Automated, Computerized System For Simultaneous Administration Of MSLT/MWT In Multiple Patients

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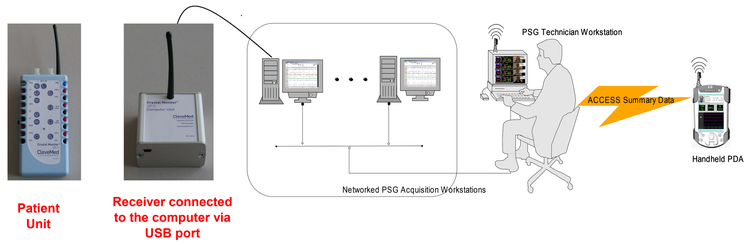
INTRODUCTION

- The current standard objective clinical tests for assessing daytime sleepiness, multiple sleep latency test (MSLT), and maintenance of wakefulness test (MWT), are short-duration tests (~30 minutes each) that are repeated 4-5 times during the day in two-hour intervals.
- MSLT/MWT require elaborate technician involvement, such as performing live, real-time sleep staging, which usually prohibits a technician from performing MSLT on more than 2 patients per day and limits the accessibility and cost effectiveness of the tests.
- Novel algorithms were developed for real-time automatic sleep staging which can facilitate administrating multiple MSLT/MWT tests at the same time.

METHODS

System Overview



- To facilitate the monitoring of up to 4 MSLT/MWT tests simultaneously, we developed a technician workstation, which is comprised of a computer system, 4 PSG monitoring units (CleveMed Crystal Monitor), and a software package that incorporates the real-time automatic Wake-Sleep Tracking Index.
- This system was then tested using a patient simulator, which outputs previously recorded data from actual patients during MSLT studies.
- The system was also evaluated in 8 normal volunteers who participated in one or two 30-minute naps during the daytime hours while being automatically monitored by the developed system.

Novel Algorithm for Wake Sleep Tracking

- One channel of raw EEG data (Occipital) from 80 previously recorded MSLT studies were used to develop the algorithm for tracking wake-sleep transition.

Raw EEG from MSLT → Time-Frequency Spectrogram (STFT) → Wake-Sleep Tracking Index (WS)

$$WS(n) = f\left(\frac{\sum P_n xx(\theta_H)^m \cdot \sum P_n xx(\delta_H)^p}{\sum P_n xx(\alpha_L)^l \cdot \sum P_n xx(\beta_L)^q}\right)$$

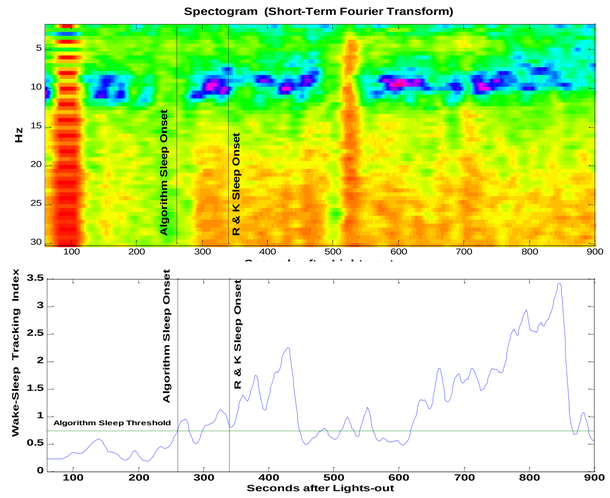
- The sleep onset times detected by the algorithm were optimized and evaluated using the gold standard sleep onset time scored by a PSG technologist.
- To compare with R & K sleep onset, sleep onset was defined as when the Wake-Sleep Tracking Index crossed and stayed above the sleep threshold for at least 15 seconds.
- Through a systematic non-linear programming optimization approach, WS is capable of automatically determining sleep threshold in real time using a single EEG channel.
- A patient simulator was used to simulate MSLT data from recorded studies to test the real-time algorithm for sleep onset detection.

CLINICAL TEST

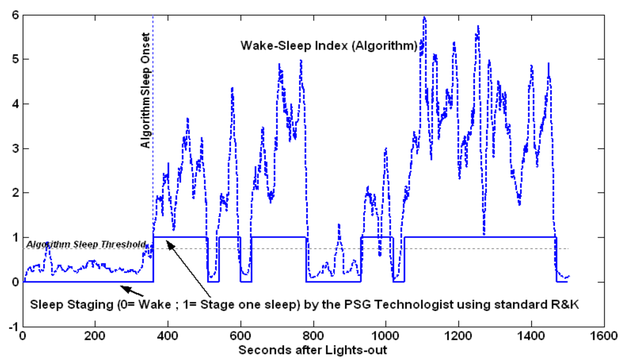
- 8 normal subjects were recruited to participate in this study by taking one or two 30 minute naps during the daytime hours (between 10 am and 3:00 pm) while being monitored by the Crystal Monitor.
- These subjects were under the condition of mild/moderate prior night sleep restriction to increase the likelihood of obtaining sleep segments during the daytime nap.
- A total of 11 naps were recorded and scored by a registered PSG technologist according to standard R & K method.
- Sleep latency from the PSG technologist (R & K) and the novel algorithm were compared for agreement by correlation coefficient study and Bland-Altman Analysis.
- The detected sleep onset times of the two methods were within 30 seconds of each other in every subject with a very high correlation coefficient (0.998).

RESULTS

Test Output Examples



Example of applying the algorithms (Spectogram, upper plot and Wake-Sleep Tracking Index, bottom plot) to a single EEG channel obtained during an MSLT nap. In the spectrogram, darker colors indicate higher relative powers. Higher values of Wake-Sleep Tracking Index indicate deeper sleep.



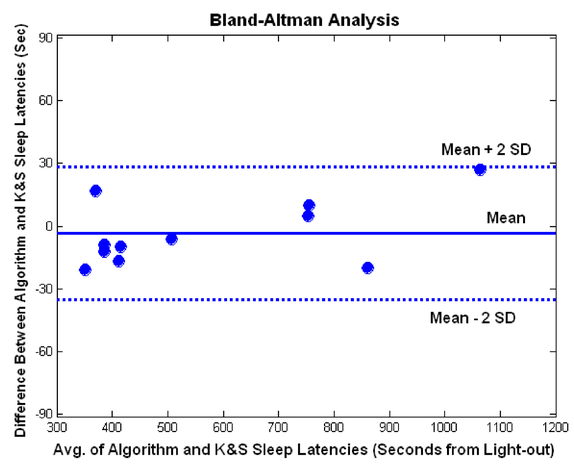
Comparison of the Algorithm Wake-Sleep Tracking Index (dashed line) with the sleep stages scored by a PSG technologist according to R & K (solid line). R & K method uses EEG/EOG/EMG for sleep staging while the automatic algorithm only uses a single channel of EEG. The R & K sleep onset time is defined as the first transition of wake to stage 1 sleep (361 sec after lights-out). Algorithm sleep onset time, which is based on crossing of the sleep threshold by the Wake-Sleep Tracking index, is at 357 sec after lights-out.

Sleep Latencies from the Algorithm and PSG Technicians (R & K)

(correlation coefficient: 0.998)

Subject	Age	Sex	Naps	R & K Latency (Sec)	Algorithm Latency (Sec)	Δ (Sec)
1	22	M	Nap1	361	378	17
2	23	M	Nap1	421	404	-17
2	23	M	Nap2	1051	1078	27
3	28	M	Nap1	751	756	5
3	28	M	Nap2	361	357	-4
4	24	M	Nap1	391	379	-12
4	24	M	Nap2	751	761	10
5	21	F	Nap1	421	411	-10
6	18	F	Nap1	391	382	-9
7	20	M	Nap1	871	851	-20
8	19	M	Nap1	511	505	-6

Bland-Altman Analysis of the agreement between the Algorithm and R & K Sleep onsets



CONCLUSIONS

- The real-time sleep onset detection capability of the developed system performed very well in these limited sets of studies with normal volunteers.
- A software package is currently being finalized to "guide" a novice operator to easily perform up to 4 MSLT/MWT studies simultaneously.
- Future studies are needed to validate the system in clinical settings.