Automatic Detection of Respiratory Events During Sleep Using Bidirectional LSTM Networks

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Methods: Phenotypes were measured within age-matched male DO mice (n=338) and the 5 common [A/J (n=6), C57BL/6J (n=14), 129S1/SvImJ (n=6), NOD/LouJ (n=6), NZO/HILJ (n=6)] and 3 wild-derived [CAST/Eij (n=8), PWK/PhJ (n=8), WSB/Eij (n=6)] inbred founders. A sleep definition of ≥40 seconds of continuous inactivity using infrared beams was utilized to quantify sleep/wake amounts and bout characteristics in light and dark phases. Latency to sleep (vigilance), multiple sleep latency test (MSLT), response to sleep deprivation, and circadian period (using wheel running) were also estimated. Reproducibility was calculated using Intraclass Correlation Coefficients (ICCs) from repeated assessments. Narrow-sense heritability (h²) was calculated as the proportion of variability explained by additive genetic effects using genotype data in DO mice, and broad-sense heritability (H²) calculated as the proportion of variability explained by genotype in founders.

Results: Most phenotypes were reproducible within individual mice, with ICC≥0.60. Sleep and wake phenotypes using alternative definitions of ≥20, ≥60 or ≥80 seconds of inactivity were highly correlated (p>0.85) with primary measures (≥40 seconds), demonstrating the robustness of the sleep definition. Differences in all traits were seen between founder strains and there was moderate-high heritability for most phenotypes; sleep/wake characteristics during lights-off and circadian period were the most heritable (H²=54-60%). There was large phenotypic variability among DO mice; values covered and extended beyond the range across founders. Estimates of heritability were lower in DO mice than in founders, with circadian period the most heritable (h²=36%). This may reflect unmeasured non-additive genetic effects.

Conclusion: A high-throughput phenotyping strategy based on monitoring of activity patterns in mice provides reproducible estimates of sleep and circadian characteristics with evidence of heritability. This paradigm is suitable for use in DO mice, where genetic factors explain some proportion of phenotypic variability.

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0327 DISTINCT PATTERNS OF EEG-EMG-COHERENCE IN VARIOUS STAGES OF DISEASE SEVERITY IN PATIENTS WITH SLEEP-DISORDERED BREATHING

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Introduction: We investigated whether using EEG-EMG-coherence (EEC) as a feature fed to a support vector machine (SVM) algorithm may allow staging of disease severity among sleep-disordered-breathing (SDB) patients.

Methods: EEG-EMG-coherence data resulted by applying a multitaper processing for estimating the power spectrums separately and calculating the coherence on raw C3-/C4-EEG- and EMG-chin data of polysomnographic (PSG) recordings of 102 SDB patients (33 female; age: 53, ± 12.4 yrs) acquired on two consecutive nights in each patient. Four epochs (30 seconds each, classified manually by AASM 2012-criteria) of each sleep stage were marked (in total 1632 epochs / night) and were included in the analysis. After multitaper processing, EEC values were fed to a SVM algorithm to classify SDB disease severity based on respiratory disturbance index (RDI). Twenty patients had a mild (RDI ≥ 10 / h and <15 / h), 30 patients had a moderate (RDI ≥ 15 / h and <30 / h) and 27 patients had a severe OSA (RDI ≥ 30 / h). Twenty five patients had a RDI <10 / h. The AUC (area under the curve) value was calculated for each receiver operator characteristic (ROC) curve.

Results: EEG-EMG coherence values could distinguish between SDB-patients without OSA and OSA patients of the above three severity groups using an SVM algorithm. Using PSG data of the first night the AUC for mild OSA was 0.602 (p = 0.032), in moderate OSA the AUC was 0.6319 (p = 0.021), and in severe OSA the AUC was 0.823 (p <0.001). On the second night, in mild OSA the AUC was 0.616 (p = 0.024), in moderate OSA the AUC was 0.659 (p = 0.003), and in severe OSA the AUC was 0.823 (p <0.001).

Conclusion: Grading disease severity in SDB patients can be performed using PSG-based multitaper-processed EEC values processed with a SVM algorithm. No clinically relevant first night- effect was shown in EEC values. EEG-EMG-coherence appears to be a robust marker for SDB severity classification.

0328 AUTOMATIC DETECTION OF RESPIRATORY EVENTS DURING SLEEP USING BIDIRECTIONAL LSTM NETWORKS

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**Introduction:** Sleep apnea is a common sleep disorder, which involves cessation of breathing due to obstruction of the upper airway (obstructive) or due to suspension of ventilatory effort (central) during sleep. Currently, sleep apnea is diagnosed using polysomnography (PSG). Breathing events are manually scored by trained sleep technicians, however this is time-consuming, expensive, and prone to subjective interpretation. Thus, the aim of this study was to develop a fully automatic algorithm to detect respiratory events in sleep.

**Methods:** Oxygen saturation, nasal pressure (transducer), oral airflow (thermistor), respiratory effort (RIP belts), and snoring signals were extracted from 2,366 PSGs from the Wisconsin Sleep Cohort (age: 59.7 ± 8.4, BMI: 31.6 ± 7.2 (mean ± SD)). After filtering, sixteen features (time and frequency domain) were extracted from each signal using a sliding window of ten seconds with eight seconds overlap. Two models were developed based on bidirectional long short-term memory (BLSTM) neural networks: 1) a two-class model for classification of windows as “normal” or “event”, and 2) a four-class model for classification as “normal”, “obstructive”, “central”, or “mixed”. 1882 subjects were used for training; 249 subjects were used for validation. Preliminary results were obtained for a test set of 235 subjects.

**Results:** With respect to the total number of events, the two-class model obtained precision of 0.740 and recall of 0.769. The four-class model obtained precision of 0.787, 0.205, and 0.100, and recall of 0.740, 0.769, and 0.903, respectively. The Pearson correlation coefficient between annotated and predicted apnea hypopnea index (AHI) were 0.844 and 0.861 for the two-class and the four-class model, respectively.

**Conclusion:** These results indicate that obstructive events can be reliably detected with a BLSTM network. However, the models had difficulties detecting central and mixed events correctly, which were present in a very limited number (1.5% and 0.21% of events). Future work includes improving the models for central and mixed event detection.

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**0330 DEVELOPMENT AND VALIDATION OF AN ALGORITHM TO QUANTIFY OBSTRUCTIVE SLEEP APNEA SEVERITY FROM THE ELECTRONIC MEDICAL RECORD.**

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**Introduction:** Electronic medical record (EMR) data can be helpful in understanding the role of obstructive sleep apnea (OSA) as a risk factor for cardiovascular disease and other adverse outcomes. Unfortunately, billing-code based identification of OSA does not allow for evaluation of OSA severity. We aimed to develop and validate a program to identify patients with OSA and quantify disease severity by extracting data from sleep study results in a large healthcare system EMR.

**Methods:** The study population included patients ≥ 18 years old who had an in-laboratory or home sleep study conducted at one of six sleep laboratories within the University of Pittsburgh Medical Center system between 1999 and 2015. We identified reports generated from the Medical Archival System (MARS) and employed Python to parse the text reports and Structured Query Language (SQL) scripts to further process the data. The program extracted study type, apnea hypopnea index (AHI), sleep stages, oxygen saturation levels and total sleep time (TST). Algorithm results were validated in a sample of 467 patients by manual review of records.

**Results:** We identified 42,329 adult patients (mean age 51.4 years, 48% female) who underwent a sleep study during the study period. Of these, 27,208 patients (64.3%) were identified as having OSA, with 39.2% mild OSA, 25.5% moderate OSA, and 35.3% severe OSA. Accuracy in identifying AHI was 99.8%, time in N3 sleep was 99.5%, time in REM sleep was 99.5%, TST 100%, and percent time with O2 saturation < 90% was 100%. The program correctly classified OSA severity (none, mild, moderate, severe) in 466/467 (99.8%) of cases.

**Conclusion:** Our EMR-based algorithm had a high level of accuracy in identifying sleep study diagnosed OSA, OSA severity and other key