Video Analysis of Behaviors and Movements in RBD

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21.1 Introduction

Rapid eye movement (REM) sleep behavior disorder (RBD) is characterized by dream enactment allowed by a loss of physiological muscle atonia during REM sleep [1]. RBD usually manifests itself as the enactment of an unpleasant, action-filled, and violent dream to which the individual is being confronted, attacked, or chased by unfamiliar people or animals, leading frequently to sleep-related injury [2–5]. However, non-violent behaviors are also observed [6]. The behaviors during RBD include talking, laughing, shouting, screaming, swearing profanities, gesturing, reaching, grabbing, arm flailing, slapping, punching, kicking, sitting up, jumping out of bed, crawling, and running [1, 4, 6–10]. The behaviors are various, nonstereotyped, and complex. Walking is not common during RBD, and leaving the room is rare. However, among 203 consecutive idiopathic RBD patients, Frenandez-Arcos et al. reported that 24% of them left their bed occasionally, with some leaving the room and even the house. Although these behaviors were only displayed once or twice within several years of RBD history, these results indicate that ambulation during sleep does not exclude the diagnosis of idiopathic RBD [11]. The eyes usually remain closed during an RBD episode, with the person attending to the dream action and not to the actual environment [12, 13]. Typically, at the end of an episode, the individual awakens quickly; becomes rapidly alert; and reports a dream with a coherent story, with the dream action corresponding to the observed sleep behaviors [14]. Associated with these complex behaviors, patients also present elementary movements. Less impressive, they are more frequent and mostly the only movements observed on video recordings during REM sleep [15, 16].

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The diagnosis of RBD requires the presence of REM sleep without atonia (over a mostly accepted threshold of 18.2% of total REM sleep time when looking at the mentalis muscle alone [17]), associated with at least a history of abnormal sleep behaviors and/or abnormal behaviors during REM sleep recorded during video-polysomnographic (vPSG) monitoring [18]. According to a recent meta-analysis, based on a total of 28 studies with 6869 Parkinson's disease (PD) cases, nearly half of the patients suffered from RBD [19]. Older age and longer duration of the disease were risk factors for RBD in PD, while male gender was not a risk factor [19]. For patients, not reaching a sufficient level of REM sleep without atonia for diagnosing RBD, but presenting movements and/or vocalizations with a seemingly expressive, purposeful component detected on vPSG during REM sleep, Sixel-Döring et al. [20] have elaborated the concept of REM behavioral events (RBE). These RBE were associated with dream contents [21] and were found in 51% of all patients with de novo PD, while the complete ICSD-2 [18] criteria for the diagnosis of RBD were observed in only 25%. Thus, RBE was considered to be a potential marker for premotor manifestations of PD as a precursor to RBD.

In other synucleinopathies, the prevalence of RBD is even higher, reaching 86% in patients with dementia with Lewy bodies [22] and 90% in patients with multiple system atrophy (MSA) [23, 24].

Surprisingly, patients with PD have an improvement of their motor control during REM sleep with a disappearance of parkinsonism [25]. This improvement is also observed in patients with MSA, a L-dopa nonresponsive parkinsonian syndrome [26].

Patients with idiopathic RBD and RBD with PD also have frequently increased periodic limb movements of sleep (PLMs) on sleep recordings [27]. This increased frequency of PLMs, however, is not observed in other diseases such as MSA [28], where RBD is highly prevalent but PLMs are not, suggesting that these two phenomena involve different pathways.

21.2 Characteristics of the Movements During RBD

On video analysis, motor events in patients with severe clinical RBD and parkinsonism are frequent, reaching more than five movements per minute of REM [15]. These movements have a strong intraindividual variability in their type and frequency from a night to another [15]. Most events are elementary (83%), whereas complex behaviors are less frequent (13.5%). Even if there are many movements during RBD, these movements are very brief, so that only 9.2% (0.1–20%) of REM sleep time is associated with a motor activity [12]. The exploration of movements during RBD, recording the EMG of 13 different muscles, has shown that movements are more often distal than proximal [29]. On video recordings of patients with PD-RBD, movements involve six times more often the upper limbs and the face than the lower limbs [25]. Moreover, in patients with PD, where the disease is mostly asymmetrical, impairing more severely one side of the body than the other, movements during RBD are more often located in the more disabled side than on the less disabled side [25].

Comparing video-monitored movements during RBD episodes in patients with PD ($n = 29$) and in patients without parkinsonism ($n = 36$: idiopathic RBD, $n = 31$; narcolepsy, $n = 5$) to movements during wakefulness, RBD movements are different. They are faster and more often repeated, jerky, and apparently in connection with the dreams contents or, not self-centered, never associated with tremor, and rarely involve the environment in an appropriate manner. The jerky movements could be a result of the absence of a real target and the lack of somatosensory feedback, preventing an accurate adjustment of movements or linked to the absence of a smoothing effect [30]. During grasping movements, 48% of the patients have a specific posture of the hand (limp wrist with flexed digits), delineating a common motor signature of RBD [30]. The limp hands of patients with RBD share similarity with the flaccid hands of awake babies. Some RBD behaviors could thus result from activation of immature motor circuits. Eventually, the limp hand could result from simultaneous tonic digits and atonic wrist posture, secondary to an incomplete restoration of muscle tone.

21.3 Cortical Involvement in Movement Generation in RBD

The role of the cortex in the generation of movements of enacted dreams during RBD is increasingly confirmed. The behaviors that the co-sleepers report and that we observe on video recordings are elaborate, complex, nonstereotyped, and sometimes learnt. Behaviors such as making a political speech, giving an English lecture, singing a song, or smoking a cigarette that we collected suggest they result from the same cortical mechanisms as awake complex activities, rather than from primary automatisms [6, 25]. Moreover, the high proportion of face and arm movements during REM sleep that we noticed could be further evidence for a cortical involvement [25]. In fact these body parts are the most largely represented on cortical area. This is not in agreement with the theory that RBD could be archaic movements, determined by central pattern generators in the brainstem, subserving innate motor behaviors necessary for survival [31]. Nevertheless, a recent reconsideration on the source of the various pathological movements and behaviors in RBD merits attention, in regard to the brainstem as a source of some of the pathological twitches, movements, and behaviors, and in regard to sensory feedback from moving limbs in REM sleep being an important influence on the content of dream-enacting mentation in RBD [32].

This cortical involvement, clinically suspected, has been confirmed by neuroimaging studies. The involvement of the supplementary motor area (SMA) has been suggested by a first study showing that during an RBD episode in a patient with MSA there was an increased perfusion measured by ictal single photon emission computed tomography (ictal SPECT) in the SMA compared to two controls during REM sleep [33, 34]. The involvement of the SMA in the generation of movement has been confirmed in a larger study that showed by ictal SPECT an increased perfusion in the SMA during RBD in one patient with idiopathic RBD, one patient with PD and RBD, and two patients with narcolepsy and RBD [35]. The tracer was injected after at least 10 s of consecutive REM sleep and 10 s of disinhibited muscle tone accompanied by movements.

SMA is involved in the selection, the preparation, and the sequencing of movements [36] during wakefulness, but also dreamed movements during vivid dreams [37]. Interestingly SMA is hypoactive in patients with PD but seems to be overactivated during the movements of RBD [38].

21.4 Increased PLMs in Patients with RBD

The association between RBD and PLMs has been reported in idiopathic RBD [39], and the association between PLMs and PD is also well known [20, 28]. There is a significantly greater amount of PLMs in patients with PD and RBD compared to patients with PD without RBD [27]. Interestingly, Schenck et al. [40] have also noticed that the PLMs index in idiopathic RBD patients who eventually develop parkinsonism is higher than in patients who remain idiopathic after 6 years. Increased PLM index could be, in patients with idiopathic RBD, a further harbinger of future PD [41]. Moreover, it suggests that motor dysfunction in PD is not limited to REM sleep but also involves non-REM sleep and that both RBD and PLMs should be considered as parts of motor manifestations of PD [41]. Even if PLMs and RBD might have some anatomic link in PD [42], they must involve different pathways since, for example, RBD is very frequent in MSA [23], but PLMs indexes in MSA are not higher than in controls [28].

21.5 Comparison Between Movements While Awake and During RBD

Surprisingly, patients with PD are able, during their RBD, to do things that they are unable to do during wakefulness (Table 21.1). While awake, due to their parkinsonism, their movements are slow and have reduced amplitude, and their voice is muffled, whereas during RBD, they shout; have violent, strong, and fast movements; and have expressive faces. In order to explore this discrepancy, we conducted a prospective study exploring the quality of movement, facial expression, and voice during RBD in 100 consecutive patients with PD [25]. Fifty-nine percent of the patients had clinical RBD. All the co-sleepers (53/59) who were able to evaluate these three items during sleep reported that the patients had an improvement of at least one of them. By history, movements were improved in 87% of patients, speech was better in 77%, and facial expression was normalized in 47%. Thirty-eight percent of the bed partners reported that movements were “much better,” even in the most disabled patients. The video-monitored purposeful movements in REM sleep in patients off levodopa for 12–20 h were also surprisingly fast, ample, coordinated, and symmetrical, without obvious signs of parkinsonism, thus confirming the clinical impression of the co-sleepers. Surprisingly, while all patients had asymmetrical parkinsonism when awake, most of the time they used the more disabled arm, hand, and leg during the RBD.

Table 21.1 Examples of the discrepancy between movements during RBD and while awake in PD patients

Example of behavior during RBD	Dream content	Difficulties while awake
Singing loud "le temps des cerises," an old French song	I am dreaming I am under my shower, singing	Hypophonia, unable to sing
Going suddenly to the window, giving a head-butt to the window, breaking it	I am dreaming I am in a hotel room, an aggressor comes in. I want to protect myself, and I head-butt the aggressor	Difficulties walking alone
Sitting on his bed, doing large, fast movements with his hands and arms	I am dreaming that I am at work bottling water for "Perrier," transferring the bottles from a shelf to another	Difficulties with doing large movements, bradykinesia
Squatting on the bed, waving his arms as if flying, shouting "pin pon" (the two-tone sound of a siren) with a duck voice	I am a police duck, flying after a pigeon thief	Unable to squat, bradykinesia, hypophonia
Crying, with a very strong emotion of sadness on her face	No memory of this dream	Strong amimia

Another study, exploring laughing during RBD, also found a strong dissociation between hypomimia and hypophonia during the daytime and pronounced facial expressions and loud laughing during sleep on video recordings [10]. The restored motor control during RBD observed in these studies could suggest a transient "levodopa-like" reestablishment of the basal ganglia loop during REM sleep. However, our other study [26], demonstrating the same improvement of motor control during RBD in patients with MSA, a poorly responsive to levodopa parkinsonian syndrome, does not sustain this hypothesis. We however observed a peculiar aspect of movements during RBD that even if they were not parkinsonian, they were also not normal, being jerky, rough, and not smooth. This aspect was not during a succession of several sequences of movement, i.e., the flow from one sequence to another, but rather it was a fragmented aspect inside the same movement. This abnormal aspect suggests that movements during RBD may use other functional pathways while bypassing the pathological basal ganglia. That this pattern was also observed in patients without any movement disorder [30] (idiopathic RBD and RBD in narcolepsy) strengthens the hypothesis of a bypass of the basal ganglia system during RBD as a basic feature of RBD.

The bypass of the basal ganglia during RBD has also been confirmed by neuroimaging. First the ictal SPECT study described before in four patients with RBD has not only shown the increased activity of the SMA but also the absence of activation of the basal ganglia [35]. In healthy subjects, voluntary leg movements during wake, as measured by blood oxygen level-dependent functional MRI, result in activations in the primary sensorimotor cortex, the supplementary motor area, cingulate motor area, the anterior cerebellar vermis, both cerebellar hemispheres, thalamus, and right putamen [43]. In this study, where movement during RBD also involved the legs, there was sparing of the activation of the basal ganglia.

An electrophysiological study has also confirmed this bypass, showing evidence for alternative motor networks in RBD, recording local field potentials in the subthalamic nucleus (STN) and scalp EEG during sleep in humans with PD and RBD. The STN has been identified as a key structure for movement control, and many studies have linked hypersynchronous neuronal activity in the low β band (12–20 Hz) of STN neurons with motor impairment [44, 45]. Within this framework, STN deep brain stimulation is thought to counteract the pathologically elevated activity, leading to significant motor improvement [46]. In this study, time-locked, event-related β band oscillations were calculated during movements in REM sleep compared with movementsREM sleep behavior disorder (RBD): in the waking state and during NREM sleep. Spectral analysis of STN local field potentials revealed elevated β power during REM sleep compared with NREM sleep, and β power in REM sleep reached levels similar to in the waking state. Event-related analysis showed time-locked β desynchronization during awake movements. In contrast, this study showed significantly elevated β activity before and during movements in REM sleep and NREM sleep. Cortico-subthalamic coherence was reduced during REM and NREM movements, suggesting that sleep-related movements were not processed by the same corticobasal ganglia network as movements in the waking state. The authors concluded that the seemingly normal motor performance during RBD in PD patients might be generated by activating alternative motor networks for movement initiation. These findings support the hypothesis that pathological movement-inhibiting basal ganglia networks in PD patients are bypassed during sleep.

Similar questions to those just discussed regarding RBD associated with PD and MSA as synucleinopathy neurodegenerative disorders were raised regarding pre-clinical RBD associated with a tauopathy neurodegenerative disorder in a case report entitled, “A first case of progressive supranuclear palsy and pre-clinical REM sleep behavior disorder presenting as inhibition of speech during wakefulness and somniloquy with phasic muscle twitching during REM sleep” [47]. In this case, there was pathologically linked, state-dependent speech motor inactivation in wakefulness and excessive speech motor activation in REM sleep.

The posterior part of the SMA, also called SMA proper, sends direct corticospinal efferents [48] and is more closely related to movement execution [49]. This specific part of the SMA could be the commander of the generation of movement during RBD, bypassing the basal ganglia.

21.6 REM Sleep Motor Events in Idiopathic RBD and PD-RBD

Video-polysomnography was used to characterize motor events (ME) in 14 PD-RBD and 18 idiopathic (iRBD) RBD cases [50]. ME were nonemotional, occurred mainly in the upper limbs, and were mostly simple, distal, and focal. ME were mostly non-violent. There were no significant differences in ME features between PD-RBD and iRBD groups. Therefore, the presence of wakeful motor dysfunction in PD patients with RBD did not affect ME features, and the ME activity during REM sleep in RBD-PD patients resembled that of iRBD patients.

Conclusion

The precise exploration of movement during RBD has led to the development of hypotheses concerning the generation and the execution of movement during the particular state of REM sleep. These hypotheses have been sustained by recent neuroimaging studies. They strongly suggest that in RBD, the SMA is involved in the generation of movement and that during the execution of movement, the basal ganglia are bypassed.

Note Added in Proof: A recent publication pertaining to RBD behavioral analysis, and another publication on alternative motor networks in RBD merit inclusion: (1) Nguyen-Michel VH, Solano O, Leu-Semenescu S, et al. Rapid eye movement sleep behavior disorder or epileptic seizure during sleep? A video analysis of motor events. Seizure 2018; doi: 10.1016/j.seizure.2018.03.021. [Epub ahead of print] (2) Hackius M, Werth E, Suruucu O, Baumann CR, Imbach LL. Electrophysiological evidence for alternative motor networks in REM sleep behavior disorder. J Neurosci 2016; 36 (46): 11795-11800.

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