

Violence in sleep

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Summary

Sleep-related violence occurs in 2% of the adult population and can result from various conditions, including parasomnias (such as arousal disorders and rapid eye movement behavior disorder), epilepsy (in particular nocturnal frontal lobe epilepsy) and psychiatric diseases (including delirium, dissociative states and factitious disorders). Its occurrence is probably favored by hypoactivity or dysfunction of the prefrontal cerebral areas, and selective activation of pathways involved in complex emotional and motor behavior. The present review outlines the different sleep disorders associated with violence, and aims to provide information on diagnosis, therapy and forensic issues. It also discusses current physiopathological models, establishing a link between sleep-related violence and violence observed in other settings.

Key words: sleep; parasomnias; violence; epilepsy

Introduction

Although generally considered as mutually exclusive, sleep and violence can coexist. What appears to be one of the first of such reports dates back to medieval times and relates to a Silesian woodcutter, who after a few hours of sleep woke up abruptly, aimed his axe at an imaginary intruder and killed his wife instead (cited by Gastaut and Broughton [1]). Another early case was reported by Yellowless in 1878 [2] and describes a young man with a history of sleep terrors who killed his 18-month old son by smashing him against the wall during the night, taking him for a wild beast that was about to attack his family. Nowadays, dramatic reports of somnambulistic homicide still gain considerable attention in the media [3, 4].

The most widely known condition in this respect is probably sleepwalking, but numerous other disorders with a potential for sleep-related violence exist, including other parasomnias, epilepsy and psychiatric diseases. Violence in the course of these disorders occurs when boundaries defining wakefulness and sleep disrupt, resulting in a dissociation between “mind sleep” and “body sleep” [5].

Neurologists and sleep specialists should be familiar with these conditions, not least because sleep-related violence is

more frequent than generally assumed, occurring in up to 2% of the adult population [6]. Important advances in the fields of genetics, neuroimaging and behavioral neurology have expanded the understanding of the mechanisms underlying violence and its particular relation to sleep. Along with this increasing knowledge, sleep specialists assume a growing role in legal issues related to violent acts committed during sleep. Lastly, most sleep disorders associated with violence are treatable; making the correct diagnosis thus constitutes the first step in the prevention of further violence.

The present review outlines the different sleep disorders associated with violence, and aims at providing information on diagnosis, therapy and forensic issues. It also discusses current physiopathological models, establishing a link between sleep-related violence and violence observed in other settings.

Definitions

For the purpose of this review, *violence* is defined as an aggressive act that inflicts unwarranted physical harm on others [7]. It is a subset of *aggression*, a broader term encompassing both mental and physical damage. Unlike violence, aggression may be considered legitimate in certain circumstances. In the light of current physiopathological models, two types of aggression can be distinguished [8–10]. *Premeditated aggression* (also referred to as instrumental, predatory or proactive aggression) is purposeful and goal-directed. It commonly occurs in psychopaths and is thought to result from a failure of moral socialization, involving the mechanisms of aversive conditioning and instrumental learning. Premeditated aggression may develop as a lack of formative learning experience, or because the underlying neuro-cognitive architecture is dysfunctional [8]. *Impulsive aggression* (also termed affective, reactive or hostile aggression) constitutes a response to a frustrating or threatening event that induces anger, and occurs without regard for any potential goal. Impulsive aggression has a particular relevance with regard to sleep-related violence.

Disorders underlying sleep-related violence

Parasomnias

On the basis of electrophysiological variables (eye movements, muscle tone, EEG activity), one can distinguish three different states of vigilance, namely wakefulness, rapid eye movement (REM) sleep and Non REM (NREM) sleep. In

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some circumstances however, boundaries between these states disrupt, resulting in conditions that share features of more than one state. Examples of such a state dissociation include, amongst others, disorders of arousal (dissociation between NREM sleep and wakefulness), rapid-eye-movement behavior disorder, lucid dreaming, peduncular hallucinosis, cataplexy, sleep-related hallucinations and sleep paralysis (dissociation between REM sleep and wakefulness). An extreme form of dissociation, referred to as “status dissociatus”, with the simultaneous presence of features of each one of the three states, has also been reported [11]. It is in the context of state dissociation, when motor activity becomes dissociated from wakefulness, that sleep-related violence occurs in the course of parasomnias.

Disorders of arousal

Disorders of arousal encompass sleepwalking, confusional arousals and sleep terrors. They consist of an incomplete awakening from NREM sleep characterized by reduced vigilance, impaired cognition, retrograde amnesia for the event and variable motor activity, ranging from repetitive and purposeless movements to more complex behaviors such as eating, drinking, driving, sexual intercourse and aggression [12].

Disorders of arousal are common during childhood (with a prevalence of 10% for sleepwalking, 17% for confusional arousals and 1–6.5% for sleep terrors), but may persist or arise *de novo* during adulthood in 2–4% of cases [12]. It is generally assumed that they result from the interplay between predisposing, priming and precipitating factors [13]. Predisposition is based on genetic susceptibility, which in the case of sleepwalking, is suggested by the 10-fold increased prevalence among first degree relatives of sleepwalkers [14]. The genes that confer the risk of sleepwalking remain essentially unknown. The only established marker is the presence of the HLA DQ1B allele found in 35% of sleepwalkers, compared to only 13% of normal subjects [15]. Priming factors act by either increasing slow wave sleep or by heightening the threshold for arousal during NREM sleep and include the acute effect of alcohol, fever, stress, a large variety of psychotropic medications, reviewed elsewhere [13], and probably sleep deprivation, although studies yield conflicting results in this respect [16–18]. Among precipitating factors, sleep disordered breathing, periodic leg movements as well as noise and touch have been identified [13].

Confusional arousals consist of mental confusion or confusional behavior upon awakening from sleep, most often from slow wave sleep in the first part of the night. If an individual leaves the bed and starts walking in the course of a confusional arousal, the disorder is referred to as *sleepwalking*. In *sleep terrors*, the arousal is characterized by intense autonomic activation and typical behavioral features such as sitting up in bed and screaming. Different arousal disorders may coexist in the same individual, and, not infrequently, an episode may start as one arousal disorder and evolve into another (i.e., sleep terror evolving into sleepwalking). They normally occur in the first half of the night and tend not to recur during the same night.

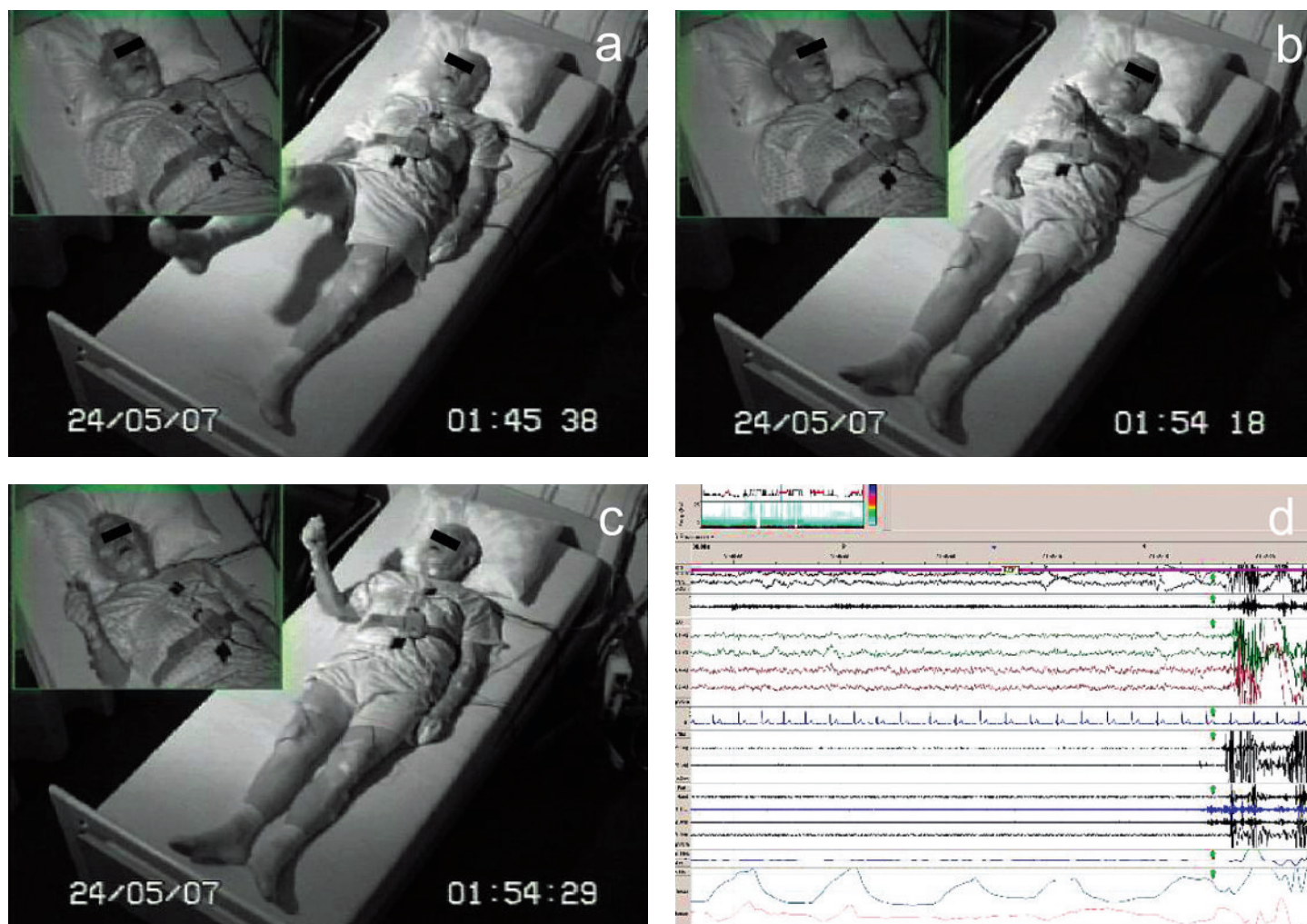
Disorders of arousal have a potential for sleep related violence. Homicide, attempted homicide, filicide, suicide and inappropriate sexual behaviors have been reported in this setting [19]. Pressman [20] reviewed 32 legal and medical case reports of violence associated with disorders of arousal, and found that aggressive behavior occurred in different ways in confusional arousals, sleepwalking and sleep terrors. In confusional arousals, violence was usually elicited when individuals were awakened from sleep by someone else. Bonkalo [21], for instance, reported the case of a night shift supervisor who fell asleep in the office, was awakened by an employee and pulled the gun in confusion, killing the employee. Violent behavior during sleepwalking, in contrast, tended to occur when the sleepwalking episode was already underway, and the individual was approached by another person or incidentally encountered someone else. As an example, Broughton [22] examined the case of a patient who during a presumed episode of somnambulism, completed a 15–20 minute drive to his parents in-law’s house, beat his father-in-law unconscious and killed his mother-in-law with a knife from her own kitchen. Violence related to sleep terrors appears to be a reaction to a concrete, frightening image that the individual can subsequently describe. In this context, Howard and D’Orban [23] reported the case of a man who fell asleep next to his friend, and upon awakening, found this friend severely injured. He described a frightening image of three figures trying to attack him, and recalled hitting and punching them.

In the same series of cases, Pressman examined the role of physical contact and proximity as triggering factors of sleep-related violence, and found that 100% of confusional arousals, 81% of sleep terrors and 40–90% of sleepwalking cases were associated with provocations including noise, touch and/or close proximity.

Two studies tried to further identify risk factors for the occurrence of violence in disorders of arousal. Moldofsky and colleagues [24] who recruited 64 consecutive patients with sleepwalking behaviour or sleep terrors, found that serious violent behavior directed towards other people occurred more frequently in men, and was significantly associated with more stressors, excessive caffeinated beverages, drug abuse and less stage four sleep. Guilleminault and coworkers [25] retrospectively reviewed a series of 41 adult individuals with nocturnal wandering of different etiologies. Compared to the non-violent individuals, the 29 violent patients were predominantly male (65% versus 42%), and comprised of the only two subjects with temporal lobe epilepsy.

Among the complex behaviors that can be observed during disorders of arousal, sleep-related sexual activity is frequently associated with violence. Sexual behaviors during sleep (also termed *sleepsex* or *sexsomnia*) encompass fondling another person, sexual intercourse, masturbation, and sexual vocalizations. In over 90% of cases, sleepsex occurs during confusional arousals; the remainder of cases are related to sleepwalking, REM behavior disorder, seizures, Kleine-Levin Syndrome, severe chronic insomnia, restless leg syndrome, narcolepsy and psychiatric diseases [26]. Among the 31 patients with parasomnia-related sleepsex reviewed by Schenck and coworkers [26], 45% displayed assaultive behavior, 29% had sex with minors, and 36%

Figure 1 82-year-old man with a 2-year history of symmetrical extrapyramidal symptoms and cognitive dysfunction, attributed to vascular leucoencephalopathy. According to his wife he displayed frequent vocalizations and violent behavior during sleep. Polysomnographic recordings show loss of normal muscle atonia during REM-sleep and increased phasic muscle activity as well as acting out of dreams with kicking (Fig. a), hitting (Fig. b) and menacing gestures. Based on these features the diagnosis of rapid eye movement disorder was established.



sustained legal consequences from their sexual sleep-related behavior. More than half of the patients induced physical harm to others, and 6% to themselves. Men were clearly overrepresented (80%) and were the only ones to initiate sexual intercourse, whereas women preferentially engaged in masturbation or displayed sexual vocalizations. None of the patients recalled their sexual behavior the next morning. Of the seven patients with seizure-related sleepsex, only one patient displayed assaultive behavior, and two patients injured themselves, while none had sex with minors, injured others or sustained legal consequences. Males and females were equally distributed in this group, and only one third were amnesic for sleepsex.

REM sleep Behavior disorder

REM sleep behavior disorder (RBD) is characterized by a loss of normal muscle atonia and an increase of phasic muscle activity during REM sleep, and is associated with altered dream content and acting out of dreams. It is disruptive

and causes injury to the patient himself or the bed partner. RBD is more prevalent in men and after the age of 50. In 45% of cases, it represents the first manifestation of a neurodegenerative disorder including Parkinson's disease, multisystem atrophy and dementia with Lewy bodies [27]. Sleep related injuries to the patient himself or to the bed partner have been reported in 32–69% of cases [28–30] and often lead the patient to seek medical advice. They generally occur when the patient hits the furniture or walls, or falls out of bed. Violent acts can be complex, such as firing an unloaded gun, or setting fire to the bed, and can result in serious injuries, including subdural hematomas and bone fractures [28, 29, 31]. Attempted assault of sleep partners has been reported to occur in 64% of cases, with injuries in 3% [28]. Unlike violence related to disorders of arousal, in RBD the individual is readily oriented upon awakening and can generally recall vivid dream imagery related to the violent act.

Of note, dreams by patients with idiopathic and secondary RBD have a more aggressive content compared to dreams

Table 1 Distinguishing features between nocturnal seizures in nocturnal frontal lobe epilepsy (NFLE) and arousal disorders.

Features	Disorders of arousal	NFLE
Age of onset	Childhood	Childhood or adolescence
Persistence into adulthood	Rarely	Frequent
Motor features	Variable, not highly stereotyped, no dystonic posturing	Highly stereotyped, often hyperkinetic
Amnesia for event	Generally present	Generally present
Postictal confusion	Frequent	Generally absent
Duration	Generally >30 seconds	Seconds to 3 minutes
Same-night recurrence	Low	High
Timing	First third of the night	Any time of the night, often in clusters
Ictal EEG	Slow waves	Clear-cut epileptiform discharges in <10%

of normal subjects, despite lower levels of daytime aggressiveness [32]. Likewise, among patients with Parkinson's disease, those affected by RBD have more aggressive dreams compared to patients without RBD, irrespective of gender [33]. A recent study has shown that in RBD associated with Parkinson's disease, motor activity may be vigorous and fast compared to the hypokinesia observed during wakefulness [34]. This restored motor control during REM-sleep (or a dissociated state between REM sleep and wakefulness), in association with loss of REM sleep atonia and the action-loaded dreams probably accounts for the injury potential of this disorder. For a practical example see figure 1.

Epilepsy

In nocturnal frontal lobe epilepsy (NFLE), seizures can occur exclusively during sleep and be associated with violence. There are three different forms of NFLE that frequently co-exist in a single patient. *Paroxysmal arousals* consist of abrupt arousals from sleep with stereotyped motor phenomena, including head movements, frightened expressions and dystonic limb posturing. They are short, lasting less than 20 seconds, and tend to recur frequently during the night. Episodes of so called *nocturnal paroxysmal dystonia* also begin with a sudden arousal but involve more complex motor activity such as bipedal automatisms, rhythmic movements of the trunk and limbs, as well as tonic and dystonic posturing. They generally last less than two minutes. *Epileptic nocturnal wanderings* also start with an abrupt arousal, proceed through the stage of paroxysmal dystonia, and eventually culminate in deambulation. This condition generally lasts less than three minutes. The clinical manifestations of seizures are often very similar to the motor activity observed during disorders of arousal, making a distinction between the two conditions difficult. In addition, in approximately half the patients with NFLE, EEG fails to show ictal or interictal abnormalities [35]. However, establishing the correct diagnosis is crucial, as these entities differ in terms of therapy. Distinguishing features between nocturnal seizures and disorders of arousal have been reviewed by Derry [36], Nobili [37] and Tinuper [38] and are summarized in table 1. A

clinical scale has been developed with the aim to distinguish between these conditions [39]; although some items seem to limit its sensitivity [40]. Nocturnal hypermotor seizures [41, 42], including epileptic nocturnal wanderings [43], can occasionally originate from the temporal lobe.

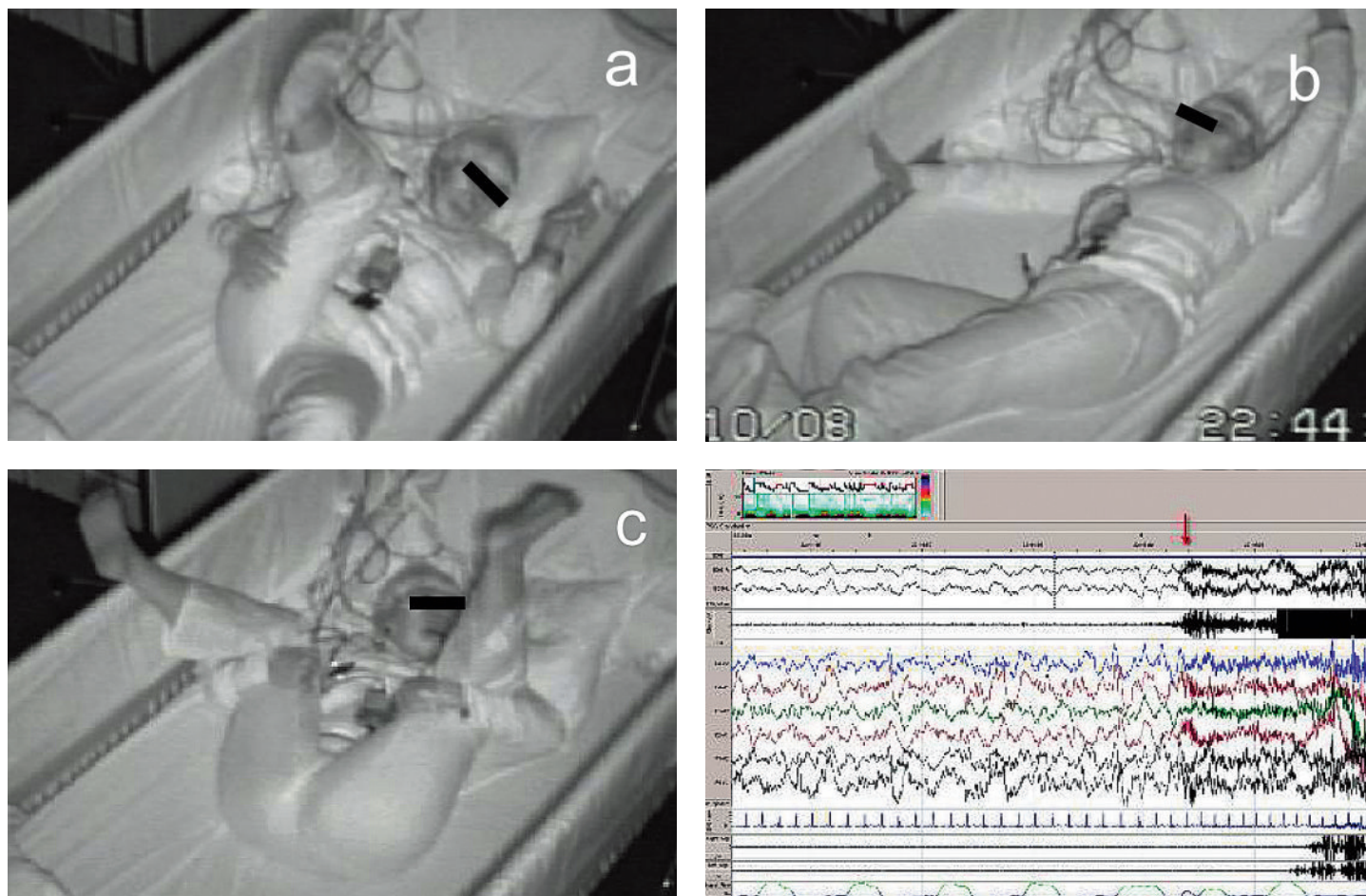
Injury resulting from nocturnal seizures can be accidental and related to hyperkinetic features [44] (figure 2), although compared to seizures during wakefulness, the injury potential of seizures occurring solely during sleep is probably lower, as the bed represents a relatively safe environment [45]. Alternatively, injury might result from aggressive, and more directed behavior as documented during episodic nocturnal wandering [25, 44, 46, 47].

More generally, violent behavior can be related to the ictal, peri-ictal and interictal period. *Ictal aggression* is exceptional [48, 49–54]. It can take the form of biting, grasping, hitting, threatening, screaming, facial expressions of anger, pushing, shoving, and spitting [48, 52]. In these circumstances the violent act is not directed towards others and does not involve intricate skills or purposeful movements. However, more directed violence can occur as a reaction to stimuli of the patient's environment and can for instance be elicited by the act of restraining the patient [48, 49]. Seizure-related violent behavior is more common in men [48, 49, 51, 54] and is associated with bilateral amygdala/hippocampal and/or ventromedial prefrontal cortex dysfunction [48]. *Peri-ictal aggression* occurs in the pre-ictal, or more commonly in the postictal period, in a setting of confusion and abnormal mood (depression, psychosis or delirium). Again, behavior is recurrent, out of character and stereotyped for a given patient, and is frequently associated with amnesia. It may also occur in a setting of postictal psychosis that typically follows a seizure after a lucid interval of hours to days. Compared to postictal confusion, postictal psychosis bears a greater potential for well-directed violent behavior [55]. *Interictal violence* is generally related to cognitive or behavioral disturbances secondary to a brain dysfunction that may also underlie epileptogenesis [56].

Nocturnal dissociative disorders

Dissociative disorders are defined as a disruption of the usually integrated functions of consciousness, memory, identity, or perception of the environment [57]. They occur without the conscious awareness on the part of the individual, are sometimes associated with violence [58] and can arise exclusively or predominantly from the sleep period [59]. In contrast to parasomnias of NREM or REM sleep, dissociative disorders occur during well established EEG wakefulness, either at the transition from wakefulness to sleep or within several minutes after awakening from stages 1 or 2 of NREM or from REM sleep [12]. Schenck and coworkers [59] determined that in 5% of patients referred for sleep-related injury, nocturnal dissociative disorder was the cause of the injuries. Patients were predominantly female (87%), had a history of sexual abuse or posttraumatic stress disorder and additional dissociative episodes during daytime (87%). Violent behavior reported in this setting included breaking windows, shredding clothes, thrashing movements, approaching a person with a knife and automutilation. One patient exclusively

Figure 2 36-year-old woman with nocturnal frontal lobe epilepsy since the age of 13. Seizures occurred up to 10 times a night and were characterized by an abrupt awakening from sleep with a feeling of chest tightness and dyspnea, and progressed to tonic posturing of the limbs and hyperkinetic features, including elevation and extension of the left arm (Fig. b) and pedaling (Fig. a and c). The patient was fully aware during the seizure but was unable to speak. She had sustained several injuries including fractures of her fingers when hitting objects during her seizures. The arrow on top of the polysomnographic recording shows the beginning of a seizure arising from slow wave sleep. Intracranial EEG recordings indicated that seizures originated from a cortical dysplasia in the left frontal cingulum.



displayed nocturnal animalistic behavior (quadrupedalism, growling, hissing) linked to a dream of being a jungle tiger. Patients were either amnesic for the episodes or recalled a dream which matched the documented behavior.

Factitious disorder

In factitious disorder (also named Münchhausen syndrome), an individual presents with an illness that is deliberately produced or falsified for the purpose of assuming the sick role. In a special form, factitious syndrome by proxy (or Münchhausen syndrome by proxy), disease is produced or feigned in another person [57]. Both disorders may occur during the sleep period and can be associated with violence. Griffith and coworkers [60] published a case of apparent nocturnal apneas, diarrhea and vomiting in a 2-month old child. Repeated polysomnographic recordings were normal. Eventually, during a hospital stay, the mother was seen administering an enema (first rectally and then orally) to the child, and the diagnosis of Münchhausen syndrome by proxy was established.

Malingering

In contrast to factitious disorder, malingering is not a mental illness, and intentionally produced symptoms or signs are motivated by external incentives for the behavior, (i.e., economic gain, avoiding legal responsibility, improving physical well-being) [57]. Again, symptoms can be referred to the sleep period, but when observed, always occur during well-established EEG-wakefulness.

Sundowning

In patients with dementia, confusion and wandering frequently increase during late afternoon and evening and improve during the day ("sundowning"). This phenomenon occurs in approximately half of the patients with Alzheimer's disease, has been shown to predict cognitive decline and can be associated with disruptive behavior [61].

Physiopathology

Time and again, attempts have been made to develop biological explanatory models for violent and sexual offenses. With the availability of modern imaging techniques, neurobiological phenomena have shifted more and more towards the center of attention. In this context, various researchers have supported the theory that offenses, in general, result from neurobiological deficits [62–64]. Particularly for violent behavior, emphasis has been placed on prefrontal lesions or disorders of emotional processing [65–67]. Following the neurobiological causality theory of criminal behavior, the authors came to the conclusion that criminal behavior is – in principle – neurobiologically determined and that the entire individual responsibility is therefore detracted from the offender [62–64]. However, it has been demonstrated that both the theory of neurobiological causality and the theory of neurobiological determinism can be traced back to several methodical misunderstandings and cannot be perpetuated in this form [68].

It is important to consider that there are very diverse forms and mechanisms of violent and sexual offenses, which differ in regard to development and etiology. In order to demonstrate relationships between individual subgroups, it would be necessary to examine a multitude of variables for very large and homogeneous populations, as – from experience – numerous interdependencies exist, especially in the areas of forensic research. Such studies are not available. Generally, for most forms of violent behavior, specific personality traits are important. These can be displayed in the form of prognostic syndromes; as risk dispositions individual to a personality. In the sense of relative determinism, these risk dispositions are associated with a certain probability for specific forms of violent behavior. The question arises, however, as to whether any of the biological parameters actually play an etiological role or whether they are simply more likely the result of a risk-relevant personality trait. Sleep-related violence is distinctly different from any other form of violent and sexual delinquency, in as much that biological and physiopathological mechanisms are of particular importance. For this reason, these parameters will be described in the following section, despite their limited explanatory power in general.

Testosterone and genetics

Epidemiological studies indicate that male gender is the most consistent risk factor for violence [69], suggesting the involvement of testosterone as a causal factor. While a direct link between aggressive behavior and testosterone has been demonstrated in animals [70, 71], this link is very weak and inconsistent in humans [72]. Other variables associated with violence include unemployment, alcohol abuse, a lower educational level and access to firearms [69, 73]. A genetic background of violence is suggested by the higher concordance of violent behavior in monozygotic twins compared to dizygotic twins [74–77], and this has been confirmed by studies evaluating twins reared apart [78].

Anatomic substrates for violence

Among the anatomic substrates of violence, the prefrontal and temporal lobes play a major role. Involvement of the anterior temporal lobe in aggressive behavior was initially suggested by Klüver and Bucy [79], who showed that bilateral amygdala ablation in monkeys resulted in placidity; an observation that was later described in humans with bilateral anterior temporal lesions [80]. Another study identified an increased occurrence of lesions in the anterior inferior temporal lobe in violent patients with organic mental syndrome compared to non violent patients of the same group [81]. As discussed above, aggressive behavior may be a feature of temporolimbic epilepsy [82].

Within the prefrontal cortex, the medial prefrontal and orbitofrontal regions seem to be selectively implicated in the control of aggressive behavior. Dysfunction in these areas is indicated by impaired emotional recognition of faces, errors in odour identification and disadvantageous decisions in gambling tests, all of which have been observed in patients with impulsive aggressive disorder; while working memory, an indicator of dorsolateral prefrontal dysfunction, was comparable to control subjects [83]. Olfactory dysfunction as a measure of orbitofrontal dysfunction has also been shown to correlate with impulsivity and physical aggression in patients with PTSD [84]. Further evidence for the involvement of these areas is suggested by the finding that head injuries in Vietnam veterans were associated with violence if localized to the frontal ventromedial or orbitofrontal regions [85]. Likewise, individuals with intermittent explosive disorder exhibit exaggerated amygdala activity and diminished activation of the orbitofrontal cortex in response to faces expressing anger, and fail to demonstrate coupling between these two structures [86].

According to functional models [8], the amygdala and the orbitofrontal lobe act on subcortical systems mediating reactive aggression. While the role of the amygdala is to up- or downregulate their responsiveness to threat, the orbitofrontal cortex exerts its modulating activity in response to social clues, including frustration, expressions of anger, staring and social disapproval.

Neurotransmitters

Despite a number of candidate molecules that have been identified with regard to violent behavior, the most consistent evidence focuses on serotonin and catecholamines. While serotonin seems to have an inhibitory effect on impulsive aggression, catecholamines are thought to act as a facilitating factor [10]. Impulsive violent offenders, for instance, have been shown to have lower cerebrospinal fluid concentrations of serotonin metabolites compared to non impulsive violent offenders [87], and these findings were later supported by other measures of serotonin function [10]. Additionally, fluoxetine, a selective serotonin reuptake inhibitor, is associated with an improvement in anger and aggression, both towards oneself and others [88]. Another study showed that induced hostile behavior was associated with an increase in basal norepinephrine levels in a group of violent individuals [89]. Moreover, reductions in assaultive behavior

have been observed after the administration of propranolol, a non selective beta-blocker antagonizing the action of epinephrine, in a double blind, placebo controlled crossover study in patients with organic brain disease [90]. Elevated levels of aggression have been shown in mice lacking monoamine-oxidase A and catechol-O-methyltransferase (COMT) [91, 92], two enzymes involved in degradation of norepinephrine and dopamine. In humans, polymorphisms in the MAO-A gene seem to be associated with violent behavior and linked to changes in brain structure and function. A low expression of MAO-A variant has been shown to increase the risk of violent behavior and to be associated with volume reductions in the limbic system and hyperresponsiveness of the amygdala during emotional arousal. In the same study, regulatory prefrontal areas showed diminished reactivity compared to the high expression allele group [93]. Likewise, violence seems to be associated with low COMT activity in violent schizophrenic patients [94]. Additional evidence for the role of dopamine in violent behavior comes from a study that found increased levels of homovanillic acid, a dopamine metabolite, in the CSF of violent offenders [95]. Another study documented a rise in dopamine efflux and a decrease of serotonin efflux in the nucleus accumbens in rats when anticipating an aggressive confrontation [96].

Automatisms arising from central pattern generators

In the aforementioned parasomnias and epileptic disorders, highly complex motor activity occurs in the absence of awareness, suggesting a deactivation of cortical structures crucial for judgment and consciousness. In fact, a series of complex behavior sequences can be generated by brainstem structures alone, without the involvement of cortical regions [97–99]. These brainstem centers are called central pattern generators and control stereotyped innate motor behavior necessary for survival, such as locomotion, swimming, sexual activity and other rhythmic motor sequences. Aggressive behavior probably represents an innate action pattern aimed at the defense of the peripersonal space [48].

Activation of central pattern generators probably underlies a series of behaviors observed in the course of parasomnias (such as sleepsex, nocturnal eating disorder, bruxism, sleepwalking and sleep-related violence) and seizures (ictal biting, grasping, oro-mandibular automatisms, locomotor activity, facial expressions of fear, and vocalizations). The involvement of central pattern generators in both conditions might result from a final common pathway involving the cingulum, as suggested by imaging studies [100, 101], which could also explain their similar semiology [102].

Occurrence of violence during sleep

As outlined above, aggression is modulated by the temporal (i.e., the amygdala) and frontal lobes (i.e., the orbito-frontal and medial prefrontal areas) and lesions in these areas might lead to unwarranted aggressive behavior. Imaging studies have shown that during NREM sleep, there is hypoactivity of the prefrontal lobe that is particularly marked in the dorsolateral and orbital prefrontal regions, and less consistently in the associative cortices of the temporal and insular

lobes [103]. This frontal, and in a lesser extent temporal, deactivation and its resultant impairment in judgment, purposeful behavior and inhibition of emotional responses might account for the propensity of sleep to generate violent behavior.

Additionally, for violence to occur during sleep, features of both sleep and wakefulness must be present. If the frontal hypoactivity arises in the context of “mind sleep”, what is the origin of the “body wakefulness”? Insight comes from a study, in which SPECT imaging was performed during an episode of sleepwalking, and demonstrated hyperperfusion of the posterior cingular cortex and cerebellar vermis and decreased cerebral blood flow in the frontal and parietal association cortices [100]. It is thus conceivable that this “dissociation of states” results from the selective activation of thalamo-cingulo-pathways implicated in the control of complex motor and emotional behavior, and from hypoactivation of other thalamocortical pathways, including those projecting to the frontal lobes.

In conclusion, reactive violence probably represents a genetically programmed innate behavior arising from central pattern generators located in the brainstem. Its occurrence is modulated by the prefrontal and temporal lobes. The association with sleep-related disorders is favored by hypoactivity of the prefrontal areas, and selective activation of pathways involved in complex emotional and motor behavior.

Diagnostic procedures

The first step in diagnosing a sleep disorder associated with violence is obtaining a complete history, if possible, from both the patient and the bed partner. Particular emphasis should be placed on identifying the key features that allow a distinction between the different sleep disorders that have been discussed earlier (see table 2). Information on sleeping and waking habits, comorbidities (particularly neurological and psychiatric conditions) and drug intake should also be obtained. Depending on the suspected diagnosis, the history might be complemented by clinical scales, such as the REM Sleep Behavior Disorder Screening Questionnaire [104] or the Nocturnal Frontal Lobe Epilepsy and Parasomnia (FLEP) Scale [39]. History should be followed by a general physical, neurological and psychiatric examination, and in case of suspected cerebral lesions, by imaging investigations of the brain and neuropsychological testing. Documentation of nocturnal episodes with home videos using a camera with infrared night vision function might be helpful, as various sleep disorders such as sleepwalking often fail to occur in a laboratory setting.

An extensive polygraphic study with a multichannel scalp EEG, electromyographic monitoring of all four extremities and continuous audiovisual recording is however necessary for diagnosis. Video-EEG-Polysomnography is superior to standard polysomnography for the evaluation of parasomnias because of the increased capability to identify and localize EEG abnormalities and to correlate behavior with EEG and polysomnography [105]. Even if they fail to capture the event, long-term recordings are useful to identify typical or specific interictal EEG markers. Sleep architecture

Table 2 Characteristics of disorders with potential for sleep related violence.

Disorder	State of occurrence	Clinical features	Normal occurrence of violence
Confusional arousals	Dissociation wake/NREM sleep	Incomplete awakening, reduced vigilance, impaired cognition and amnesia for the event	When being awakened from sleep
Sleepwalking	Dissociation wake/NREM sleep	Similar to confusional arousals but with deambulation	On an incidental encounter or when approached by another person
Sleep terror	Dissociation wake/NREM sleep	Incomplete awakening from NREM-sleep with manifestations of fear	Linked to a frightening dream image
Rapid eye movement disorder	Dissociation wake/REM sleep	Acting out of dreams	In relation to a dream that is being acted out
Nocturnal paroxysmal dystonia	Possible in all sleep stages, preferentially stage NREM2	Bipedal automatisms, twisting of trunk and pelvis, vocalizations, dystonic posturing of head/limbs	Accidental or in relation to hyperkinetic features of seizures
Epileptic nocturnal wandering	Possible in all sleep stages, normally in stage NREM2	Similar to sleepwalking, more directed, violence possible	Accidental or when approached or restrained by another person
Confusional states	Wake	Variable	Variable
Psychiatric dissociative states	Wake or wake/sleep transition	Variable, most frequent manifestation is wandering, generally amnesia for the event	Often automutilation, trashing movements, assaults
Malingering	Wake	Variable; associated with primary or secondary gain	Variable

is essentially normal in patients with arousal disorders [106–108] but may show increased numbers of arousals or fragmentation of slow wave sleep, in particular in the first NREM-REM sleep episode [109, 110]. Hypersynchronous delta activity (HSD), consisting of bilateral rhythmic, delta-waves occurring for 10–20 seconds during slow wave sleep, is considered as a typical but non-specific EEG marker for arousal disorders. The low specificity of HSD is due to the fact that it also occurs in up to 66% of normal arousals [107, 108]. Documentation of epileptic potential is diagnostic and specific in patients with suspected nocturnal seizures. Unfortunately, certain areas of the frontal lobe (e.g., the medial and orbital cortex) are not accessible to surface EEG recordings, so that interictal epileptic potentials cannot be documented in up to 60% of cases [111, 112]. Even ictal recordings remain inconclusive in 20–40% of cases due to overlapping motor artifacts [113–115]. Polysomnographic recordings are also useful in identifying coexistent sleep disorders, which may act as trigger for parasomnias and require specific treatment (i.e., sleep apnea as a trigger for sleepwalking). Prior sleep deprivation has been shown to increase the diagnostic yield of these studies [16, 17]. Technicians are often of great help, as they can give information on possible precipitating factors of events (e.g., noise) and can interact with the patient after the event in order to assess postictal confusion or dream recall. Additional daytime EEG, preferentially after sleep deprivation, should be carried out in patients with suspected seizures.

Treatment

Treatment is aimed at the specific etiology. In all cases, the environment of the sleeping patient should be made safe. This can be accomplished by advising sleeping on the first

floor or in the basement, securing doors and windows, and removing potentially dangerous objects from the bedrooms.

In disorders of arousal, any underlying trigger or precipitating factor should be treated or avoided, (i.e., coexisting disorders such as sleep apnea, but also touching or waking up the patient). The first choice of drug in this setting is clonazepam, which should be started at a dosage of 0.5 mg at bedtime, and progressively increased up to 2–3 mg. Other benzodiazepines (including triazolam, diazepam and flurazepam), antiepileptics (including carbamazepine, phenytoin and gabapentin) and antidepressants (including imipramine, trazodone and paroxetine) as well as melatonin have shown to be effective, although data relies on small case series or single cases [5]. Behavioral treatments such as hypnosis can also be effective [116].

In the case of RBD, clonazepam is usually very effective, with reported success rates between 87 and 90% [28, 117]. Although it is generally regarded as safe, this drug should be used with caution in elderly patients because of the risk of falling and developing a confusional state. It is also associated with a worsening of obstructive sleep apnea syndrome. Alternatively, melatonin is an option, especially in patients with multiple comorbidities.

Nocturnal seizures require specific antiepileptic treatment. In case of NFLE, carbamazepine is the treatment of choice.

Forensic issues

When assessing criminal responsibility, it is necessary to establish whether relevant psychological dysfunctions were present at the time of the offense. There are, however, neither mental disorders nor psychological symptomatology that mandatorily lead to a diminished criminal responsibility.

Table 3 Criteria for establishing the role of an underlying sleep disorder in a violent act.

Presence of an underlying sleep disorder – presence of solid evidence supporting the diagnosis – previous occurrence of similar episodes
Characteristics of the act – occurs on awakening or immediately after falling asleep – abrupt onset and brief duration (lasting minutes) – impulsive, senseless, without apparent motivation – lack of awareness of individual during event – victim: coincidentally present, possible arousal stimulus
On return of consciousness: – perplexity, horror, no attempt to escape – amnesia for event
Presence of precipitating factors – attempts to awaken the subject – intake of alcohol or sedative/hypnotic drugs – prior sleep deprivation

Existing symptoms and associated psychological dysfunctions must always be assessed in relation to the timing and characteristics of the offense. Possible deficits in psychological functions contrast with perceivable abilities in the areas of will-formation, decision-making, thought, perception, as well as steering and control of behavior. In this context, the spectrum of possible actions available to the offender, along with a precise behavioral analysis, is at the center of attention when assessing criminal responsibility. Here, behavior is examined using both intra-individual and inter-individual comparison studies. In doing so, the entire life history of the offender, his personality and in particular the characteristics of the offence itself are taken into account [68]. Sleep-related automatisms that occur in the course of parasomnias or seizures usually qualify for diminished responsibility because the person is not conscious of his act, its consequences and of the fact that it is wrong. However, applying this concept to a particular act can be problematic for a variety of reasons. Firstly, there are several degrees of consciousness, with numerous transitions between normal and pathological sleep [118], and establishing the exact level of consciousness retrospectively with regard to a particular act is sometimes impossible. Secondly, there is currently no diagnostic tool that enables the diagnosis of an underlying sleep disorder with absolute certainty, and even if there was one, the presence of a sleep disorder does not necessarily establish a causal link to the committed act.

Criteria for establishing the putative role of an underlying sleep disorder in a specific violent act have been proposed by Mahowald and coworkers (table 3). They include [119]: 1) good evidence for an underlying sleep disorder, with similar episodes having occurred previously, 2) a brief duration of the act (lasting minutes), 3) that the behavior has an abrupt onset, is immediate, impulsive, senseless, without apparent motivation, inappropriate, out of character for the individual, and without evidence of premeditation 4) the almost coincidental presence of the victim, who may have acted as a stimulus for the arousal, 5) the behavior after the return of consciousness (perplexity, horror, no attempt to escape) and the lack of awareness on the part of the individual during the event 6) the presence of some degree of amnesia for

the event 7) in the case of disorders of arousal, the timing of the act in relation to sleep (on awakening or immediately after falling asleep) and the presence of precipitating factors (attempts to awaken the subject, alcohol ingestion, sedative/hypnotic administration, prior sleep deprivation).

The presence of a sleep-related violent offense must be distinguished from a simulation. Along with a thorough analysis of the behavioral pattern, one must examine whether the offender possesses a personality profile relevant to risk, from which a plausible offense mechanism can be derived. As soon as an offense can plausibly be explained through the offender's risk disposition, the assumption of a sleep-related violent offense becomes more unlikely. From a forensic-psychiatric perspective, a robust offense hypothesis must (1) reconcile all the important findings with as many aspects of the offense as possible and be able to explain them consistently (explanatory value), (2) be consistent within itself and plausible from a professional point of view, regarding forensic-psychiatric criteria (plausibility) and (3) be corroborated by the evidence at hand (e.g., the results of the preliminary investigation, witness accounts, findings of the psychiatric evaluation) in such a way that all relevant information has been considered and the hypothesis can be sustainably deduced from the available evidence (corroboration). Against this background, it is advisable, in case of sleep-related violent offenses, not to base an assessment of criminal responsibility solely on the medical findings of the offenders sleep patterns. Rather, an additional, extensive forensic-psychiatric evaluation is required.

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