Arousal detection in sleep

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Introduction
Arousals are part of normal sleep. They become pathological if the frequency of occurrence passes a limit, beyond which the normal, dynamic course of the sleep process is disturbed. This results in the subjective experience of shallow sleep and daytime fatigue or somnolence, often accompanied by complaints about insufficient proper daytime functioning. Next to spontaneously occurring, arousals very often are caused by an underlying pathology like e.g. the obstructive sleep apnea syndrome (OSAS) or periodic limb movement syndrome (PLMS). In 1992, the ASDA made proposals about criteria how to score arousals in NREM and REM sleep. Using these guidelines, we developed a computerized method for scoring and evaluation of arousals in sleep. Given a logical order and an appropriate time frame, the algorithm also may link detected arousals with possible underlying pathological events like desaturations, snores, apneas/hypopneas or limb movements.

Methods
In short, the EEG arousal detection is based on a weighted score from the evaluation, in one channel of EEG, of
a) EEG frequency shifts, with zero-crossing,
b) the ratio slow vs. fast EEG activity, with the Alpha-Slow-wave Index (ASI) and
c) mean frequency, with the Hjorth-parameter Mobility.
During REM-sleep, user-defined detectable changes in chin EMG level are also considered. We used the arousal detection method in combination with REMbrandt, a computerized system for polysomnography and evaluation of sleep recordings. We processed polysomnographic data of 5 full-night recordings (from three female patients A, B and C, resp. 75, 35 and 24 yrs, and from one healthy male D, 49 yrs; patient A was recorded twice, the others for one night). All recordings had been visually scored on sleep stages by two experienced raters, as well as on the occurrence of arousals according to the ASDA scoring criteria. To facilitate the visual arousal scoring, the raters supportively used EEG spectral analysis from the evaluation module of the REMbrandt system. Also, apnea- and PLM detection and labelling was made with REMbrandt. In addition, the automatic arousal analysis was performed on the same EEG channels used for visual evaluation. A time window of 6 s was chosen as de-
fault, to make a causal link between detected arousals and apnea/hypopnea- or PLM events, i.e. a link was made, if the start of the arousal overlapped with the event or occurred maximally 6 s after the end of the event.
Results and discussion

The figure depicts a typical example of an arousal event that was linked, in this case, with a leg movement. The pane labeled ‘Signal window’ displays 30 seconds of the sleep recording and shows the following traces, from top to bottom: a) the C3-A2 EEG; this signal was used for the arousal evaluation, b) the arousal, as detected by the algorithm and automatically labeled ‘LM’, to indicate the causal relationship with a leg movement, c) the arousal, as indicated by the human rater, d) the C4-A1 EEG, e) EOG left, f) EOG right, g) leg movement signal, obtained from piezo sensors on both legs, h) the leg movement, as detected automatically by the REMbrandt system and indicated with ‘LM-B’ (the ‘B’ stands for ‘both legs’), i) the EMG from the chin, f) the EKG. The pane labeled ‘Overview window’ displays from top to bottom respectively, a) the visually rated hypnogram with time axis, b) the automatically detected arousals in the whole recording and c) the visually rated arousal events. The arousals under b) and c) are both indicated with a maximum of 2 events per epoch.

If there was any overlap of a visually evaluated arousal event with an automatically detected one, the detection was rated as ‘concordant’. A visually scored arousal without automatic detection was was rated as ‘negative’ and an automatically detected arousal without visual indication was rated as ‘false positive’. Comparison of the automatically detected arousals with the visually scored ones gave the following results.

<table>
<thead>
<tr>
<th>Recording</th>
<th>Concordance of visually det. with automatically det. (aut.det.=100%)</th>
<th>False positives</th>
<th>Concordance of automatically det. with visually det. (vis.det.=100%)</th>
<th>Negatives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pt. A, night 1</td>
<td>90%</td>
<td>10%</td>
<td>78%</td>
<td>22%</td>
</tr>
<tr>
<td>Pt. A, night 2</td>
<td>88%</td>
<td>12%</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Pt. B, night 1</td>
<td>92%</td>
<td>8%</td>
<td>76%</td>
<td>24%</td>
</tr>
<tr>
<td>Pt. C, night 1</td>
<td>92%</td>
<td>8%</td>
<td>81%</td>
<td>19%</td>
</tr>
<tr>
<td>Pt. D, night 1</td>
<td>94%</td>
<td>6%</td>
<td>74%</td>
<td>26%</td>
</tr>
</tbody>
</table>

The EEGs of the subjects showed age dependent differences, as well as specific individual traits. The present results were however obtained with similar, default detection settings. An optimization of the detected parameters with respect to every individual night recording (a user-controlled option, integrated in the arousal detection method) will therefore certainly increase the quality of detection.

Sleep monitoring equipment affects the assessment of nocturnal oxygenation in patients with COPD

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Introduction
Patients with Chronic Obstructive Pulmonary Disease (COPD) run a risk of developing nocturnal oxygen desaturations, predominantly during rapid eye movement (REM) sleep (1-4). When measuring nocturnal oxygen saturation, the monitoring conditions may cause a less efficient sleep. Studies on polysomnography (PSG) show a delayed sleep onset, sleep fragmentation, frequent arousals and shortened periods of REM sleep as compared to a common sleep (5-8). When sleep is disturbed, less oxygen desaturations may occur in patients with COPD. It was hypothesised that, as a result, an overestimation of nocturnal oxygenation will be found. The aim of this trial was to determine the impact of the monitoring equipment and of the unfamiliar hospital environment on the assessment of nocturnal oxygen saturation in COPD.

Methods
The study was performed in patients with COPD, with a stable disease and with a daytime arterial oxygen tension (PaO2) < 10 kPa. COPD was defined according to the standards of the American Thoracic Society (9). Stability of the disease was defined as a fluctuation in FEV1 < 10% in the last 3 months and an absence of an exacerbation in the last 8 weeks preceding the study. Subjects were considered suitable for evaluation if the mean nocturnal SaO2 during oxymetry at home was below 92%. Subjects with a history of a sleep apneas were excluded.

Sixty subjects were screened during the first night of the study: oximetry at home. This showed a mean nocturnal SaO2 < 92% in 17 subjects. These subjects were then invited for the second night: PSG in the hospital sleep laboratory. Three subjects had to be excluded at this phase of the study because sleep apneas were found. The remaining 14 subjects completed the study with the third night: PSG at home. The latter population consisted of 7 males and 7 females, with a mean (± SD) age of 70 (7) years and a mean (± SD) FEV1 of 39