

Bruxism and nocturnal groaning

L. FERINI-STRAMBI, P. POZZI, M. MANCONI, M. ZUCCONI, A. OLDANI

Sleep Disorders Center, Division of Neuroscience and Università Vita-Salute San Raffaele, Milan, Italy

ABSTRACT

Sleep bruxism (SB) is a sleep-related movement disorder, characterized by tooth grinding and/or clenching. The causes of SB range from psychosocial factors to an excessive sleep arousal response. Some studies showed that SB episodes during sleep are under the influences of transient activity of the brainstem arousal.

Nocturnal groaning (NG) is a parasomnia characterized by an expiratory monotonous vocalization occurring during sleep, especially in REM sleep and during the second half of the night. The pathogenesis of NG remains still unclear and many hypotheses arose, ranging from the persistence of a vestigial ventilatory pattern rather than an expiratory upper airways' obstruction. Sleep microstructure fluctuation might modulate the NG, since the end of the NG episode usually is synchronized with a cortical arousal and an autonomic activation

Further studies should clarify the pathophysiology of SB and NG, especially when the two phenomena are associated.

Key words

Bruxism • Nocturnal groaning • Sleep-related movement • Disorder • Parasomnia • Arousal

Introduction

The International Classification of Sleep Disorders (AASM, 2005) categorizes sleep bruxism as a sleep-related movement disorder and defines it as an oral activity characterized by grinding or clenching of the teeth during sleep. Catathrenia or nocturnal groaning, included as parasomnia in the same Classification (AASM, 2005), is a rare phenomenon characterized by an expiratory monotonous vocalization occurring predominantly during REM sleep. In the present article we reviewed the clinical and polysomnographic data of nocturnal groaning cases published so far, and we discuss the possible points of contact between the two disorders.

Bruxism

Definition

Sleep bruxism (SB) is defined as a stereotyped movement disorder occurring during sleep and characterized by tooth grinding (TG) and/or clenching (Bader and Lavigne, 2000). The last International Classification of Sleep Disorders (AASM, 2005) categorizes SB as a sleep-related movement disorder. SB should be distinguished from the daytime-awake bruxism that is mainly related to "stress/anxiety" reactivity and expressed as a jaw muscle clenching habit/tic. TG is described as secondary or iatrogenic, when medical disorders, medication or drug use are present (Lavigne et al., 2011). It is well known that consequences of SB are tooth destruction, temporomandibular joint and muscle pain or jaw lock,

temporal headaches and cheek-biting (Bader and Lavigne, 2000; Lavigne et al., 2011). The odds ratio (OR) of reporting temporomandibular disorders or chronic myofascial pain of masticatory muscles, when clenching and/or grinding are concomitant, have been estimated at between 4.2 and 8.4 (Velly et al., 2003). Up to 65% of SB patients of all ages report headaches (Camparis and Siqueira, 2006). The noise made by the TG can greatly disturb the sleep of bedroom partners. Risk factors that have been shown to exacerbate SB-TG are the following: (1) smoking, caffeine and heavy alcohol drinking; (2) type A personality-anxiety; (3) sleep disorders such as snoring (OR: 1.4), sleep apnea (OR: 1.8) or periodic limb movements (concomitant in 10%) (Bader and Lavigne, 2000; Lavigne et al., 2011).

Epidemiology

SB is a frequent habit. In normal subjects, primary SB is reported by 8% of the adult population. Its prevalence decreases with age from 14% in childhood to 3% in the elderly (Lavigne et al., 1994; Ohayon et al., 2001) and no gender difference is observed. However, the exact prevalence of SB is difficult to estimate because, in most cases, there are no clinical symptoms.

Etiopathogenesis

Several hypotheses have been proposed for the SB, but no single mechanism or theory may fully explain the pathophysiology of this motor activity.

Stress and anxiety have been suggested as possible cause of SB (Pierce et al., 1995; Major et al., 1999), however rigorous evidence is lacking to support the notion that SB is an anxiety-related disorder (Lavigne et al., 2007). The possible involvement of the dopaminergic system remains to be confirmed. It is known that dopamine has a role in the execution of movement and in maintaining vigilance during wakefulness. During sleep, the dopaminergic system is probably minimally active with the exception of brief period of arousal-related movements such as periodic limb movements (Lavigne et al., 2001). Some authors hypothesized that in SB there is an asymmetry in the dopamine uptake level of D2 receptors in the basal ganglia (Chen et al., 2005). This asymmetry could favour the appearance of SB in stressful conditions that stimulate the production and secretion of dopamine in the substantia nigra of the midbrain (meso-

corticolimbic and nigrostriatal pathways). However, in most randomised experimental trials with dopaminergic medications (e.g., l-dopa, bromocriptine), the onset of SB episodes is only marginally reduced (Lobbezoo et al., 1997; Lavigne et al., 2001).

Another catecholamine-related medication reported to reduce SB and teeth grinding is propranolol, a beta-blocker (Sjoholm et al., 1996). However, a controlled study in young patients with SB showed that propranolol did not reduced teeth grinding or influence the frequency or duration of jaw muscle contractions (Huynh et al., 2006a).

Researches with the recording of masseter electromyographic activity to assess rhythmic masticatory motor activity (RMMA) in the jaw-closer muscles found that about 60% of normal sleepers showed RMMA during sleep (Lavigne et al., 2011). In SB, RMMA probably represents an extreme manifestation of an ongoing or natural activity during sleep. A hypothesis on the genesis of nocturnal RMMA is that, contrary to wakefulness, cortico-bulbar influences are not dominant during sleep. The top-down circuits seem to be partially de-activated during sleep to preserve the so-called sleep continuity (Massimini et al., 2005). Some evidences support this hypothesis in the physiopathology of SB: (1) a specific increase in the cortical activity, over the motor cortex, precedes most limb movements. This brief and large deflection of brain wave activity is termed the pre-motor potential. It has been reported that RMMA are not preceded by such pre-motor cortical potentials during sleep (Lavigne et al., 2007). Thus, SB is not generated by a clear pattern of cortical activation; (2) SB episodes are not associated with the so-called cortical K-complexes that are electroencephalographic (EEG) markers of sudden changes in brain activity (Lavigne et al., 2002); (3) In the macaca fascicularis, the intracortical microstimulation (ICMS) threshold did not evoke RMMA (or a rhythmic jaw movements = RJM) responses from the cortical masticatory area (CMA) during light non-rapid eye movement (NREM) sleep in comparison to the quiet awake state (Adachi et al., 2005). However, as soon as the animal wakes up, there is a rapid return of RJM at ICMS threshold levels comparable to pre-sleep. These data suggest that the geneses of RJM or RMMA during sleep are probably not directly under the influence of the cortical network as seen during wake condition.

Another hypothesis is that the onset of RMMA and SB episodes during sleep are under the influences of transient activity of the brainstem arousal (Kato et al., 2001). It is possible that the sudden onset of RMMA during sleep is occurring in brief time windows at which the brain is switching from sleep to an aroused state. These periods are termed micro-arousal which is defined as 3-15 s abrupt shifts in EEG activity accompanied by a rise in heart rate and muscle tone. Micro-arousals (MA) tend to recur 8-15 times per hour of sleep in young healthy subjects (Parrino et al., 2001). To initiate NREM sleep, a massive inhibition of GABA on brain arousal ascending system is needed to reverse the influences of arousal related orexin/hypocretin, from the hypothalamus, and on acetylcholine, noradrenalin, histamine and serotonin brain networks (Saper et al., 2005). Moreover, from the sleep onset, a reduction in muscle tone to a clear hypotonia in the rapid eye movement (REM) sleep is observed. It has been proposed that the reduction of muscle tone during REM sleep is due to withdrawal of excitatory effects of norepinephrine on motoneurons (Fenik et al., 2005) and/or GABA- and glycine-mediated inhibition on both brainstem and spinal cord motoneurons (Chase and Morales, 1990).

SB tends to occur in relation to recurrent MA within the so-called cyclic alternating pattern, or CAP (Macaluso et al., 1998). MA are characterized by a repetitive rise in heart and brain activity within sleep and they represent a natural process for maintaining body homeostasis (Terzano et al., 2000). Some authors explored the role of MA, as a physiological state that may increase the probability of initiating an episode of SB, with the use of a sensory vibrator during sleep (Kato et al., 2003). Experimentally induced RMMA related MA were followed by TG in over 70% of trials in SB patients only and not in control subjects. The same research group also demonstrated that the onset of SB is related to a sequence of physiological activations in relation to the MA (Huynh et al, 2006b): a) a rise in sympathetic cardiac activity around 4 min before RMMA; b) a rise in the frequency of EEG activity 4 s before RMMA; and c) tachycardia starting one heart beat before RMMA.

Diagnosis

In most cases, clinicians can diagnose sleep bruxism by accurate medical history supported by a visual inspection of orofacial structures. The typical TG or

tapping is usually noted by the patient's partner or family members. Orofacial discomfort, such as pain, fatigue, muscular tension, and teeth hypersensitivity to cold food or beverages are often reported by the patient. Clinicians can corroborate the suspect of bruxism by observing teeth wear, tongue indentation, masseter and temporalis muscles hypertrophy, and temporo-mandibular joint sound during chewing (Lavigne et al., 2011).

Instrumental techniques are recommended only in specific cases: confirmation of diagnosis in uncertain patients; severe bruxism; differential diagnosis, especially with other sleep disorders; scoring of bruxism episodes for an improved quantification of its severity; for research purpose; or for documentation of the teeth and oro-mandibular damage.

The first level of instrumental diagnosis is represented by the ambulatory assessment of bruxism by the detection of sound, EMG activity of masticatory muscles or pressure exerted by jaw movements (Koyano et al., 2008). Self-made audio-video recordings may be useful for confirming bruxism and verifying its frequency of occurrence. Ambulatory polygraphic monitoring is available with different levels of complexity: from a single channel EMG recording of masseter muscle, to a full multichannels polysomnography which can include EEG, EOG, EMG and respiratory efforts. Ambulatory poligraphy may provide a good quality of signal and, depending on the number of recorded parameters, a highly reliable diagnosis. Moreover ambulatory techniques allow a low-cost monitoring over multiple nights in the habitual environment of the patient. The lower specificity compared to laboratory full polysomnography in differentiate bruxism from other orofacial physiological (talking, yawning, coughing, swallowing) or pathological (oro-manibular myoclonus, nocturnal groaning, epileptic bursts) activities, mainly depend of the absence of the audio-video recording during ambulatory studies (Lavigne et al., 2011).

Nocturnal groaning

Definition

Firstly described as a REM sleep phenomenon by De Roeck and Van Hoof (1983), nocturnal groaning (NG) is a disorder characterized by an expiratory

monotonous vocalization occurring during sleep, especially in REM sleep and during the second half of the night. NG is usually reported by the bed partner as a gloomy and dark sound produced at low intensity and not accompanied by other motor or behavioral phenomena. For its similarity with a sort of stereotyped complain the term of “catathrenia”, which comes from the ancient Greek word *κατάρηνος* (like a groan), was proposed and is still used as synonymous of NG.

According to the International Classification of Sleep Disorders (AASM, 2005), catathrenia belongs to parasomnias, which are an unusual and undesirable behavioral phenomena occurring almost exclusively during the sleep period. Central to parasomnias, such as sleep-talking, sleepwalking or nocturnal eating, it is the atypical emergence of regular daytime behaviour in the normally quiescent state of sleep with a partial and variable state of consciousness. According to this point of view, NG and some other parasomnias may be considered as arousal disorders, that are triggered by an incomplete awakening, probably as a consequence of an abnormal central nervous compartmentalization of the three main states of being: wakefulness, NREM sleep and REM sleep. Therefore, these states of dissociation often occur during the transition between wakefulness and sleep, in both directions, or during shifts in sleep stages. Before its inclusion among parasomnia, a possible pathogenetical relationship between NG and sleep-related breathing disorders has also been considered.

Epidemiology

There are no specific prevalence studies of NG. However, it seems to be a quite rare disorder representing less than 1% of the patients who refer to a sleep center. During a 4-year period, Oldani et al. (2005) observed 21 patients with NG who represented about 0.3% of the population evaluated at their Sleep Disorders Centre. Indeed, the disorder is probably common but, since the patient is usually unaware of the phenomenon and the impact of the NG on the quality of life is generally not so significant, the number of subjects who report this disturbance to the physicians might be much lower than those affected by NG in the general population. Based on the few published case reviews, it appears that NG is more prevalent in the male

population than in females, with a possible ratio of 3:1. Although a familiar pattern of inheritance is not known, Oldani et al. (2005) described the occurrence of NG in 3 members of a same family and in another 4 members belonging to a second family.

Etiopathogenesis

The pathogenesis of NG remains still unclear and many hypotheses arose, ranging from the persistence of a vestigial ventilatory pattern rather than an expiratory upper airways' obstruction (Oldani et al., 2005; Guilleminault et al., 2007; Vetrugno et al., 2008).

Sleep microstructure fluctuation might modulate the NG. The end of the NG episode usually is synchronized with a cortical arousal and an autonomic activation, suggesting a possible modulation by the cyclic alternating pattern (CAP). CAP is a spontaneous or stimulus-induced episodic oscillation in brain activity occurring during NREM sleep, with a periodicity of 20-40 s, composed of an activation component (phase A) followed by a deactivation component (phase B). CAP fluctuations influence the time-structure of several physiological and pathological phenomena such as periodic limb movements, bruxism and epileptic EEG discharges. In particular, the control exerted by CAP is particularly strong in sleep breathing disorders, especially in the sleep apnea syndrome, where respiration is interrupted during the CAP phase B and restored during the phase A. The same trend also seems to be followed in NG where the episodes tend to occur during the inhibitory phase B. Some authors (Prihodova et al., 2009) found that about two-thirds of the groaning episodes are connected with cortical arousals. The authors postulated that NG might be a source of sleep disruption, at least in some specific cases, and that the arousal mechanism might be involved in the pathogenesis of NG.

Diagnosis

The onset and the course of the disorder is unknown, however it usually becomes evident in young subjects; often when patients start to sleep with a bed-partner who can recognize the disturbance as a noise. Patients, in fact, are usually completely unaware of their vocalization. The main impact of this parasomnia is interpersonal, with possible repercussion on the bed-partner sleep quality.

Notwithstanding there are no long term follow up

studies available on NG, the course of the disease seems to be chronic with possible periods of remission. The frequency of the occurrence of the nocturnal vocalization is often nightly and generally not more than a few episodes might be reported per single night. The long term consequences of the NG are unknown, but at the moment, the patients affected seem to be generally healthy and exhibit normal sleep structure. Results of otorhinolaryngologic and neurologic examinations are usually normal. The relationship between NG and snoring or other breathing disorders is unclear but probably very weak. The expiratory sound usually occurs with closed mouth and with the person lying in any position. Recently, some authors (Iriarte et al., 2010) compared the sound analysis of two patients with clinically diagnosed NG, with the sound analysis of snoring. They found that NG is a vocal, well-organised sound, while snoring does not have a rhythmic internal organisation. The origins of the sounds are clearly different: NG is laryngeal, while snoring is mainly guttural. No factors precipitating NG have been identified, but some patients presented a history of other parasomnia even a long time before NG was first diagnosed.

Together with other typical polysomnographic parameters, such as EEG, electro-oculogram and submental muscle EMG, breathing function and sound assessment provide the fundamental information for a reliable polysomnographic diagnosis of NG. In particular, the recording should always include the EMG of the intercostalis muscle, bilateral anterior tibialis muscles, EKG, oxyhemoglobin saturation (SaO₂), oronasal airflow, thoracic and abdominal respiratory movements, and a video and an audio monitoring, better if detected by a piezoelectric larynx microphone.

The PSG revealed typical features of the disorder: a deep inspiration without sound production, followed by a prolonged expiration with groaning, lasting up to 45 s and accounting for up to four fifth of a single respiratory cycle (De Roeck and Van Hoof, 1983; Vetrugno et al., 2001; Pavernagie et al., 2001; Oldani et al., 2005; Steinig et al., 2007; Prihodova et al., 2009). The episodes tend to appear in clusters and are accompanied by a sudden change in respiratory rhythm (bradypnea) without any oxygen desaturation. The sound might be loud and usually dark, similar to complain. It is different from snoring, as previously mentioned, or from laryngeal stridor.

The polysomnographic appearance of NG resembles tightly that of the central sleep apnea, except for its occurrence during the expiratory phase, instead of inspiratory one in which the central apnea occur and for the presence of the vocal noise (Fig. 1). Given the polygraphic similarity between NG and central apnea, scoring of NG with similar rules to those for the apneas has been proposed (Pavernagie et al., 2001). Expiratory groaning may occur both during REM and NREM sleep stage 2, with a preponderance during REM sleep, and is usually absent during slow wave sleep. Data coming from a large series of patients with NG reveals that 92.6% of subjects produce the sound exclusively or predominantly during REM sleep (Oldani et al., 2005).

NG occurs as hypopneic events with a typical monotonous vocal noise which can vary in term of timbre among patients, but it usually constant within each subject. When the episodes of NG occur as isolated events, they usually last about 15 s, but duration of up to 30 s is not uncommon. If the NG episodes occur in clusters, the entire sequence might last up to 3-4 min. During the noise expiratory phases, no significant EMG activity in rectus abdominis and intercostalis muscles is detected. A slight decrease in heart rate, together with a mild increase in frequency at the end of the groaning episode has been described. There is no clear impact of NG on the sleep structure, and no specific symptoms of non-restorative sleep are usually reported by the patients. An association between NG and SB has been described, but the relationship between them is debated (Manconi et al., 2008).

Clinical and polysomnographic review of the groaning cases reported in the literature

In the present review we considered only PSG-monitored patients, since the pattern of catathrenia may erroneously resemble a central sleep apnea, which differs from groaning as it is typically inspiratory and not accompanied by vocalization; moreover, PSG allows recognizing catathrenia episodes through the sound recording channel, since it has a sound analysis that differs from expiratory snoring (Vetrugno et al., 2007). Indeed, video-PSG represents the diagnostic gold standard for bruxism. Clinical data from patients are reported in Table I. PSG data are reported in Table II. The following polysomnographic data were considered: sleep

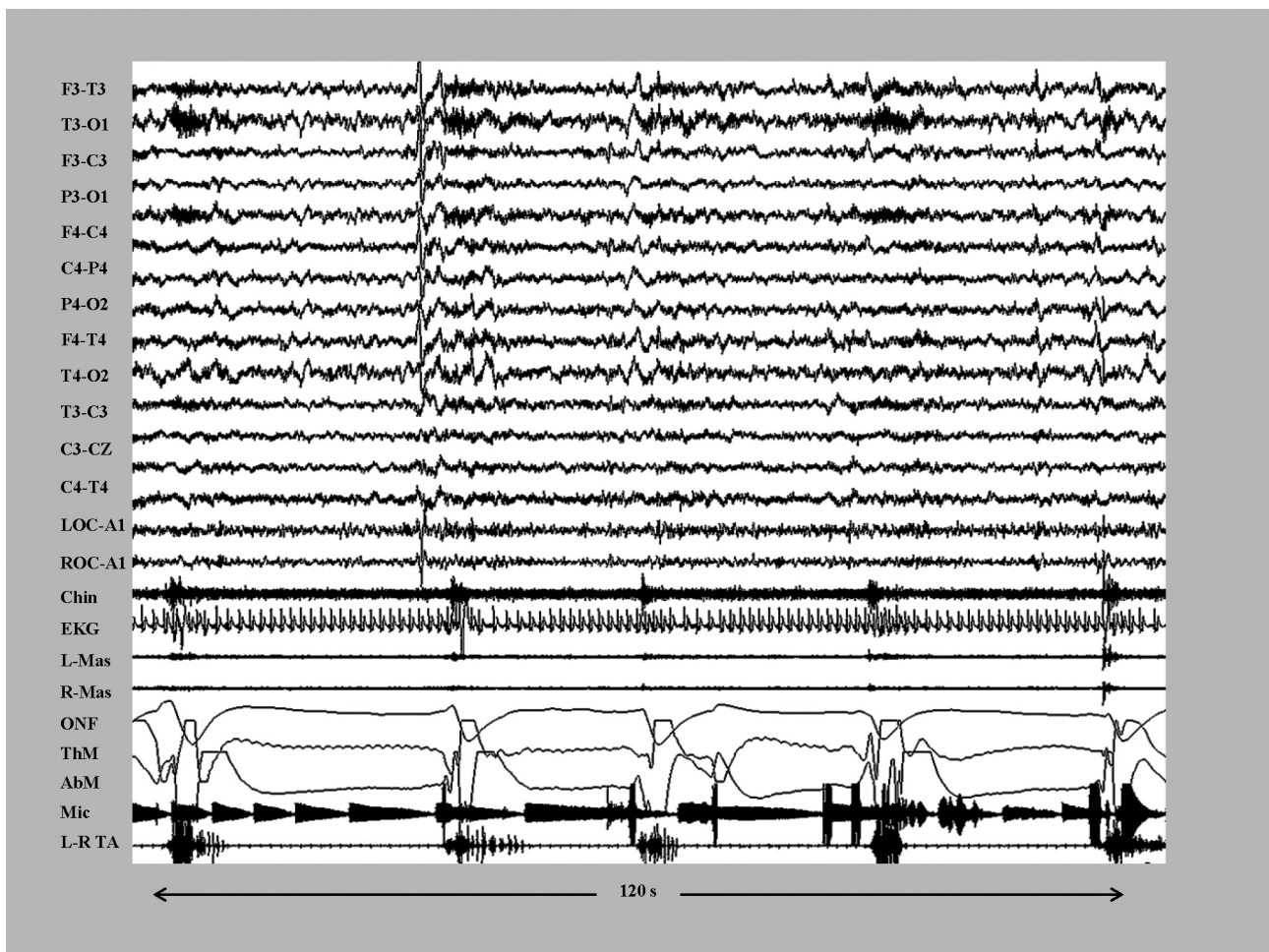


Fig. 1. - Polysomnographic recording (120 s) of a sequence of groaning episodes, occurring during sleep stage 2 NREM.

LOC and ROC = left and right ocular cants; A1 = left mastoid; EKG = electrocardiogram; L-Mas and R-Mas = left and right masseter muscles; ONF = oronasal flow; ThM = thoracic movements; AbM = abdominal movements; Mic = microphone; L-R TA = left referred to right tibialis anterior muscle. the groaning episode has been described.

latency, total sleep time (TST), sleep efficiency, percentages of NREM and REM sleep, REM sleep latency, arousal index, and apnea-hypopnea index. Literature analysis allowed retrieval of 57 cases: the first case was reported by De Roeck Van Hoof (1983), while the last cases by Zinke et al. (2010). Catathrenia affected men with a higher prevalence than women (32 vs. 25 patients, 56.1% vs. 43.9%). As previously underlined, catathrenia affects mostly young patients, with a mean \pm SD age of 29.2 ± 9 years. Symptoms' onset anticipates the diagnosis by about 10 years (mean \pm SD age of onset 18.2 ± 8.1 years). NG seems not to be an inherited disease, though a family history of parasomnias was present in 12 patients (21%). At the same time 13 patients (22.8%) presented

a positive anamnesis for sleep disorders, namely parasomnias (9 patients out of 13, 69%). Only in the study of Guilleminault et al. (2008), a high prevalence of orthodontic interventions, abnormally high Mallampati scale score and small jaw structure was observed. Five patients (8.7%) presented a history of focal epilepsy or asymptomatic EEG abnormalities. All patients denied the presence of sleep paralysis, hypnagogic hallucinations or cataplexy. Patients were often unaware of their condition; they referred to a sleep center for social reasons rather than for hypersomnolence, as their nighttime noise troubled parents and bedpartners. However, unrefreshing sleep or morning fatigue were reported by 21 patients (36.8%).

Table I. - Clinical characteristics of patients with NG in different studies.

Author	Pts (n)	Sex (F/M)	Age (yrs)	Age of onset	Frequency	History of SD	Familiarity for SD	EDS	NG in REM	NG in NREM	Bruxism	Therapy
De Roeck	1	M	35	15	n.a.	-	-	-	+	-	-	n.a.
Pevernagie	10	3F/7M	20-49	12-36	High (10 cases)	ST (1 case)	Violent behavior in sleep (1 case); SB (1); NG (1)	+(8 cases)	+(10 cases)	+(4 cases)	+(2 cases)	CNZ (3 cases); TRA (2); Dos (2); Parox (1); nCPAP (2)
Vetrugno	10	5F/5M	15-41	5-19	High (10 cases)	E (1 case); ST (1); STe (1); SW (1)	SB+ST (1 case); ST+STe (1)	-	+(10 cases)	+(6 cases)	n.a.	n.a.
Oldani	17	7F/10M	18-48	8-36	High (16 cases)	-	NG (1 case); NG+SB (1); NG+ST+SB (1); SB (1); SB+ST (1); ST (2); STe (1)	+(6 cases)	+(8 cases)	+(2 cases)	+(4 cases)	n.a.
Steinig	1	M	33	n.a.	n.a.	n.a.	n.a.	+	+	-	-	nCPAP
Manconi	1	M	31	29	High	-	-	-	-	+	+	nCPAP
Iriarte	1	F	62	childhood	High	-	-	-	+	+	-	nCPAP
Guilleminault	7	7F	20-34	Childhood-14	High (7 cases)	E (1 case); SW+ST (1); STe (1)	n.a. (6 cases); - (1)	-	+(7 cases)	+(7 cases)	-	nCPAP (2 cases); nCPAP + ADT (2); nCPAP + UPP (1); nCPAP+PP (2)
Prihodova	8	3F/5M	11-32	4-21	High (8 cases)	Ins+Snor (3 cases); Snor (1); SW+SB (1)	-	+(6 cases)	+(8 cases)	+(4 cases)	+(4 cases)	n.a.
Zinke	1	M	22	11	High	n.a.	Nocturnal Epilepsy	-	-	+	-	-

NG = nocturnal groaning; SD = sleep disorder; EDS = excessive daytime sleepiness; High (frequency) = more than 5 nights/week; ST = sleep talking; STe = sleep terrors; SW = sleepwalking; E = enuresis; Ins = insomnia; Snor = snoring; SB = sleep bruxism; CNZ = clonazepam; TRA = trazodone; Dos = dosulepine; Parox = paroxetine; ADT = adenotonsillectomy; UPP = uvulopalato-pharyngoplasty; PP = pharyngoplasty.

Sleep induction and maintenance, as well as macrostructure parameters were normal in the NG population (Table II). On the contrary, sleep microstructure was slightly abnormal, with a mean \pm SD arousal index of $16.3 \pm 10.9 \text{ h}^{-1}$ (normal value of number of arousals per hour < 10). No periodic limb movements (PLMs) were recorded. Sleep apneas were ruled out, as the mean \pm SD apnea-hypopnea index was $5.5 \pm 5 \text{ h}^{-1}$ and the oxyhemoglobin saturation was constantly above 90% in all evaluated patients. The polygraphic recordings showed that most groaning and bradypneic events occurred in REM sleep (95.9%); however, 51% of patients also showed NREM sleep episodes. Bruxism episodes were recorded in 11 out of 56 patients (19.6%). Interestingly, in both cases where the criteria of sleep-related bruxism

were met (Manconi et al., 2008; Prihodova et al., 2009), catathrenia and NG occurred in strict relation to cortical arousals and mostly in NREM sleep. In the first report, bruxism preceded invariably catathrenia and bradypneic events (Manconi et al., 2008). In the patient meeting the diagnostic criteria for bruxism described by Prihodova et al. (2009), bruxism was closely associated with bradypneic events prevailing in stage 2 NREM and mostly accompanied by arousals. In the case reported by Manconi et al. (2008), during bruxism events and at the end of each groaning episode, activation of the tibialis anterior muscles has been observed, but it could not be scored as a PLM for its duration and periodicity. Despite its improved identification, catathrenia is still an unsolved medical problem. Empirical treat-

Table II. - Polysomnographic data from patients with NG in different studies.

Author	Pts (n)	SL (min)	TST (min)	SE (%)	1-2 NREM sleep (%)	3-4 NREM sleep (%)	REM (%)	REM latency (min)	AR-I	AHI
Pevernagie	10	20.3 ± 16.5	377.9 ± 50.3	80.7 ± 11.4	55.5 ± 7.9	19.0 ± 8.2	25.8 ± 6.3	117.5 ± 59.3	24.9 ± 12.9	8.5 ± 6.5
Vetrugno	10	11.4 ± 4.8	335.0 ± 45.5	86.0 ± 6.2	55.5 ± 5.2	21.4 ± 3.1	23.1 ± 5.6	94.9 ± 34.3	7.6 ± 2.3	n.a.
Oldani	9	5.6 ± 3.2	383.9 ± 52.4	87.8 ± 9.6	61.3 ± 9.2	16.6 ± 7.7	21.9 ± 8.2	97.6 ± 53.2	n.a.	n.a.
Guilleminault	7	n.a.	380.8 ± 16.7	n.a.	n.a.	n.a.	17.7 ± 1.9	n.a.	n.a.	3.2 ± 0.6
Prihodova	8	12.5 ± 7.9	452.5 ± 42.9	93.0 ± 2.6	44.9 ± 5.3	26.7 ± 5.3	24.6 ± 5.0	83.1 ± 17.9	16.7 ± 5.4	3.0 ± 2.7

SL = sleep latency; TST = total sleep time; SE = sleep efficiency; AR-I = arousal index; AHI = apnea-hypopnea index.

ments proposed to patients failed to correct groaning: clonazepam, antidepressant drugs or dosulepine showed a minimal or inconsistent impact on vocalization (Pevernagie et al., 2001).

In most reports nocturnal continuous positive airways pressure (n-CPAP) failed to correct groaning episodes (Pevernagie et al., 2001; Oldani et al., 2005; Vetrugno et al., 2007). In a limited number of only 8 patients (Guilleminault et al., 2008; Iriarte et al., 2006) n-CPAP was administered and achieved a complete remission of the sleep noises; however, this population presented unique morphometric characteristics and a highly successful response to soft tissue surgery such as adenotonsillectomy or uvulopalatoplasty, either alone or in conjunction with oral appliances (Guilleminault et al., 2008).

Is there a link between catathrenia and bruxism?

Only few cases of NG have been described in the medical literature; therefore it is likely that catathrenia is a rare condition that accounts for less than 1% of prevalent cases admitted to a sleep disturbances laboratory (Oldani et al., 2005). Data also show that NG affects young people, its onset takes place in adolescent age and it frequently runs asymptomatic until a social rather than a medical problem arises. Patients suffering from catathrenia present a normal sleep macrostructure, which may account for the asymptomatic presentation of the disease and its favorable lifetime course. However, *groaners* present an instable sleep microstructure, with an arousal index higher than normal. This finding could justify the sensation of unrefreshing sleep reported by a third of the NG population.

Despite its infrequent presentation, even in our

review about 20% of patients suffering from groaning had a familial history and/or suffered from other parasomnias. Moreover, Pevernagie et al. (2001) found a positive family of SB in one of 10 patients affected by NG. Oldani et al. (2005) found that 4 of 21 NG patients reported SB in at least one of their first relatives. Manconi et al. (2008) described the first case of an association between NG and SB. According to the PSG findings, SB and NG episodes were closely related to each other and seemed to be organized in stereotyped sequences. As previously reported, SB usually occurs during NREM sleep, while NG is a predominantly REM sleep-related phenomenon. In the case described by Manconi et al. (2008), both phenomena always occurred during NREM sleep (stage 1 or 2), and were usually associated with cortical arousals and increase in EKG frequency. Also in the case reported by Prihodova et al. (2009), SB with NG prevailed in stage 2 NREM and most were accompanied by arousals. These findings suggest that the overlap between SB and NG seems to be more evident in those patients with a greater sleep microstructure fluctuations.

Thus, we may speculate about two distinctive patterns of catathrenia: 1) a typical groaning episode that usually takes place in REM sleep, non-sleep disrupting and not associated with any other motor events; 2) an atypical groaning episode linked to a cortical arousal that gates motor phenomena like SB in NREM sleep and may lead to unrefreshing sleep. According to this view, it is conceivable that NREM sleep-related groaning may happen during the CAP, that has been linked to stronger and longer SB episodes, mainly in NREM sleep (Macaluso et al., 1998), as already proposed by other authors (Manconi et al., 2008).

In contrast with this hypothesis, pharmacological treatment with clonazepam was efficacious in SB

(Saletu et al, 2005), whereas it had no effect in the groaning population. However, SB is predominantly a NREM sleep disorder (Macaluso et al, 1998), while groaning more frequently occurs in REM sleep. Moreover, clonazepam had a minor effect on arousal index in the bruxers' population (Saletu et al., 2005), while an increased arousability may play an important role in atypical episodes of catathrenia. More generally, there are still open questions regarding the pathophysiology of NG, as far as some authors believe that NG is a sleep-related breathing disorder rather than a parasomnia (Iriarte et al., 2006; Guilleminault et al., 2008). In our opinion, the population described by Guilleminault et al. (2008) presented distinctive clinical and polysomnographic features, that didn't match with the majority of groaning patients (NREM sleep presentation, female predilection, anatomic evidence of small upper airway and small jaws, short lasting and protoexpiratory sound emission, brilliant response to n-CPAP, surgical interventions and/or oral appliances). Whether catathrenia is a abnormal, vestigial ventilatory pattern during sleep (Vetrugno et al., 2007) should be a matter of new investigations; we agree with the hypothesis that catathrenia presents with its own distinctive pattern on PSG (Vetrugno et al., 2007) and we propose a further distinction between typical and atypical groaning, presenting in NREM sleep, strictly related to arousal phenomenon and possibly associated with SB. It should also be emphasized that, even if we cannot currently offer patients any effective treatment, the long-term follow-up confirms the benign course of the disease (Vetrugno et al., 2007). However, it is mandatory to differentiate between catathrenia and other respiratory sleep disturbances by means of a complete PSG recordings.

Summary

SB occurs relatively frequently but the exact prevalence is difficult to estimate because, in most cases, there are no clinical symptoms. The causes of SB range from psychosocial factors to an excessive arousal response. Catathrenia is a rare sleep disorder presenting predominantly in REM sleep with social, rather than medical, consequences. Catathrenia may present along with SB, particularly during NREM sleep, and may be associated with fluctuations

of sleep microstructure, such as cortical arousals. Further studies should clarify the pathophysiology of the two phenomena, especially when they occur concurrently. In consideration of to the high prevalence of SB, the possibility of a casual association with nocturnal groaning should be ruled out.

References

- Adachi K., Rompre S., Yao D., Lavigne G.J., Sessle B.J. Loss of corticobulbar motor excitability during sleep in primates: preliminary findings. [Abstract] Soc. Neurosci. 35th Meeting, Washington, DC: 399, 2005.
- AASM *International Classification of Sleep Disorders*. 2nd ed. Westchester, American Academy of Sleep Medicine, 2005.
- Bader G. and Lavigne G.J. Sleep bruxism; an overview of an oromandibular sleep movement disorder. *Sleep Med. Rev.*, **4**: 27-43, 2000.
- Camparis C.M. and Siqueira J.T. Sleep bruxism: clinical aspects and characteristics in patients with and without chronic orofacial pain. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.*, **101**: 188-193, 2006.
- Chase M.H. and Morales F. The atonia and myoclonia of active (REM) sleep. *Annu. Rev. Psychol.*, **41**: 557-584, 1990.
- Chen W.H., Lu Y.C., Lui C.C., Liu J.S. A proposed mechanism for diurnal/nocturnal bruxism: hypersensitivity of presynaptic dopamine receptors in the frontal lobe. *J. Clin. Neurosci.*, **12**: 161-163, 2005.
- De Roeck J. and Van Hoof E. Sleep-related expiratory groaning: a case report. *J. Sleep. Res.*, **12**: 377, 1983.
- Fenik V.B., Davies R.O., Kubin L. REM sleep-like atonia of hypoglossal (XII) motoneurons is caused by loss of noradrenergic and serotonergic inputs. *Am. J. Respir. Crit. Care. Med.*, **172**: 1322-1330, 2005.
- Guilleminault C., Hagen C.C., Khaja A.M. Catathrenia: parasomnia or uncommon feature of sleep disorder breathing? *Sleep*, **31**: 132-139, 2008.
- Huynh N., Lavigne G.J., Lanfranchi P., et al. The effects of two sympatholytic medications – propranolol and clonidine – on sleep bruxism: experimental randomized controlled studies. *Sleep*, **29**: 307-316, 2006a.
- Huynh N., Kato T., Rompré P.H., et al. Sleep bruxism is associated to micro-arousals and an increase

- in cardiac sympathetic activity. *J. Sleep Res.*, **15**: 339-346, 2006b.
- Iriarte J., Alegre M., Urrestarazu E., Viteri C., Arcocha J., Artieda J. Continuous positive airway pressure as treatment for catathrenia (nocturnal groaning). *Neurology*, **66**: 609-610, 2006.
- Iriarte J., Fernandez S., Fernandez-Arrechea N., et al. Sound analysis of catathrenia: a vocal expiratory sound. *Sleep Breath*, **15**: 229-235, 2011.
- Kato T., Rompre P., Montplaisir J.Y., Sessle B.J., Lavigne G.J. Sleep bruxism: an oromotor activity secondary to micro-arousal. *J. Dent. Res.*, **10**: 1940-1944, 2001.
- Kato T., Montplaisir J.Y., Guitard F., Sessle B.J., Lund J.P. Lavigne G.J. Evidence that experimentally induced sleep bruxism is a consequence of transient arousal. *J. Dent. Res.*, **82**: 284-288, 2003.
- Koyano K., Tsukiyama Y., Ichiri R., et al. Assessment of bruxism in the clinic. *J. Oral Rehab.*, **35**: 495-508, 2008.
- Lavigne G.J. and Montplaisir J.Y. Restless legs syndrome and sleep bruxism: prevalence and association among Canadians. *Sleep*, **17**: 739-743, 1994.
- Lavigne G.J., Soucy J.P., Lobbezoo F., Manzini C., Blanchet P.J., Montplaisir J.Y. Double-blind, crossover, placebo-controlled trial of bromocriptine in patients with sleep bruxism. *Clin. Neuropharmacol.*, **24**: 145-149, 2001.
- Lavigne G.J., Rompre P.H., Guitard F., Sessle B.J., Kato T., Montplaisir J.Y. Lower number of K-complexes and K-alphas in sleep bruxism: a controlled quantitative study. *Clin. Neurophysiol.*, **113**: 686-693, 2002.
- Lavigne G.J., Huynh N., Kato T., et al. Genesis of sleep bruxism: motor and autonomic-cardiac interactions. *Arch. Oral Biol.*, **52**: 381-384, 2007.
- Lavigne G.J., Manzini C., Huynh N. Sleep bruxism. In: Kryger M.H., Roth T., Dement W.C. (Eds.) *Principles and Practice of Sleep Medicine*, Philadelphia, Elsevier Saunders: 1128-1139, 2011.
- Lobbezoo F., Lavigne G.J., Tanguay R., Montplaisir J.Y. The effect of catecholamine precursor l-dopa on sleep bruxism: a controlled clinical trial. *Mov. Disord.*, **12**: 73-78, 1997.
- Macaluso G.M., Guerra P., Di Giovanni G., Boselli M., Parrino L., Terzano M.G. Sleep bruxism is a disorder related to periodic arousals during sleep. *J. Dent. Res.*, **77**: 565-573, 1998.
- Manconi M., Zucconi M., Carrot B., Ferri R., Oldani A., Ferini-Strambi L. Association between bruxism and nocturnal groaning. *Mov. Disord.*, **23**: 737-739, 2008.
- Major M., Rompre P.H., Guitard F., et al. A controlled daytime challenge of motor performance and vigilance in sleep bruxers. *J. Dent. Res.*, **78**: 1754-1762, 1999.
- Massimini M., Ferrarelli F., Huber R., Esser S.K., Singh H., Tononi G. Breakdown of cortical effective connectivity during sleep. *Science*, **309**: 2228-2232, 2005.
- Ohayon M.M., Li K.K., Guilleminault C. Risk factors for sleep bruxism in the general population. *Chest*, **119**: 53-61, 2001.
- Oldani A., Manconi M., Zucconi M., Castronovo V., Ferini-Strambi L. 'Nocturnal groaning': just a sound or parasomnia? *J. Sleep Res.*, **14**: 305-310, 2005.
- Parrino L., Smerieri A., Rossi M., Terzano M.G. Relationship of slow and rapid EEG components of CAP to ASDA arousals in normal sleep. *Sleep*, **24**: 881-885, 2001.
- Pevernagie D.A., Boon P.A., Mariman A.N., Verhaeghen D.B., Pauwels R.A. Vocalization during episodes of prolonged expiration: a parasomnia related to REM sleep. *Sleep Med.*, **2**: 19-30, 2001.
- Pierce C.J., Chrisman K., Bennett M.E., Close J.M. Stress, anticipatory stress, and psychologic measures related to sleep bruxism. *J. Orofacial Pain.*, **9**: 51-56, 1995.
- Prihodova I., Sonka K., Kemlink D., Volna J., Nevsimalova S. Arousals in nocturnal groaning. *Sleep Med.*, **10**: 1051-1055, 2009.
- Saletu A., Parapatics S., Saletu B., Anderer P., Prause W., Putz H., Adelbauer J., Saletu-Zyhlarz G.M. On the pharmacotherapy of sleep bruxism: placebo-controlled polysomnographic and psychometric studies with clonazepam. *Neuropsychobiology*, **51**: 214-225, 2005.
- Saper C.B., Scammell T.E., Lu J. Hypothalamic regulation of sleep and circadian rhythms. *Nature*, **437**: 1257-1263, 2005.
- Sjöholm T.T., Lehtinen I., Piha S.J. The effect of propranolol on sleep bruxism: hypothetical considerations based on a case study. *Clin. Auton. Res.*, **6**: 37-40, 1996.
- Steinig J., Lanz M., Krügel R., Happe S. Breath holding - A rapid eye movement (REM) sleep parasomnia (catathrenia or expiratory groaning). *Sleep Med.*, **9**: 455-456, 2008.
- Terzano M.G. and Parrino L. Origin and significance of the cyclic alternating pattern (CAP): review article. *Sleep Med.*, **4**: 101-123, 2000.

- Velly A.M., Gornitsky M., Philippe P. Contributing factors to chronic myofascial pain: a case-control study. *Pain*, **104**: 491-499, 2003.
- Vetrugno R., Provini F., Plazzi G., Vignatelli L., Lugaresi E., Montagna P. Catathrenia (nocturnal groaning): a new type of parasomnia. *Neurology*, **56**: 681-683, 2001.
- Vetrugno R., Lugaresi E., Plazzi G., Provini F., D'Angelo R., Montagna P. Catathrenia (nocturnal groaning): an abnormal respiratory pattern during sleep. *Eur. J. Neurol.*, **14**: 1236-1243, 2007.
- Vetrugno R., Lugaresi E., Ferini-Strambi L., Montagna P. Catathrenia (nocturnal groaning): what is it? *Sleep*, **31**: 308-309, 2008.
- Zinke J., Rupperecht S., Schwab M., Hagemann G. Nocturnal groaning (catathrenia) and epilepsy. *Epileptic Disord.*, **12**: 136-137, 2010.