Nocturnal visual hallucinations in patients with disorders of arousal: a novel behavioral and EEG pattern

**Aim** To investigate clinical and video-polysomnography (VPSG) findings of hallucinatory experiences in patients suffering from disorders of arousal (DOA) in the absence of other pathologies.

**Methods** The authors retrospectively reviewed the records of 370 adults with DOA. Thirty (8.1%) patients concomitantly reported complex nocturnal visual hallucinations. VPSG recordings were scrutinized, and motor behavioral and electroencephalogram (EEG) patterns were classified according to previous descriptions of DOA.

**Results** Thirty DOA patients also reported seeing images of objects, people, and animals; either distorted, static, or mobile. The images disappeared with increased illumination in 80% of patients, and 23.3% reported preceding dream imagery. In addition to the classical DOA patterns on VPSG, a distinct pattern of behavioral and EEG manifestation associated with complex hallucinatory episodes was identified in 16 (53.3%) DOA patients. This consisted of low-voltage mixed-frequency EEG activity before eye opening that persisted while patients were observed staring or visually tracking before the onset of motor behavior.

**Conclusion** A novel, distinct behavioral and EEG pattern in patients with DOA and history of reported complex nocturnal visual hallucinations was identified. This may represent a unique phenotype of dissociation between sleep states that merits further investigation.
Disorders of arousals (DOA) are a group of non-rapid eye movement (NREM) parasomnias believed to arise from an incomplete arousal from slow-wave sleep (SWS). Inappropriate or reduced responsiveness to external stimuli and partial to complete amnesia are commonly reported (1). These are believed to reflect an underlying dissociative state where sleep and wake coexist across different brain regions (2-7). Frequently, individuals suffer from more than one DOA subtype, and parasomnias emerging from different sleep stages can occur in the same individual (8). Classically, DOA were believed to be characterized by limited or absent dreams and cognition, but several recent studies have cast doubt upon this view, reporting several cases of mentation but also complex narrative, structured dreams during the episodes of DOA (9-11). Some authors have additionally proposed that the brief scenes of mentation during DOA could be more similar to hallucinations from slow-wave sleep than to typical dreams (12).

Historically, there is a lack of clear definition and distinction between dreams and hallucinations (13-15). This may be due to their similarities, a possible similar pathophysiological mechanism, and to the difficulty in being described by patients and how these descriptions are interpreted (15).

Specifically, hallucinations are defined as sensory perceptions that occur in the absence of an actual external stimulus (14). Classically, sleep-related hallucinations are associated with sleep onset or sleep offset (hypnagogic and hypnopompic) (1), and often within the boundaries of REM-related phenomena that may be normal (16) or may be related to central disorders of hypersomnolence (17). In addition, a subtype of sleep-related hallucinations have been defined as complex nocturnal visual hallucinations (CNVH), which are phenomena that occur following an abrupt arousals and are associated with complex vivid images and are also known to occur in the presence of other neurological/medical disorders (1).

Besides this clear definition of sleep-related hallucinations, some hallucinatory experiences have been described in association with other sleep disorders. In fact, comparative experiences have been effectively reported in the literature in conjunction with sleepwalking and other complex behaviors (18-21).

Visual hallucinatory experiences occurring during DOA episodes have been sparsely described in the literature. Therefore, the aim of this study was to investigate the clinical and video-polysomnographic features of hallucinatory experiences in a cohort of patients with DOA in the absence of other pathologies, including neurological, psychiatric, and eye disorders.

METHODS

We retrospectively reviewed patients’ records in the sleep disorder center’s clinical database between August 2017 and May 2020. Among 370 adult patients with a diagnosis of DOA, 30 patients (mean age 33 ± 6.2 years, 21 women) were identified who concomitantly presented with a complaint of nocturnal visual hallucinations. Patients were excluded if they reported hypnagogic and hypnopompic hallucinations occurring in isolation or associated with sleep paralysis or other features of REM dysregulation and central disorders of hypersomnolence. Patients with psychiatric, neurologic (eg, neurodegenerative disorders and other disorders that can present with hallucinations), and eye diseases were also excluded.

Polysomnography evaluation

All patients underwent a single-night videopolysomnography (VPSG) recording in the sleep center. This included six electroencephalogram (EEG) channels (F3/A2, C3/A2, O1/A2, F4/A1, C4/A1, O2/A1), bilateral electrooculogram (EOG), submental and bilateral anterior tibialis electromyogram (EMG) (20 patients). Ten patients underwent extended 10-20 montage EEG recording (EEG; FP1, FP2, F7, F3, Fz, F4, F8, T3, C5, Cz, C4, T4, T5, P3, Pz, P4, T6, O1, O2) due to the clinical judgment of their respective physician. Respiration was monitored by using nasal cannula with nasal pressure transducer, thoraco-abdominal respiratory inductance plethysmography, and pulse oximeter. Studies were scored by expert somnologist technologists according to AASM criteria (22).

Clinical review

The cases were further comprehensively reviewed through analysis of medical records and VPSG recordings. All recordings were additionally reviewed in the multidisciplinary team meeting with neurophysiologists in order to rule out any underlying epileptic abnormalities. We reviewed morning questionnaires given to all patients following their sleep study, as per standard sleep center’s protocol. Morning questionnaires are semi structured, self administered, and contain open-ended questions with elements of the Hall and Van der Castle dream coding system (23). Items relating to recall of events and specific
Some disturbing imagery was described, including shadows or people with distorted or featureless faces standing immobile in the corner of the room or moving toward the patient. Human characters could be in the form of children, men, or women, usually unknown to the patient, and they could be standing over the patient or sitting on the edge of the bed. These figures were sometimes also reported to interact with the environment. For example, patients reported that they had seen people rummaging through their belongings. Other examples included seeing animals, cats, mice, or insects crawling on the walls, ceiling, or even the bed. Another patient reported that a large spider, the size of a cat, was sitting on their chest. Objects hanging from the

### Table 1. Demographics and clinical presentation (N = 30)*

| Demographics                              | N     | %    |
|-------------------------------------------|-------|------|
| Age, years, mean (SD)                     | 33 (6.2) |     |
| Body mass index, kg/m², mean (SD)        | 24 (4) |      |
| Epworth sleepiness score, /24, mean (SD) | 8.5 (6.7) |     |
| Male                                      | 9     | 30   |
| Female                                    | 21    | 70   |
| Event frequency                           |       |      |
| high (>1 per night)                       | 5     | 16.7 |
| moderate (<1 per night, >3 per week)     | 7     | 23.3 |
| low (>1 per week, <3 per week)           | 15    | 50   |
| very low (<1 per week)                   | 3     | 10   |
| Parasomnias                               |       |      |
| past reports of DOA hallucinations       | 30    | 100  |
| sleepwalking                              | 22    | 73.3 |
| sleep terrors                             | 22    | 73.3 |
| confusional arousals                      | 3     | 10   |
| sleeptalking                              | 19    | 63.3 |
| childhood history                         | 23    | 76.7 |
| Other presenting sleep complaints         |       |      |
| none                                      | 16    | 53.3 |
| history of insomnia                       | 5     | 16.7 |
| history of nightmares                     | 4     | 13.3 |
| history of sleep paralysis                 | 3     | 10   |
| history of RLS                            | 3     | 10   |
| history of suspected OSA                  | 2     | 6.7  |
| excessive daytime sleepiness              | 3     | 10   |
| history of bruxism                        | 1     | 3.3  |
| Hallucination characteristics             |       |      |
| people/shadows of people                 | 27    | 56.7 |
| insects                                   | 10    | 33.3 |
| animals                                   | 5     | 16.7 |
| objects                                   | 4     | 13.3 |
| disappear with illumination              | 24    | 80   |
| interaction with images                   | 16    | 53.3 |

*Abbreviations: OSA – obstructive sleep apnea; RLS – restless legs syndrome; SD – standard deviation.
ceiling or emerging from wardrobes, mirrors, or cupboards were also described. Macropsia was noted; for example, one patient reported a spherical microphone lowering down from the ceiling and increasing in diameter as it was getting closer. Seven (23.3%) patients were able to recall dream imagery preceding the hallucination episodes, while the remainder were unsure or had no recall of previous dreams (76.6%). Interestingly, dream imagery was commonly related to the subsequent visual hallucinatory images but no underlying unfolding plot or narrative story was recalled.

Patients reported only a partial early insight, with hallucinatory images initially generating significant fear and distress. This would subside after a few seconds or minutes, when they became aware that they were experiencing their “visions”. This usually coincided with presumed full wakefulness and awareness, and the patients would turn on the light and, on occasion, leave the bed to investigate.

Videopolysomnography findings

Videopolysomnography analysis was only remarkable for the DOA diagnosis, with no other overt sleep pathology identified despite other additional sleep complaints at presentation. In 14 patients (53.5%), classical DOA patterns were recorded during VPSG and were characterized by sudden arousals from slow-wave sleep (Figure 1). However, in 16 (53.5%) patients, alongside classical DOA features, an additional, novel pattern of EEG and behavioral manifestations corresponding to the hallucinatory episodes was identified (Figures 2 and 3).

During DOA episodes, previously described post-arousal EEG patterns (24,25) were identified on the basis of predominant slow or fast activity or intermixed activity between the two. More specifically, we found three distinct patterns: 1) diffuse, rhythmic delta activity; 2) diffuse delta and theta activity intermixed with alpha and beta activity; and 3) prominent alpha and beta activity.

Behavioral patterns were also identified with differing complexities, ranging from simple movements, including eye opening and head raising, to more complex motor behaviors involving ambulation. These patterns are consistent with previous descriptions by Loddo et al (26). Among the group that did not demonstrate the novel pattern, 12 patients had typical DOA behavioral manifestations characterized by simple behaviors (eg, eye opening and head raising). However, complex behaviors including sitting up, interacting with the environment, or attempting ambulation were also noted in 2 patients. Eleven patients experienced more than one episode during the VPSG.

FIGURE 1. Typical disorder of arousal episode. Upper figure depicts a 30-second epoch from video-polysomnography (VPSG) showing the episode arising from N3 sleep. Motor activity onset corresponds with the electroencephalogram (EEG) artifact, increased electromyogram (EMG) tone on submental and anterior tibialis EMG and movement artifact on respiratory effort bands. Following the resolution of the artifact there is clear intermixed alpha/delta activity in the frontal and central regions, with the eyes remaining open. Lower sequence presents snapshots of the event. The patient is in N3 sleep then suddenly raises her head and trunk with eyes open and looks around the room before lying back down in the supine position with eyes open.

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A completely distinct EEG and behavioral pattern was found in 16 patients. This EEG and behavioral pattern differed from the abrupt-onset pattern typically seen in DOA, and it differed from the three typical post-arousal EEG patterns. Specifically, in this group of DOA patients, after an arousal from NREM sleep, patients were seen to open their eyes, stare or visually track while remaining still for a period of time. Subsequent to this, they exhibited motor behaviors of varying complexity, from simple to complex. Out of 16 patients in this group, 12 manifested simple behaviors that involved eye opening and raising the head and or trunk from the pillow. The patients were seen to be staring at a point in the room or visually tracking (Figure 2). Four out of 16 DOA patients demonstrated complex behaviors, which included sitting upright in the bed, appearing to reach out for something, or interacting with the environment (Figure 3). In regards to the post-arousal EEG pattern, in all 16 patients, an EEG arousal was followed by a one- to six-second delay until eye opening. This quiescent behavioral period coincided with diffuse low-voltage mixed-frequency activity comprising theta intermixed with alpha, which remained stable and artifact free for another one to 12 seconds, until the onset of motor behavior obscured the EEG. Concomitantly, a rapid increase in heart rate was observed. Subsequently, once movement and muscle artifact resolved, an awake EEG was observed for up to three minutes, with EEG returning to N1 sleep in all recorded episodes. From initial arousal to the return to sleep, events lasted from between eight seconds to three minutes (Figures 2-3).

VP5Gs of 30 DOA patients were further compared based on the distinct EEG and behavioral patterns observed. Specifically, those who demonstrated the novel EEG and behavioral pattern were compared with those who did not. Differences between the two groups were not significant regarding sleep parameters (Table 2). However, patients who exhibited the novel EEG and behavioral pattern were predominantly female (N = 13). Notably, 7 patients had full recollection of the episodes the morning after the VP5G and they were patients who demonstrated the novel hallucinatory pattern.

Some examples of complex hallucinatory experiences include the following episodes. For instance, during one event, the patient grabbed their t-shirt that was near their pillow and repeatedly swatted at something in the air. Dur-
ing this episode they were heard to shout and swear and appeared quite distressed. In the morning, they recalled the episode and described seeing a sinister person in the room by the wardrobe that began to move toward them. Another patient was seen to stare at a specific spot in the corner of the room, in the dark, before raising their head and trunk while continuing to stare at the same point. They then reached for their mobile phone to turn on the torch and shone the light in the direction of their gaze (Figure 3). Shortly after illumination, the patient laid down in the supine position and relaxed. The EEG correlate subsequently showed awake alpha rhythm. In the morning they recalled having seen children in the room.

DOA events in all 30 patients were recorded during the first two NREM cycles in VPSG but there was no identifiable temporal relationship between the events (between typical DOA and the hallucinatory episodes). All sleep parameters and arousals characteristics are shown in Table 2.

DISCUSSION

This study showed for the first time a distinct post-arousal EEG and behavioral pattern in patients with DOA during their ongoing hallucinatory experiences. This pattern significantly differs from the traditional VPSG pattern of parasomnic events. Thus, it can be hypothesized, that as such, it may reflect the underlying mechanism of ongoing hallucinatory experiences in the DOA patients.

In this study, in all 16 patients, the EEG and temporal semiology of recorded hallucinations was strikingly similar. All events were from N3 sleep, and shared a similar post-arousal EEG and temporal behavioral pattern. For instance, all patients, after a varying delay, appeared to open their eyes and to visually track for a period of time before more complex behaviors started. The distinct post-arousal EEG pattern comprised of diffuse, initially mixed, low-voltage frequencies including theta and alpha, which subsequently progressed into wake EEG activity. This is in sharp contrast with the typical abrupt-onset and the post-arousal EEG patterns that are historically described and associated with DOA episodes (24,25). These results may support the assertion that in patients suffering from DOA, hallucinatory experiences may represent other features of a dissociation of states occurring during the DOA episodes.

DOA represent a form of sleep-wake state dissociation (2,11,27,28). During transitions between NREM sleep and wakefulness, in predisposed subjects, a dissociation of states can occur among different brain structures manifesting as DOA episodes (2,11). It has been similarly argued that DOA may be disorders of transition from slow-wave sleep to REM sleep (29,30). The common agreement would

![Figure 3. Hallucination episode arising from N3 sleep. Upper figure shows three consecutive 45-second epochs of video-polysomnography (VPSG). Lower figure shows a sequence of snapshots of the event. Eye opening follows arousal by 3 seconds and corresponds with a change in electroencephalogram (EEG) demonstrating mixed frequencies and increase in muscle tone. After a 4-second delay, the patient abruptly raises her head and trunk and begins to stare at a specific point in the corner of the room. She then reaches for her mobile phone to illuminate the corner of the room that she is staring at during the entire episode. Shortly after illumination, the patient returns to a supine position and relaxes (resolution of artifact), and the EEG demonstrates clear alpha rhythm.](https://www.cmj.hr)
state that dissociation between states can be the key feature of several sleep disorders (3,5,7). The dissociation may rise from prevailing wakefulness, prevailing NREM sleep, and from REM sleep, and it is caused by the intrusion of features of other stages into the ongoing state (6,31). For instance, sleep-related hypnagogic and hypnopompic hallucinations are considered to be dissociative phenomena as well, in which REM imagery intrudes into wakefulness or into a relatively high level of arousal (32), most likely at the transition between wakefulness and sleep and vice versa (6). They represent one of the cardinal features of narcolepsy (17,33), although they also occur in around 25%-37% of the general population (34), and are difficult to differentiate from dream-related experiences (15).

Another distinct form of sleep-related hallucinations are the so-called CNVH (1), characteristics of which are shared by this group of patients. However, CNVH are commonly associated with other central nervous system pathologies, including midbrain and diencephalic disorders (peduncular hallucinosis) (35-37), visual impairment (eg, Charles Bonnet syndrome) (38), and neurological disorders (Parkinson’s disease and Lewy body dementia) (37,39), which were not present in this group of patients. Nonetheless, some patients with CNVH also have comorbid NREM parasomnias (40). CNVH often take the form of vivid mobile or immobile images of animals or people, sometimes distorted in shape, typically occurring following a sudden awakening and often, they are initially perceived as being real and frightening (1,21,41). CNVH have also been reported to cease with an increase in the background illumination (1). In keeping, 80% of this cohort of patients reported disappearance of imagery when turning lights on. This may suggest that illumination levels, visual processing mechanisms, as well as arousal mechanisms and the length of the events moderate hallucinatory experiences and their subsequent recall (19,37,38). It is therefore possible that the episode resolves with the increased level of arousal, with gained insight, and the recovery of the visual input.

Furthermore, among the patients reporting to ‘suddenly see’ things at varying frequencies during the night, only

| TABLE 2. Clinical and video polysomnography findings* |
|-----------------------------------------------|
|                                           | With hallucinations (N = 16) | Without hallucinations (N = 14) | P |
| Clinical data                              | N                           | %                          | N  | %  |      |
| Age in years, mean±SD                      | 33 ±5.18                    | 35 ±7.35                   | 0.667 |
| Gender (M-F)                               | 13-3                        | 8-6                        | 0.035 |
| Recall                                     | 7                           | 43.75                      | 0   | 0  |      |
| >1 episodes                                | 12                          | 75                         | 11  | 78.6 |      |
| DOA pattern                                 | simple behavior             | 13                         | 81.2 | 12  | 85.7 |
|                                            | complex behavior            | 3                          | 18.8 | 2   | 14.3 |
| Hallucination pattern                       | simple behavior             | 12                         | 75  | n/a | n/a |
|                                            | complex behavior            | 4                          | 25  | n/a | n/a |
| Sleep parameters, median (IQR)             | 484.6 (471.1-531.9)         | 472.5 (449-506.7)          | 0.131 |
|                                            | 460.8 (449.1-507.3)         | 452.8 (422.5-493.8)        | 0.58 |
|                                            | 407.2 (377.1-460.8)         | 392 (358.9-429.1)          | 0.473 |
|                                            | 54.6 (37.3-73)              | 59.3 (33.8-109.6)          | 0.822 |
|                                            | 21.8 (13.5-28.4)            | 12.8 (8.9-20.3)            | 0.142 |
|                                            | 85.1 (813-88.3)             | 79 (72.6-89.3)             | 0.4  |
|                                            | 8.3 (5.7-11.2)              | 12.3 (4.1-13.7)            | 0.44 |
|                                            | 41.3 (34.8-48.6)            | 44.2 (38.1-54)             | 0.423 |
|                                            | 278 (22.3-33.2)             | 24.8 (18.27-2)             | 0.8  |
|                                            | 20.4 (18.2-24.5)            | 21 (17.7-23.3)             | 1    |
|                                            | 15.7 (11.5-21.2)            | 13.5 (8.1-16.2)            | 0.2  |
|                                            | 0.7 (0.3-1.9)               | 0.4 (0.0-3.1)              | 0.88 |
|                                            | 0.4 (0.0-1.1)               | 0.5 (0.0-2.4)              | 0.64 |
|                                            | 1.6 (0.2-6.9)               | 0.7 (0.0-6)                | 0.38 |

*Abbreviations: DOA – disorder of arousal; SD – standard deviation; IQR – interquartile range.
7 of the 16 patients reported having had their usual episodes during the VPSG. The 4 patients who exhibited complex motor behavior during the episodes reported full recall of the visual hallucination the morning after the VPSG. It may be hypothesized that the complexity of the behaviors and the varying duration of the succeeding period of wakefulness may explain the subjective differences in the recall or the amnesia for it.

Of note, 23.3% of patients recalled having structured, narrative dreams, which were related to post-arousal hallucinatory experiences (42). Dream mentation may be present in DOA, and some studies have supported the hypothesis that DOA may represent a form of dream-enacting behavior (12,43). More interestingly, patients in this study reported that dream imagery that preceded the hallucination episodes was related to the visual hallucinatory experiences. The dream imagery was then perceived to be real, superimposed, and to exist in the real world environment. While this is beyond the scope of this study, future studies should elucidate if post-arousal hallucinatory experiences reflect a juxtaposition of dream and real world imagery.

It can be posited that in predisposed subjects, in delicate conditions of transition of states, an admixture of wake, NREM, and possibly also REM sleep elements can coexist until a complete, full wakefulness is reached, manifesting as hallucinatory experiences (42). However, in contrast to the abrupt onset typically seen in the DOA events, during the hallucinatory phenomena, the progression of events appears to be more gradual, and more transition errors of switching between different states may take place, arguably allowing for a more prolonged flux between different brain sleep states.

The coexistence of different states may result in the images of the sleeping mind becoming incorporated and projected into the real-world environment, so that they are visualized upon the surroundings until full wakefulness and a full insight into their hallucinatory nature are achieved.

In conclusion, this study advances and describes an important and a distinct post-arousal EEG and behavioral pattern, which was found in patients with DOA who concomitantly experienced ongoing hallucinations. This pattern differs from previously described post-arousal patterns, and likely reflects the acute nature of recorded hallucinations during DOA events and may be a useful, additional diagnostic tool in clinical practice.

However, there are several noteworthy limitations to this small, retrospective study of DOA events, which detract from finite mechanistic inferences. For instance, one-night VPSG may misrepresent the frequency and the nature of sleep pathology. Thus, it is possible that this particular pattern is either more or less prevalent than the study findings suggest. Furthermore, medications and other sleep, neurological, and psychiatric disorders might also influence the occurrence of parasomnias. Notably, in this study only one patient was taking treatment that could potentially modify the sleep structure and the occurrence of sleep disorders. Morning questionnaires may pose another important limitation. It is uncertain how much of patient recall may be lost and or confabulated unless collected immediately post DOA event, and future prospective studies are required to investigate this intriguing nocturnal phenomenon further. It is hoped that by learning more about any involved neurocircuitry, it may be possible to shed light onto the pathophysiological mechanisms of the hallucinations experienced in other disorders.

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