hypertension	Coumadin, furosemide, labetalol	+	+	+	Successful PAP titration
3, 53, M	0.5	Diabetes mellitus with neuropathy, Hypothyroid	Insulin, metformin, glipizide, levothyroxine	+	-	-	Normal
4, 51, M	9	None	None	+	+	+	Mild OSA
5, 47, M	19	Fibromyalgia, hypercholesterolemia	Fluoxetine, amitriptyline, piroxicam pravastatin	-	-	-	Moderate OSA
6, 79, F	NA	Hypertension	Atenolol, isosorbide mononitrate, aspirin	+	-	-	Successful PAP titration
7, 57, M	NA	Hypertension, Diabetes mellitus sin neuropathy, RLS	Hydrochlorothiazide, aspirin, metformin, hydrocodone-acetaminophen	+	-	-	Successful PAP titration
8, 58, M	6.5	None	None	+	+	+	Mild OSA

Three studies had both REM and SWS sleep and were scored by a secondary (2°) scorer. CHF: congestive heart failure. NA: not available. PAP: positive airway pressure titration. OSA, obstructive sleep apnea; PSG, polysomnogram; REM, rapid eye movement sleep; RDI, respiratory disturbance index (apnea, hypopneas, and respiratory effort related arousals per hour of sleep); RLS, restless legs syndrome; SWS, slow wave sleep.

Table 2—Excessive fragmentary myoclonus (EFM) rate data

Data	≥ 25 μ V	≥ 40 μ V	≥ 50 μ V
Bilateral lower extremity EFM in wake $\pm$ SD, independent of impedance	7.19 $\pm$ 5.90	2.43 $\pm$ 2.02	2.08 $\pm$ 2.23
Bilateral lower extremity EFM in stage 1-2 $\pm$ SD, independent of impedance	7.38 $\pm$ 5.79	3.13 $\pm$ 3.33	2.36 $\pm$ 2.66
Bilateral lower extremity EFM in SWS $\pm$ SD, independent of impedance	10.05 $\pm$ 8.04	2.71 $\pm$ 3.13	1.38 $\pm$ 1.92
Bilateral lower extremity EFM in Total REM $\pm$ SD, independent of impedance	15.96 $\pm$ 11.32	6.32 $\pm$ 4.25	3.94 $\pm$ 3.73
Bilateral lower extremity EFM in Phasic REM $\pm$ SD, independent of impedance	19.69 $\pm$ 15.45	8.63 $\pm$ 7.06	5.52 $\pm$ 6.44
Bilateral lower extremity EFM in Non-phasic REM $\pm$ SD, independent of impedance	13.93 $\pm$ 11.31	5.16 $\pm$ 3.57	3.20 $\pm$ 2.92
Bilateral EFM with impedance > 30 K Ω in wake	5.34 $\pm$ 5.31	2.24 $\pm$ 1.58	1.69 $\pm$ 1.36
Bilateral EFM with impedance > 30 K Ω in stage 1-2	6.00 $\pm$ 4.96	3.26 $\pm$ 2.73	3.50 $\pm$ 0.35
Bilateral EFM with impedance > 30 K Ω in SWS	NA	NA	NA
Bilateral EFM with impedance > 30 K Ω in Total REM (1 patient)	7.27	3.77	3.07
Bilateral EFM with impedance < 30 K Ω in wake	2.68 $\pm$ 1.72	0.82 $\pm$ 0.58	0.70 $\pm$ 0.96
Bilateral EFM with impedance < 30 K Ω in stage 1-2	3.26 $\pm$ 2.67	1.11 $\pm$ 1.11	0.93 $\pm$ 0.87
Bilateral EFM with impedance < 30 K Ω in SWS	4.11 $\pm$ 3.67	1.39 $\pm$ 1.47	0.80 $\pm$ 0.90
Bilateral EFM with impedance < 30 K Ω in Total REM	8.09 $\pm$ 6.19	3.05 $\pm$ 2.30	1.78 $\pm$ 1.97

NA, data not available; REM, rapid eye movement; SD, standard deviation; SWS, slow wave sleep.

Impedance Effects

Regardless of amplitude criteria, the mean EFM frequencies in wake and stage 1-2 and were higher in PSG epochs with impedance > 30 K Ω versus PSG epochs with impedance < 30 K Ω . In REM, the mean EFM frequencies were similar for amplitude criteria of 25 μ V and 40 μ V. EFM rates were higher in wake and stages 1-2 utilizing all amplitude criteria when impedance was > 30 K Ω versus epochs with impedance < 30 K Ω .

Reproducibility of Scoring Method

The rescoring of the EFM's of 3 patients by 2 independent scorers (RH, DM) showed that though this method is not perfectly reproducible, the results were very similar from scorer

to scorer (**Table 3**). There are only 3 cases for which there was no agreement between the 2 readers (p-value > 0.05 for the κ statistic): readings utilizing the 25 μ V amplitude criterion in Patient 2 during SWS, readings utilizing the 25 μ V in Patient 8 during REM; and readings utilizing the 50 μ V amplitude criteria in Patient 8 during wake. For these 3 cases, the 95% confidence interval for the κ statistic included zero, the hypothesized value.

DISCUSSION

EFM rates increased with deeper stages of sleep (i.e., SWS and REM; **Figure 2**). EFM frequency was highest in phasic

Table 3A—Independent amplitude analysis of EFMs in three patients with N1, N2, REM, and SWS

	1° scorer (RH)			2° scorer (DM)		
	≥ 25 μ V	≥ 40 μ V	≥ 50 μ V	≥ 25 μ V	≥ 40 μ V	≥ 50 μ V
Patient #2						
Bilateral EFM in wake, independent of impedance	18.05	4.35	2.95	22.1	4.8	2.60
Bilateral EFM in Stages 1-2, independent of impedance	16.45	6.75	3.80	16.5	6.65	4.10
Bilateral EFM in SWS, independent of impedance	22.05	8.60	5.05	16.4	7.75	4.95
Bilateral EFM in Total REM, independent of impedance	21.8	9.55	6.10	17.75	8.25	5.30
Patient #3						
Bilateral EFM in wake, independent of impedance	3.1	1.15	0.75	2.2	0.9	0.55
Bilateral EFM in Stages 1-2, independent of impedance	2.95	0.85	0.5	2.45	0.65	0.50
Bilateral EFM in SWS, independent of impedance	16.46	1.0	0.66	15.6	0.86	0.40
Bilateral EFM in Total REM, independent of impedance	1.75	0.30	0.20	1.30	0.30	0.25
Patient #8						
Bilateral EFM in wake, independent of impedance	10.7	3.5	5.65	8.65	3.1	1.75
Bilateral EFM in Stages 1-2, independent of impedance	10.75	3.9	4.35	8.8	3.35	2.05
Bilateral EFM in SWS, independent of impedance	14.0	4.55	1.8	10.9	3.65	1.45
Bilateral EFM in Total REM, independent of impedance	16.8	5.4	2.8	13.0	4.65	2.55

Excessive fragmentary myoclonus (EFM) rate data scoring performed independently by 2 scorers for 3 patient polysomnograms. Though not perfectly reproducible, the results are quite similar using the same manual scoring protocol.

Figure 2—Excessive fragmentary myoclonus (EFM) rates from this study compared to the literature

Regardless of amplitude criteria employed (≥ 25 μ V, ≥ 40 μ V, or ≥ 50 μ V) our study showed greater EFM rates in wakefulness and across all sleep stages. Hoque et al (2012) combined Stages 1 and 2, with the data displayed as Stage 1. Hoque et al. (2012) and Mizuma et al. (1997) combined stages 3 and 4 into SWS, with the data displayed as SWS. REM, rapid eye movement sleep; SWS, slow wave sleep.

REM. This finding is consistent with increased muscle activity during phasic REM. It is not clear why EFMs were more prominent in SWS and total REM than stages 1-2 and wake.

Prior studies of EFM used varied terminology and varied equations to define EFM rates (Table 4). Historical terminology for EFM-like events include such terms as excessive fragmentary hypnic myoclonus, fragmentary myoclonus, hypnic myoclonus, physiologic hypnic myoclonus, and sleep related fragmentary pathological multifocal myoclonus. The AASM

scoring manual has provided a useful definition for EFM, but does not discuss amplitude or sleep stage distribution due to lack of prior validated data. In comparison to prior studies of EFM, our small study shows higher EFM rates across all sleep stages regardless of amplitude criteria employed.

A limitation of our impedance analysis was that none of the 8 patients had EFMs in SWS with PSG impedances greater than 30 K Ω . A second limitation was that only one patient had EFMs in REM with PSG impedances greater than 30 K Ω .

Many PSG software platforms recommend an impedance cutoff of 30 K Ω . Utilizing impedance criteria of ≤ 30 K Ω resulted in smaller EFM rates across all sleep stages regardless of amplitude criteria. This rate reduction implies a possible artifactual origin to some measure of the EFMs noted. Unfortunately it is not possible to determine what percentage of EFMs is purely artifactual in origin vis-à-vis the percentage of EFMs that represent a true electrophysiologic manifestation of the tibialis anterior muscles recorded bilaterally. Despite this limitation, the use of clearly defined impedance standards in documentation of EFM potentials may: allow for electrophysiologic evaluation less clouded by artifact; aid sleep laboratory technicians intervention during the recording when the values are problematic; and help scorers in either clinical or research settings to standardize data gathering.

Neither of the impedance categorical values we used (i.e., < 30 K Ω or > 30 K Ω) are “gold standard” values from the literature. They are common settings for commercially available equipment guidelines. However, these same leads are used in PSG for monitoring periodic limb movements of sleep (PLMS), and by scoring manual criteria should have impedances less than 10 K Ω . We recommend for consistency and dual use of the leads that 10 K Ω be adopted to facilitate consistency and future research.

Our proposed amendments to the AASM scoring manual EFM criteria definition are put forth in Table 5. *A priori* benefits of using lower amplitude criteria (i.e., ≥ 25 μ V) compared

Table 3B—Cohen κ statistic analysis of independent scoring of EFMs

Patient, Sleep stage amplitude criteria	Number of epochs	κ statistic (standard error), [95 % confidence interval]	p-value
Patient 2, Wake			
50 μ V	40	0.73 (0.16), [0.49 – 0.98]	< 0.01
40 μ V	40	0.67 (0.14), [0.47 – 0.87]	< 0.01
25 μ V	40	0.19 (0.08), [0.04 – 0.35]	< 0.01
Patient 2, N1-N2			
50 μ V	40	0.87 (0.12), [0.73–1.0]	< 0.01
40 μ V	40	0.69 (0.09), [0.52 – 0.87]	< 0.01
25 μ V	40	0.50 (0.06), [0.33 – 0.68]	< 0.01
Patient 2, SWS			
50 μ V	40	0.87 (0.11), [0.73 – 1.0]	< 0.01
40 μ V	40	0.53 (0.10), [0.33 – 0.74]	< 0.01
25 μ V	40	0.13 (0.07), [-0.03 – 0.29]	0.06
Patient 2, REM			
50 μ V	40	0.51 (0.10), [0.28 – 0.74]	< 0.01
40 μ V	40	0.39 (0.10), [0.18 – 0.59]	< 0.01
25 μ V	40	0.32 (0.06), [0.18 – 0.46]	< 0.01
Patient 4, Wake			
50 μ V	40	0.79 (0.15), [0.38 – 1.0]	< 0.01
40 μ V	40	0.73 (0.15), [0.44 – 1.0]	< 0.01
25 μ V	40	0.69 (0.12), [0.10 – 0.88]	< 0.01
Patient 4, N1-N2			
50 μ V	40	1.0 (0.16), [1 – 1]	< 0.01
40 μ V	40	0.66 (0.15), [0.03 – 1.0]	< 0.01
25 μ V	40	0.81 (0.12), [0.62 – 1.0]	< 0.01
Patient 4, SWS			
50 μ V	23	0.75 (0.20), [0.42 – 1.0]	< 0.01
40 μ V	23	0.80 (0.17), [0.55 – 1.0]	< 0.01
25 μ V	23	1.0 (0.16), [1 – 1]	< 0.01
Patient 4, REM			
50 μ V	40	Not applicable	Not applicable
40 μ V	40	0.66 (0.11), [0.04 – 1.0]	< 0.01
25 μ V	40	0.64 (0.11), [0.32 – 0.96]	< 0.01
Patient 8, Wake			
50 μ V	40	0.23 (0.10), [-0.005 – 0.45]	0.051
40 μ V	40	0.79 (0.10), [0.63 – 0.95]	< 0.01
25 μ V	40	0.41 (0.08), [0.22 – 0.61]	< 0.01
Patient 8, N1-N2			
50 μ V	40	0.72 (0.10), [0.54 – 0.90]	< 0.01
40 μ V	40	0.80 (0.10), [0.64 – 0.96]	< 0.01
25 μ V	40	0.36 (0.07), [0.17 – 0.54]	< 0.01
Patient 8, SWS			
50 μ V	40	0.70 (0.11), [0.52 – 0.89]	< 0.01
40 μ V	40	0.65 (0.09), [0.47 – 0.84]	< 0.01
25 μ V	40	0.29 (0.07), [0.11 – 0.47]	< 0.01
Patient 8, REM			
50 μ V	40	0.21 (0.07), [0.03 – 0.38]	< 0.01
40 μ V	40	0.17 (0.06), [0.02 – 0.32]	< 0.01
25 μ V	40	0.09 (0.04), [-0.02 – 0.19]	0.051

κ statistics comparing 2 independent scorers. p-values in bold show significant differences between the 2 scorers. The vast majority of values show no significant differences between the 2 scorers.

Table 4—Literature on excessive fragmentary myoclonus (EFM)

Reference	Term used	Amplitude criteria used	Number of patients; Sex distribution; Mean age; Age range	Sleep stage distribution		Formulas used
		Duration criteria used				
Dagnino et al. 1969 ¹	Hypnic myoclonus	ND	18; NA	1: 8.43 ± 4.51 2: 2.16 ± 1.56 3: 1.24 ± 1.57 4: 0.31 ± 0.43 REM: 3.87 ± 3.55		Myoclonus index: ((number of myoclonic EMG potentials)/(time in seconds for that stage)) × 1,000
		ND				
Broughton et al. 1984 ³	Sleep related fragmentary pathological multifocal myoclonus	≥ 50μV peak to peak amplitude	1; Male; 42	WASO: 6.5% 1: 14.5% 2: 37.6% 3: 10.9% 4: 7.4% REM: 23.2%		None
		ND				
Broughton et al. 1985 ⁵	Excessive fragmentary myoclonus (<i>first use of this term</i>)	ND	38; 94% male; 51.2; 22-70	Wake: None 1, 2, and SWS: Present REM: EFM could not be differentiated from normal phasic REM.		None
		ND				
Montagna et al. 1988 ⁶	Physiologic hypnic myoclonus (PHM)	ND	7; 100% male; NA; 19-27	Wake: 0.84 1: 1.36 3 / 4: 0.95 REM: 1.75		Myoclonus index: (% total PHM in a sleep stage)/(% of total recording time of that stage)
		< 100 m sec				
Lins et al. 1993 ⁴	Excessive fragmentary myoclonus (<i>second use of this term</i>)	≥ 50μV peak to peak amplitude	11; 100% male; 53.4; 34-72	1: 4.25 2: 4.00 SWS: 3.75 REM: 4.25 Figures reported in this table are extrapolated from bar graph. Numbers not reported		Fragmentary myoclonus index: Divides each epoch into ten 3-sec mini-epochs. If potentials are ≥ one 50 μV EMG spike in the mini-epoch, then it is scored as 1. Epoch score range from 0-10.
		ND				
Mizuma et al. 1997 ⁷	Fragmentary myoclonus	ND	1; Male; 21	1: 15, 13, 20 2: 18, 15, 10 SWS: 15, 12, 3 REM: 30, 40, 20 (right tibialis anterior muscle, left tibialis anterior muscle, right biceps muscle) Figures reported in this table are extrapolated from bar graph. Numbers not reported		Fragmentary myoclonus index: ((number of jerks)/(time in seconds for the stage)) × 1,000
		< 150 m sec				
Vetrugno et al. 2002 ⁸	Excessive fragmentary hypnic myoclonus	ND	2; 100% male; 71 (patient #1) and 53 (patient #2)	1 st half of the night (Pt. 1, Pt. 2)	2 nd half of night (Pt. 1, Pt. 2)	Mean number of EMG spikes per epoch
		ND (> 200 μV or > 150 msec were associated with visible twitches)		1-2: 8,4 SWS: 8, NA REM: 12, 0	1-2: 22, 7 SWS: 22, NA REM: 24, 8	
Pincherle et al. 2006 ⁹	Excessive fragmentary hypnic myoclonus	ND	1; Male; 34	None reported		None
		ND				

EMG, electromyography; ND, no data available; REM, rapid eye movement sleep; SWS, slow wave sleep; WASO, wake after sleep onset.

Table 5—Hoque et al.'s excessive fragmentary myoclonus (EFM) proposed criteria to standardize EFM evaluation

1. Baseline tibialis anterior muscle EMG recording at the start of the PSG $\leq 2 \mu\text{V}$
2. Maximum EMG electrode impedance of 10 K Ω
3. Use both legs for counting EFM as EFM may be present in either leg
4. EFM event duration ≤ 150 msec
5. EFM amplitude $\geq 25 \mu\text{V}$ negative deflection above the baseline
6. 20 minute samples for each stage
7. EFM rate calculated per minute

to the one employed by other authors previously (i.e., $\geq 50 \mu\text{V}$) are the allowance for a more sensitive assessment of EFM across all sleep stages and a more robust correlation of EFM with other polysomnographic data such as sleep disordered breathing indices. While studying the significance of EFM in the future, inclusion of all likely EFM events seems reasonable. Correlation of individual EFM potentials with cortical arousals may still prove to be difficult given the short duration of EFM potentials and their high frequency when present. Data regarding correlation of EFM with cortical arousals were not collected in this study.

The use of the 50 μV criterion in the past may have been an attempt to adjust for impedance related skin artifact. However, with newer software and better skin preparation techniques this may be no longer necessary. Also a manual assessment of EFM, as performed in this study, will no longer be necessary, as the process can be automated with more sophisticated software. Since the maximum allowable impedance limits for the EMG electrodes during a PSG are not defined by the AASM scoring manual, we recommend explicitly defined the maximum EMG electrode impedance cut off at 10 K Ω to fit with the AASM scoring manual requirements for periodic limb movements of sleep monitoring. Our proposed additions to the standardized AASM definition of EFM may allow for more extensive

research into the physiologic and clinical associations of this phenomenon in the future.

REFERENCES

1. Dagnino N, Loeb C, Massazza G, Sacco G. Hypnic physiological myoclonias in man: an EEG-EMG study in normals and neurological patients. *Eur Neurol* 1969;2:47-58.
2. Iber C, Ancoli-Israel S, Chesson A, and Quan SF for the American Academy of Sleep Medicine. The AASM Manual for the Scoring of Sleep and Associated Events: Rules, Terminology and Technical Specifications, 1st ed.: Westchester, Illinois: American Academy of Sleep Medicine, 2007.
3. Broughton R, Tolentino MA. Fragmentary pathological myoclonus in NREM sleep. *Electroencephalogr Clin Neurophysiol* 1984;57:303-9.
4. Lins O, Castonguay M, Dunham W, Nevsimalova S, Broughton R. Excessive fragmentary myoclonus: time of night and sleep stage distributions. *Can J Neurol Sci* 1993;20:142-6.
5. Broughton R, Tolentino MA, Krelina M. Excessive fragmentary myoclonus in NREM sleep: a report of 38 cases. *Electroencephalogr Clin Neurophysiol* 1985;61:123-33.
6. Montagna P, Liguori R, Zucconi M, et al. Physiological hypnic myoclonus. *Electroencephalogr Clin Neurophysiol* 1988;70:172-6.
7. Mizuma H, Sakamoto T. Excessive twitch movements in rapid eye movement sleep with daytime sleepiness. *Psychiatry Clin Neurosci* 1997;51:393-6.
8. Vetrugno R, Plazzi G, Provini F, Liguori R, Lugaresi E, Montagna P. Excessive fragmentary hypnic myoclonus: clinical and neurophysiological findings. *Sleep Med* 2002;3:73-6.
9. Pincherle A, Mantoani L, Villani F, Confalonieri P, Erbetta A. Excessive fragmentary hypnic myoclonus in a patient affected by a mitochondrial encephalomyopathy. *Sleep Med* 2006;7:663.

SUBMISSION & CORRESPONDENCE INFORMATION

Submitted for publication November, 2011

Submitted in final revised form June, 2012

Accepted for publication June, 2012

Address correspondence to: Romy Hoque, M.D., Department of Neurology, Division of Sleep Medicine, Louisiana State University School of Medicine, 1501 Kings Highway, Shreveport, LA 71101; E-mail: romy.hoque@gmail.com

DISCLOSURE STATEMENT

This was not an industry sponsored study. The authors have indicated no financial conflicts of interest.