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Spectral analysis of the sleep onset period in primary insomnia

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HIGHLIGHTS

- This study shows that the patients with primary sleep onset insomnia (SOI) and sleep maintenance insomnia (SMI) present different spectral characteristics during sleep onset period.
- The lower level of beta (18–29.75 Hz) frequency band found in SOI in comparison with SMI suggests that the hyperarousal is not involved in the etiology of primary sleep onset insomnia.
- The results of the current study seem to corroborate a "wake-sleep switch problem" as a basic mechanism of SOI.

ABSTRACT

Objective: To compare the EEG power spectra characteristics of the sleep onset period (SOP) in patients with sleep onset insomnia (SOI), sleep maintenance insomnia (SMI) and good sleepers (GS).
Methods: The time course of EEG power density (1–40 Hz) during the SOP was examined in thirty subjects (SOI patients: $N = 10$, SMI patients: $N = 10$, GS: $N = 10$).
Results: The EEG power of the beta2 frequency band (18–29.75 Hz) was significantly lower in SOI than in SMI in the period preceding sleep onset. The alpha power was significantly higher for the SMI group compared to GS before sleep onset. Despite the lack of statistical significance, several differences in EEG dynamics were observed in SOI compared to two other groups: delta power increased slower after sleep onset; beta2 and 3 (18–29.75 and 30–39.75 Hz) power decrease less abruptly before sleep onset; beta1 (15–17.75 Hz) power increase through the whole SOP.
Conclusions: The lower level of beta2 frequency band in SOI and the differences in dynamics in delta and beta bands may suggest that a mechanism other than hyperarousal participates in etiology of SOI.
Significance: SOI and SMI patients have different spectral characteristics in SOP, thus future studies should avoid the inclusion of mixed insomnia samples.

1. Introduction

Primary insomnia (PI) is a common condition which severely affects the quality of life. The diagnosis of PI is based on a subjective complaint of difficulty with sleep initiation (sleep-onset insomnia, SOI), maintenance (sleep-maintenance insomnia, SMI) and/or quality, which occurs despite adequate time and opportunity for sleep and results in some form of daytime impairment (Fortier-Brochu et al., 2012). A further factor in PI diagnosis is absence of another sleep disorder, medical or neurological disorder, mental disorder and medication use or substance abuse disorder.

The pathophysiology of PI remains unknown but there is a large body of evidence indicating that an increased level of arousal plays a critical role. While the term hyperarousal includes several physiological modifications (Bonnet and Arand, 2010), the EEG component of hyperarousal or cortical hyperarousal (an increase in beta and gamma EEG frequencies) seems to be specifically linked to PI, while some controversies still remain (Riemann et al., 2010). The results of some studies (Perlis et al., 2001a,b) suggest that PI patients may be "hypervigilant" at sleep onset or during sleep, supporting the "neurocognitive model" hypothesis (Perlis et al., 1997). In addition to beta and gamma power changes, a lower absolute delta power (Lamarche and Ogilvie, 1997) and an increase in the beta/delta ratio (Merica and Gaillard, 1992) have been observed during the sleep onset period in PI patients. It has also been shown that, during this period, the dynamics of beta and delta EEG frequencies are different in insomniacs and controls. In good sleepers (GS), there is a progressive increase in delta activity concomitant to

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a decrease in beta activity (De Gennaro et al., 2001; Merica and Gaillard, 1992), whereas in PI patients this pattern is dampened (Merica and Gaillard, 1992).

Owing to different definitions and methodological problems, the findings on spectral analysis of sleep onset in PI are inconsistent. In one of the first and most influential studies of power spectra EEG in PI, Freedman and colleagues (Freedman, 1986), using selected sleep periods at night, found that PI subjects had increased absolute beta power during wake, stage 1 sleep and REM compared to the controls. However, these findings were not completely replicated in further studies focusing on sleep onset. An increase in beta power in PI has been observed during wake only when using beta relative spectral values (Jacobs et al., 1993; Lamarche and Ogilvie, 1997) while no significant differences were found for absolute beta power. In addition, some studies did not find an increase in beta power in PI during the stage 1 sleep (Jacobs et al., 1993), while others reported a decrease (Staner et al., 2003).

The reasons why some studies failed to show an increase in fast frequencies in PI are unclear but could be connected with the different methodological approaches. First of all, the different choice of the beta frequency range, including the sigma band (12–14 Hz) (Jacobs et al., 1993; Staner et al., 2003) in some cases, may be one of the reasons for this discrepancy. Data from some studies suggest that the sleep dynamics of the wide range beta frequency of the classical EEG are not homogeneous (Uchida et al., 1992). It has been shown that, at the low range (15–18 Hz) beta frequency rises at the beginning of NREM sleep while the higher beta frequencies (18 Hz and above) fall (Merica and Fortune, 2005). Another reason could be that some authors analysed absolute frequency power measures only and others relative frequency power measures only (and the direct comparison of results is not obvious).

Secondly, while most studies have measured overnight EEG power spectra (Buysse et al., 2008; Merica et al., 1998; Perlis et al., 2001a,b), only a few studies have focused specifically on the transition from wakefulness to sleep at the beginning of the night (sleep onset period, SOP). The definitions of this boundary period are very heterogeneous across the literature: some authors use the simple EEG criteria of stage 1 sleep (Freedman, 1986), others defined the SOP as the entire period from lights off to the first 5 min of stage 2 sleep (Lamarche and Ogilvie, 1997), while others as a period of approximately 5 min before and 15 min after the "1st page of stage 1 sleep immediately preceding stage 2 sleep" (Merica and Gaillard, 1992). Only a few studies (Staner et al., 2003) are based on the appearance of the first sleep spindle and there is robust evidence that this definition of SOP represents the most reliable marker of sleep onset (De Gennaro et al., 2001; Wright et al., 1995).

Furthermore, most of these studies included mixed samples of PI and fail to distinguish between PI patients with SOI and those with SMI. At a clinical level, however, we usually differentiate between these two forms of insomnia (with regard to pharmacological treatments for example). It can be hypothesized that SOI patients (or mixed SOI/SMI) may have different underlying etiological mechanisms than pure SMI patients. From a neurocognitive perspective, we can expect a higher cognitive/cortical arousal in SOI (or mixed SOI/SMI) patients or different dynamics in spectral characteristics, at least in the SOP. Therefore the study of the transitional phase between wakefulness and sleep can be of major interest in the study of EEG changes in sub-groups of PI patients.

The goal of the present study was to measure the power spectra during the transitional phase of the sleep onset period in PI patients by separately assessing the time course of brain activity in SOI and SMI patients. We wanted to determine whether SOI and SMI patients have different intensities of cortical arousal or a different process of falling asleep. We hypothesized that (1) SOI and SMI patients have different characteristics of spectral power in the SOP; (2) that SOI would show evidence of greater cortical arousal than SMI and GS and (3) that the dynamic of time courses of EEG spectral bands will differ in the two insomnia subtypes and good sleepers. To our knowledge, this is the first comparative study of spectral characteristics between SOI and SMI patients.

2. Methods

2.1. Subjects

Ten GS, 10 SOI and 10 SMI patients participated in this study (clinical and demographic data for the three groups are summarized in Table 1). All participants had a stable sleep/wake schedule (no shift work), with a preferred sleep phase between 22.00 and 08.00 h. They had no significant medical or psychiatric illness affecting sleep or a past history of substance abuse. They had been free of psychotropic medication for at least 3 weeks prior to polysomnographic recordings. The apnea/hypopnea index and the periodic leg movement index were lower than 10/h of sleep. The study was approved by the Ethics Committee of the University Hospital of Geneva and was in line with the Helsinki Declaration.

Patients were selected from an initial sample of 433 insomniac subjects that underwent a polysomnography study in the Sleep Laboratory of the University Hospital of Geneva between 1999 and 2010. From this group, we selected 99 patients who had three consecutive polysomnographic nights. This selection allowed us to divide PI patients into two SOI and SMI subgroups with greater precision (see below).

Only 55 patients from this sample were free of psychotropic medication. Of those patients, only 39 fulfilled the criteria for primary insomnia according to DSM IV (American Psychiatric Association, 2000):

Table 1
Demographic data.

	GS	SMI	SOI
	(n = 10) mean ± (sd)	(n = 10) mean ± (sd)	(n = 10) mean ± (sd)
Age (years)	41.4 ± (13.1)	41.6 ± (9.3)	34.2 ± (10.4)
Sex (F/M)	5/5	4/6	3/7
Insomnia duration (years)		10.7 ± (9.3)	10.7 ± (6.0)
BMI (kg/m^2)	24.6 ± (1.9)	24.9 ± (5.9)	24.4 ± (3.3)
ESS	7.2 ± (3.9)	7.8 ± (5.2)	5.6 ± (5.1)
HADS (A)	6.2 ± (4.3)	8.8 ± (4.6)	11.5 ± (4.4)[a]
HADS (D)	3.5 ± (3.3)	6.6 ± (1.9)[b]	8.7 ± (6.9)

T-test comparisons between sleep onset insomnia (SOI), sleep maintenance insomnia (SMI) and good sleepers (GS). BMI: body mass index; ESS: epworth sleepiness scale; HADS (A): hospital anxiety and depression scale (anxiety score); HADS (D): hospital anxiety and depression scale (depression score).

[a] Between SOI and GS (t = 2.41; p < 0.05, 2 tailed).

[b] Between SMI, and GS (t = 2.34; p < 0.05, 2 tailed).