WAVELET MAPPING OF SLEEP SPINDLES

Miroslaw Latka[1], Andrzej Kozik, Jakub Jernajczyk[1], Wojciech Jernajczyk[2], Bruce J.West[3].

1. Institute of Physics, Wroclaw University of Technology, Wroclaw Poland
2. Sleep Disorders Center, Institute of Psychiatry and Neurology, Warsaw, Poland.
3. Mathematical & Information Science Directorate, Army Research Office, Research Triangle, USA

INTRODUCTION

The sleep spindle is a defining property of stage 2 NREM sleep. We developed the software which not only detects spindles but also visualizes the distribution of spindle intensity across EEG channels. We apply the novel procedure of wavelet mapping to study the influence of focal epilepsy on spindle distribution.

CASE SELECTION

The study comprised the EEG recordings of 23 patients with focal epilepsy.
The inclusion criterion was the apperance of at least 20 spindles. The maximum number of spindles in one record was 147.

METHODS

The detection of sleep spindles and the mapping of their intensity employ the continuous wavelet transform (cwt) of EEG signal $s(t)$:

$$W[s](a, t_0) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} s(t)\psi^*(a; t_0)dt \qquad (1)$$

and the corresponding **normalized wavelet power**

$$w(a, t_0) = W^2(a, t_0)/\sigma^2 \qquad (2)$$

where σ is the standard deviation of the analyzed EEG epoch.
We find that the complex Morlet wavelet

$$\psi(t) = \sqrt{\pi f_b} e^{2\pi i f_c t} e^{-t^2/f_b} \qquad (3)$$

with parameters $f_b = 15$ and $f_c = 1$ faithfully captures the wave-packet nature of sleep spindles (Fig. 1). It is possible to associate pseudofrequency f_a with the scale a of the wavelet transform:

$$f_a = \frac{f_c}{a\delta t} \quad . \qquad (4)$$

SPINDLE DETECTION

The apperance of the sleep spindle is marked by the peak in the normalized wavelet power (Fig. 2). We search for such maxima for pseudofrequencies in the interval between 11 Hz and 16 Hz (c.f. equation 4). The special procedure was designed to eliminate false detections originating from various biological artifacts.

SPINDLE WAVELET MAPPING

At the center of the detected sleep spindle we calculate the normalized wavelet power for all EEG channels. We generate the topography of spindle intensity using cubic spline interpolation (Fig. 3).

RESULTS

Fig. 3 presents the sleep spindle wavelet mapping for patients with focal epilepsy. For each patient the distribution of the normalized wavelet power was averaged over all detected spindles. One can see that not only the displayed distribution is not uniform but also that its maximum in positioned away from the epileptic focus.

CONCLUSION

We discovered the influence of epileptic focus localization on spindle distribution. This efect may be usefull for pinpointing the localization of epileptic foci.
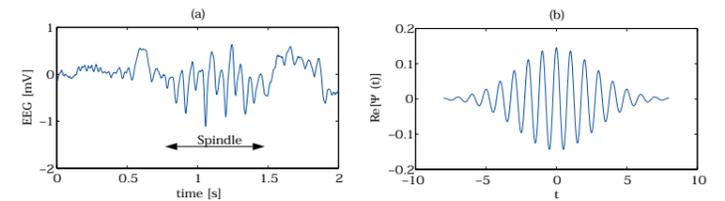
www: http://www.if.pwr.wroc.pl/~mirek/WmapSite/wmap.html   http://www.sen-instytut.pl

Fig. 1: (a) Arrow marks the sleep spindle. (b) The real part of the complex Morlet wavelet calculated for $f_b = 15$ and $f_c = 1$.
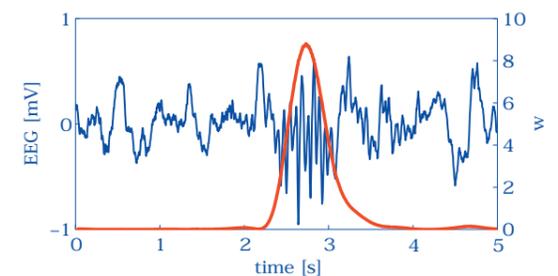

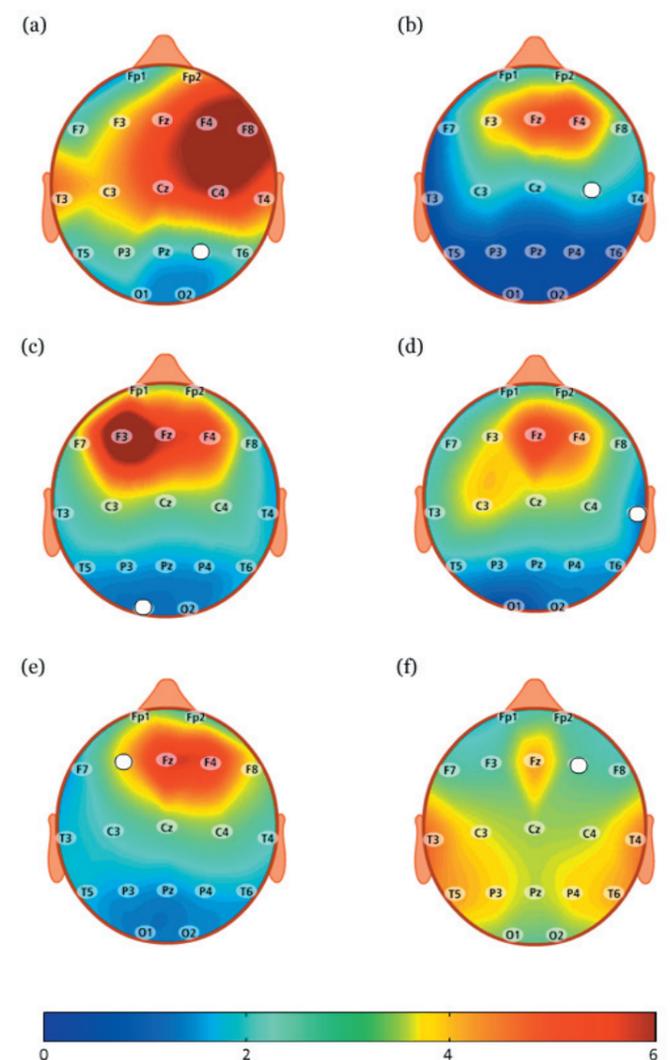Fig. 2: The EEG signal is superposed with the normalized wavelet power $\omega(a)$, $a=17$ (redline).

Fig. 3: The wavelet mapping of sleep spindles for six children with focal epilepsy. The normalized wavelet power was averaged over all spindles detected during monitoring. White circles mark the epileptic foci.