



MANDIBLE BEHAVIOUR DURING SLEEP-DISORDERED BREATHING: A SURROGATE FOR OESOPHAGEAL PRESSURE

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INTRODUCTION: Just about everyone has noticed that snorers sleep with their mouths open; and, what's more, many sleep clinicians have observed that the jaw animates during sleep-disordered breathing events. Mandible position and activity during sleep has long been a subject of interest. In 1991 Hollowell and Suratt demonstrated that the jaws of patients with obstructive sleep apnea (OSA) are more open during sleep than the jaws of normal subjects [1]. They also showed that the jaw opens further during end inspiration in sleeping OSA patients. A later study concluded that mandibular opening increases progressively during apneic episodes and decreases at the termination of those episodes [2] and another that the jaw closes towards the clenched position during spontaneous arousals or arousals associated with termination of apneic events during sleep [3].

Thus, the recording of jaw movements during sleep could provide a wealth of information. To permit further investigation, a technology termed "Jawac" (for Jaw Activity) was developed. The Jawac sensor consists of a simple, non-invasive magnetic distance sensor that measures jaw opening.

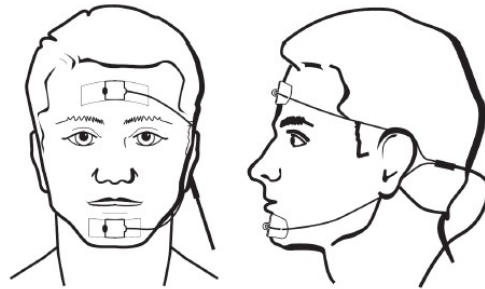


Figure 1: The Jawac sensor monitors jaw movements, via the measurement of the distance between the two elements of the sensor, one taped on the forehead and the other one on the chin.

Using this technology, simultaneous recordings of mandibular position and oesophageal pressure were conducted on sleeping patients. These recordings demonstrated that the measurement of mandibular movements during sleep is an excellent surrogate for oesophageal pressure measurement.

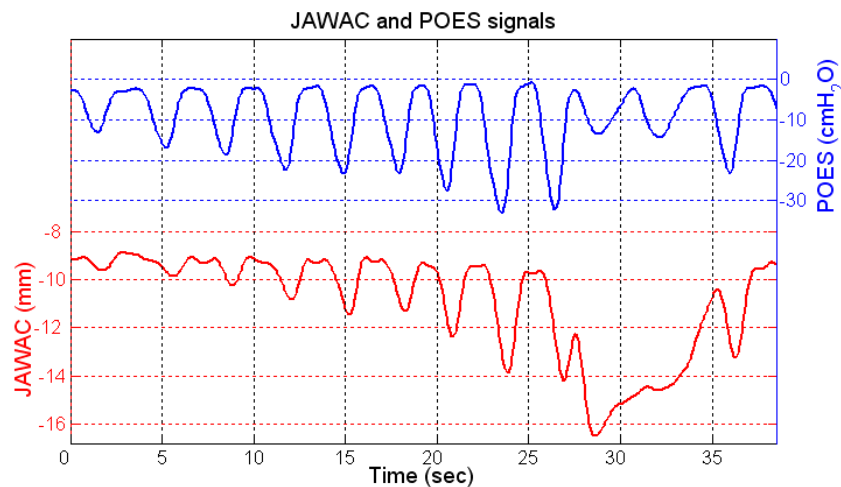
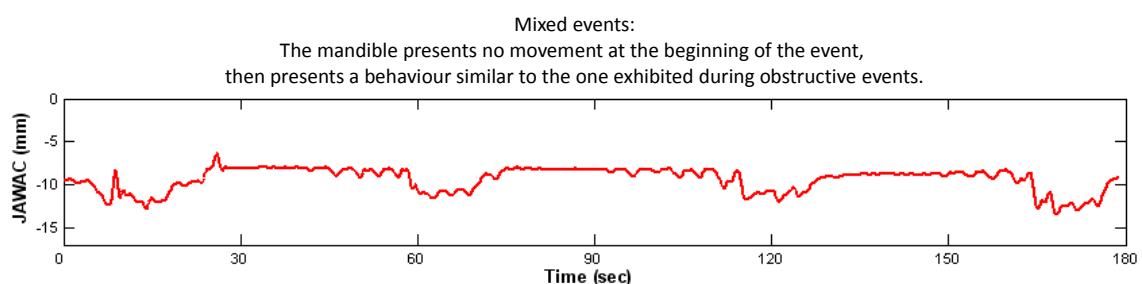
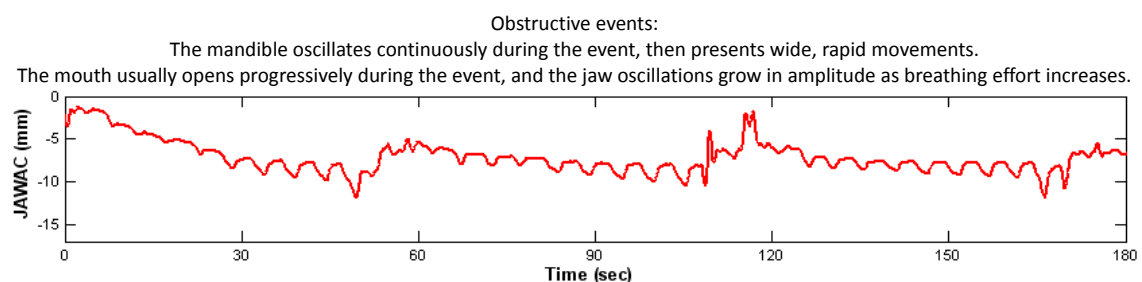
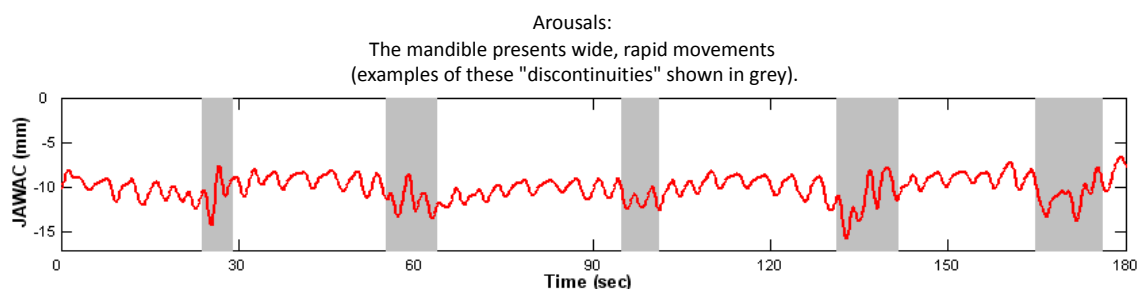
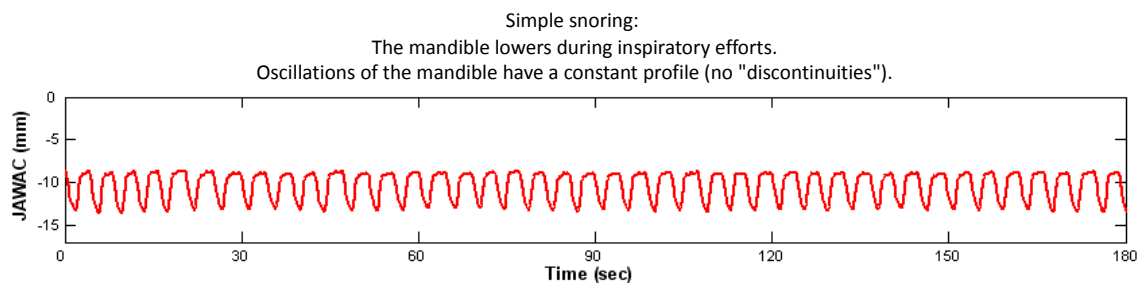
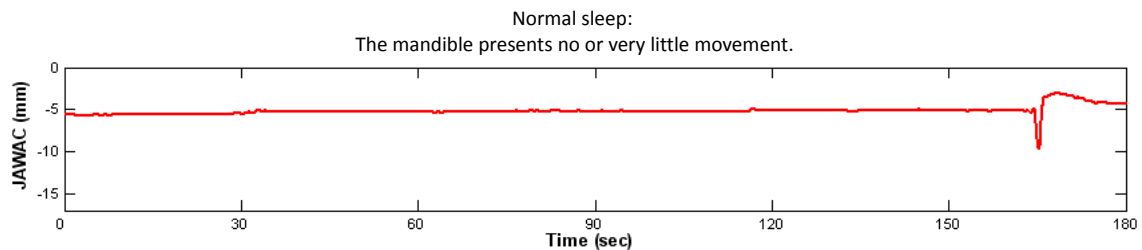


Figure 2: Simultaneous recording of mandibular movements (JAWAC) and oesophageal pressure (POES) during the course of an obstructive apnea.

MANDIBULAR BEHAVIOUR: During normal sleep the jaw presents no or very little motion, whereas when abnormal breathing efforts occur, the mandible oscillates at the breathing frequency. The mandible lowers during abnormal inspiratory efforts, with an amplitude which is soundly correlated with oesophageal pressure [4] (Figure 2).

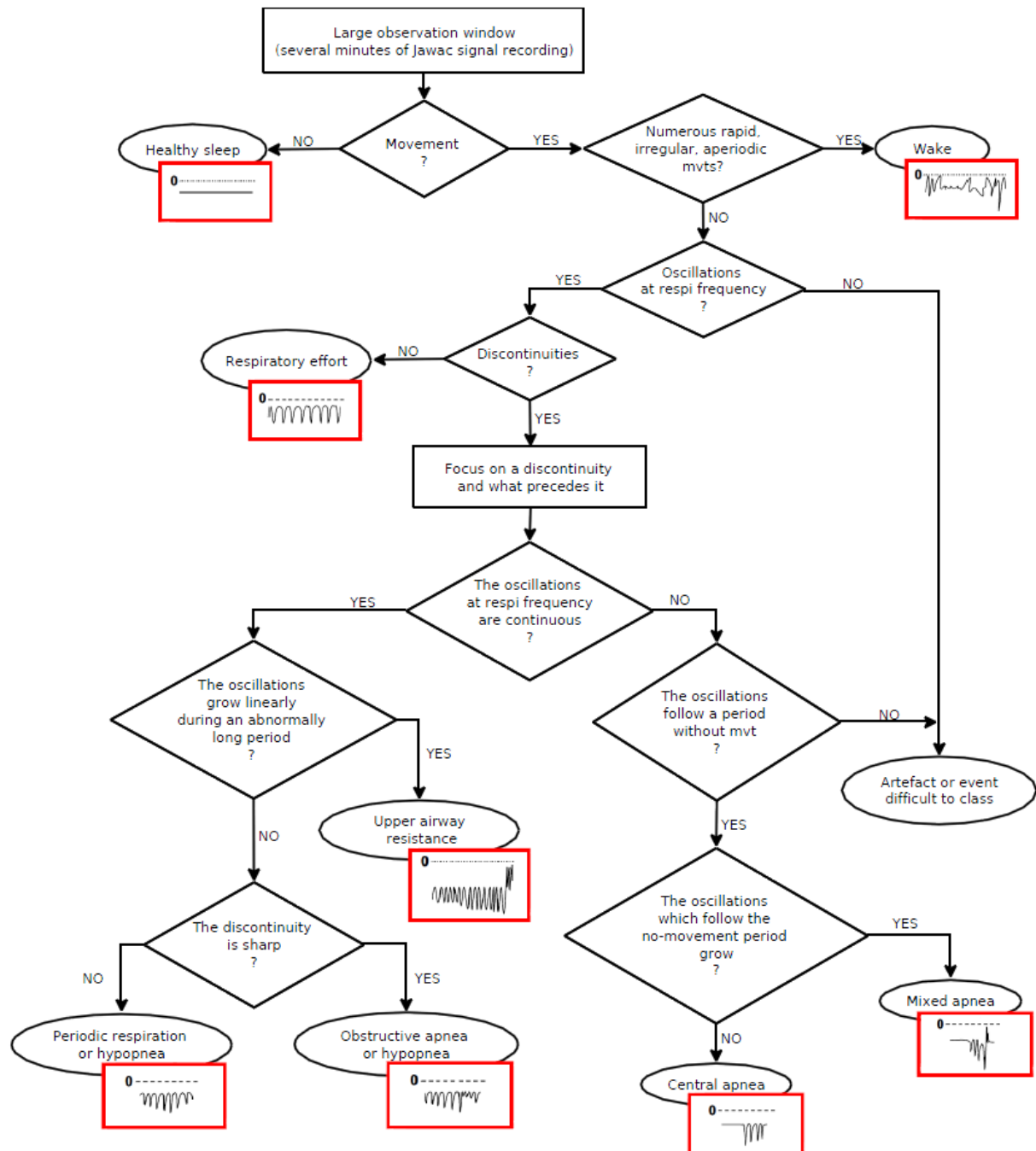
While abnormal breathing efforts are accompanied by mandibular oscillations at the breathing frequency, arousals that terminate breathing events are recognizable by wide, rapid closing and opening movements of the jaw. These movements appear as "discontinuities" in the Jawac signal.

Moreover, the mandible is subject to different behaviours during different types of abnormal breathing events. Therefore, the analysis of mandibular movements during sleep allows to detect and to classify sleep-disordered breathing events [5].



CLASSIFICATION OF EVENTS: Oesophageal pressure measurement is regarded as the gold standard method for quantifying respiratory efforts during sleep and for distinguishing between obstructive, central and mixed apneas. It can be used as an adjunct to polysomnography or even substitute for it. However, it is invasive and poorly tolerated by patients undergoing sleep monitoring.

The Jawac technology provides a simple, non-invasive surrogate for oesophageal pressure measurement. The decision tree displayed below illustrates how one can evaluate breathing efforts and classify sleep-disordered breathing events from the recording of mandibular movements.



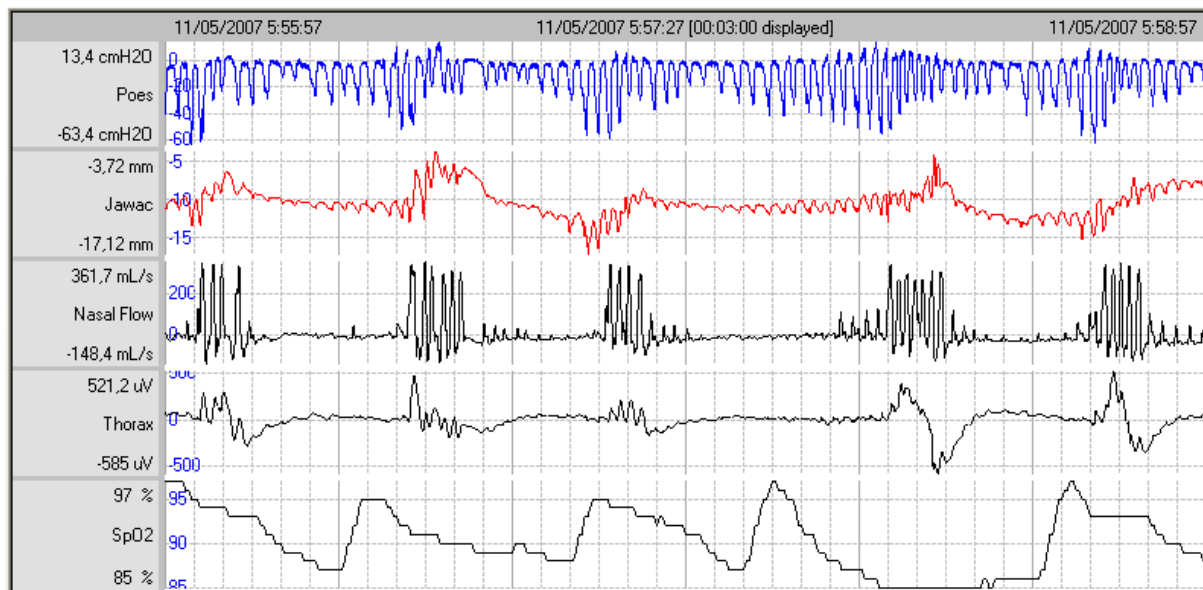
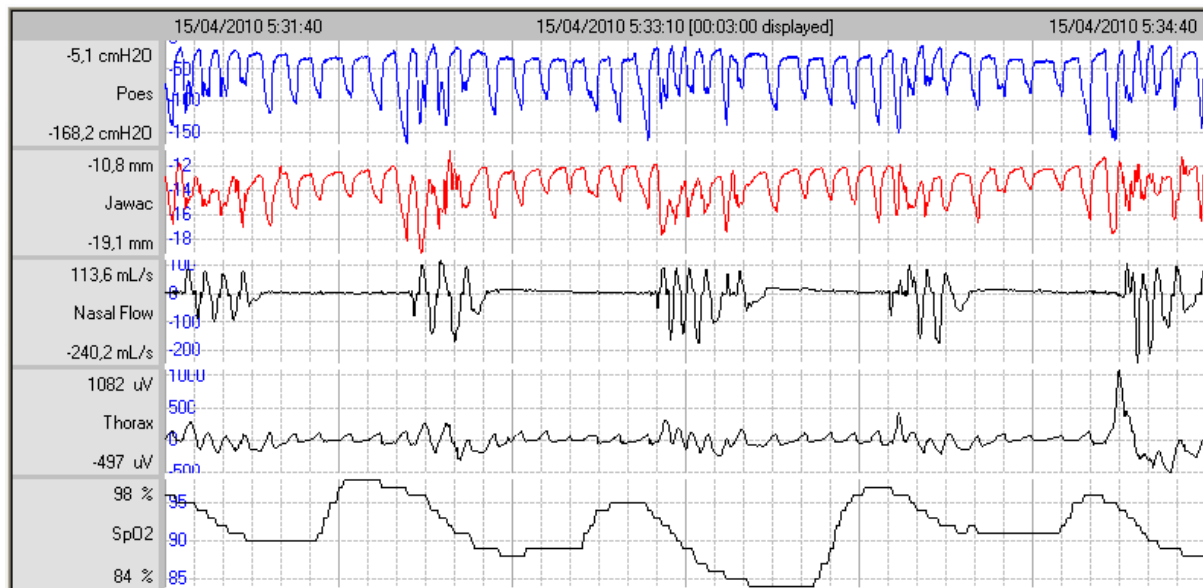
JAWAC vs OESOPHAGEAL PRESSURE – EXAMPLES: Extracts of polysomnographic recordings performed with measurement of oesophageal pressure and mandibular movement are shown hereafter.

In the following examples:

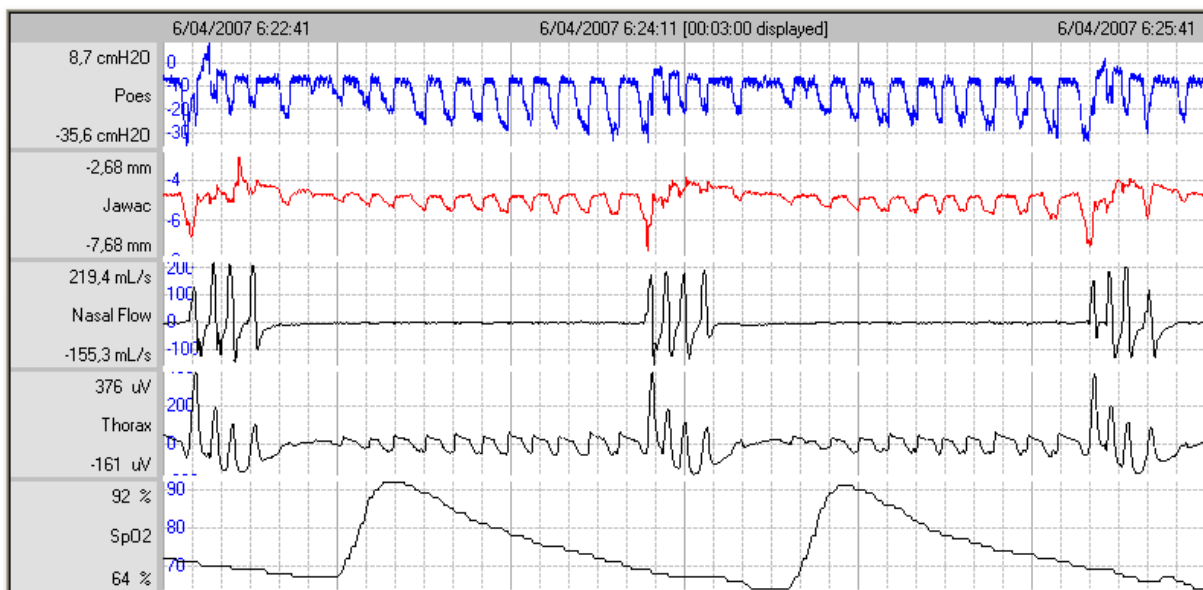
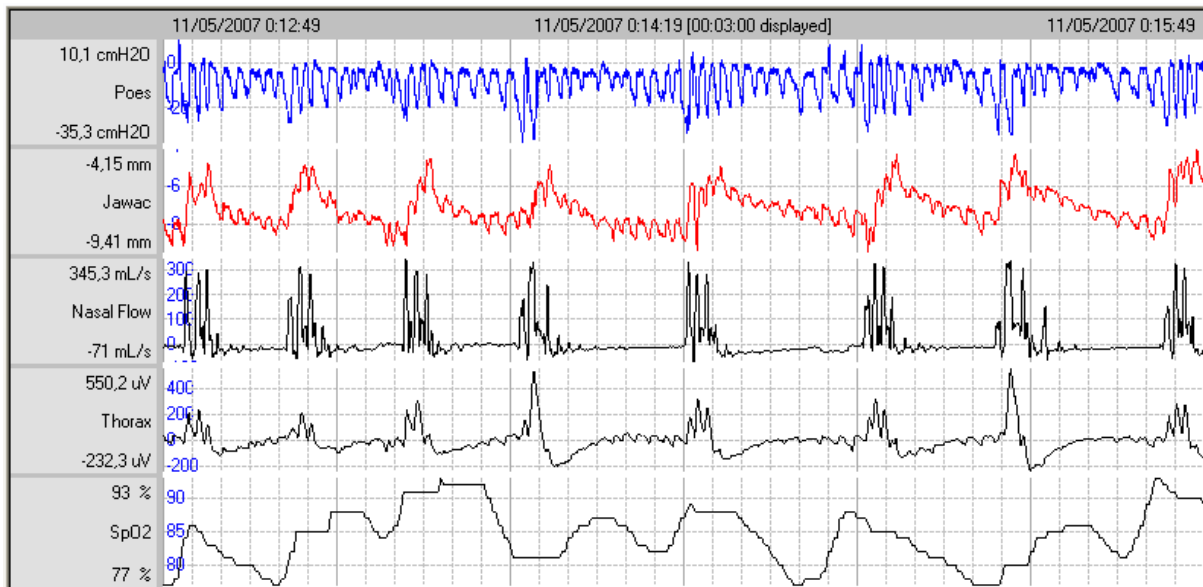
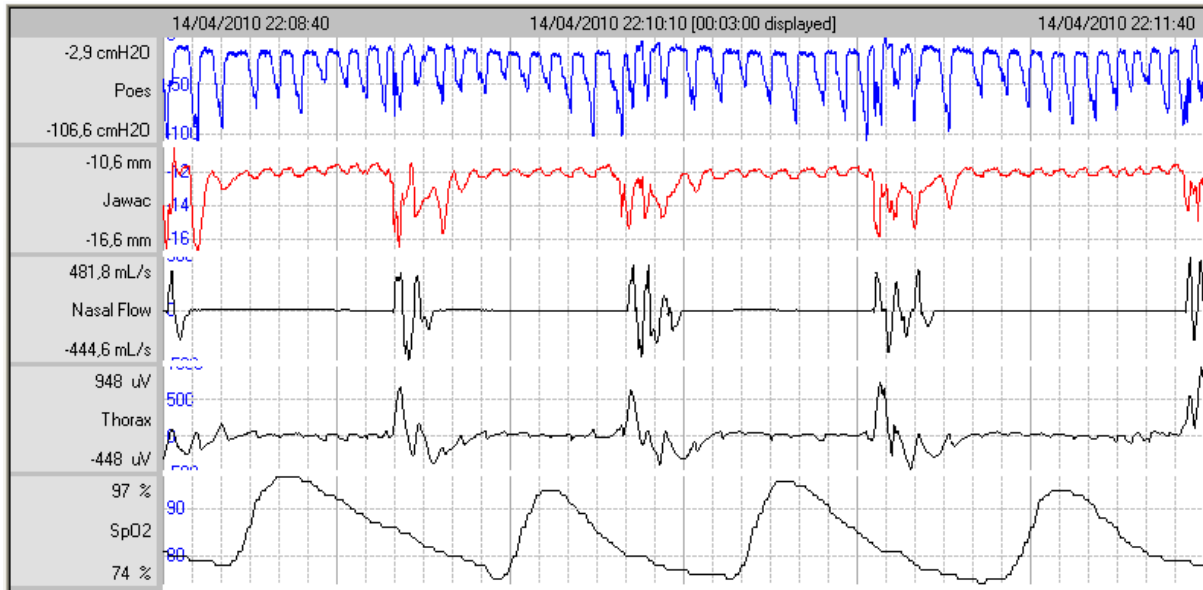
- "Poes" is oesophageal pressure measured by a pressure transducer,
- "Jawac" is mandibular movement measured by Nomics' magnetic distance sensor,
- "Nasal Flow" is nasal cannula airflow measured by a pressure transducer,
- "Thorax" is respiratory motion measured by inductance plethysmography, and
- "SpO2" is oxygen saturation given by pulse oximetry.

Although the examples given here were extracted from full polysomnography examinations, it is worth to note that, apart from oesophageal pressure, the Somnolter device – Nomics' type 3 portable monitoring device – records all of these signals. By hiding Poes from the examples, one can see the added value of recording the Jawac signal in addition to the other signals traditionally recorded by home sleep testing devices. By allowing respiratory effort quantification and the detection of arousals, the Jawac signal provides information on the type of the event being visualized. Its characteristic features make it an extremely useful signal, both as an adjunct to other traditional signals (as in the Somnolter) or stand alone (as in the Brizzy).

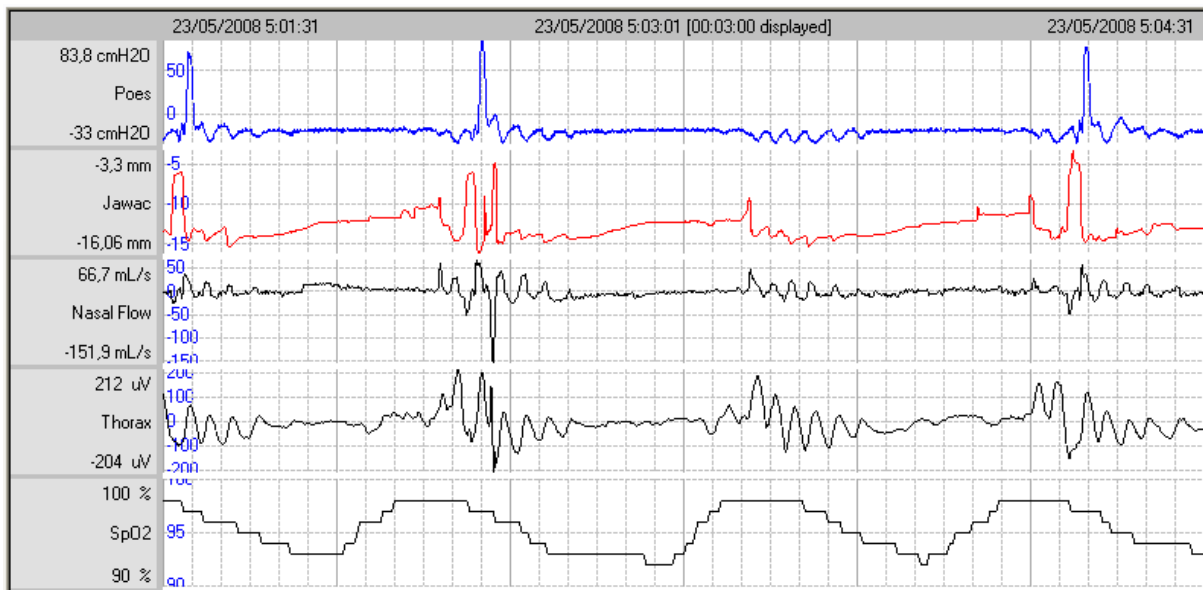
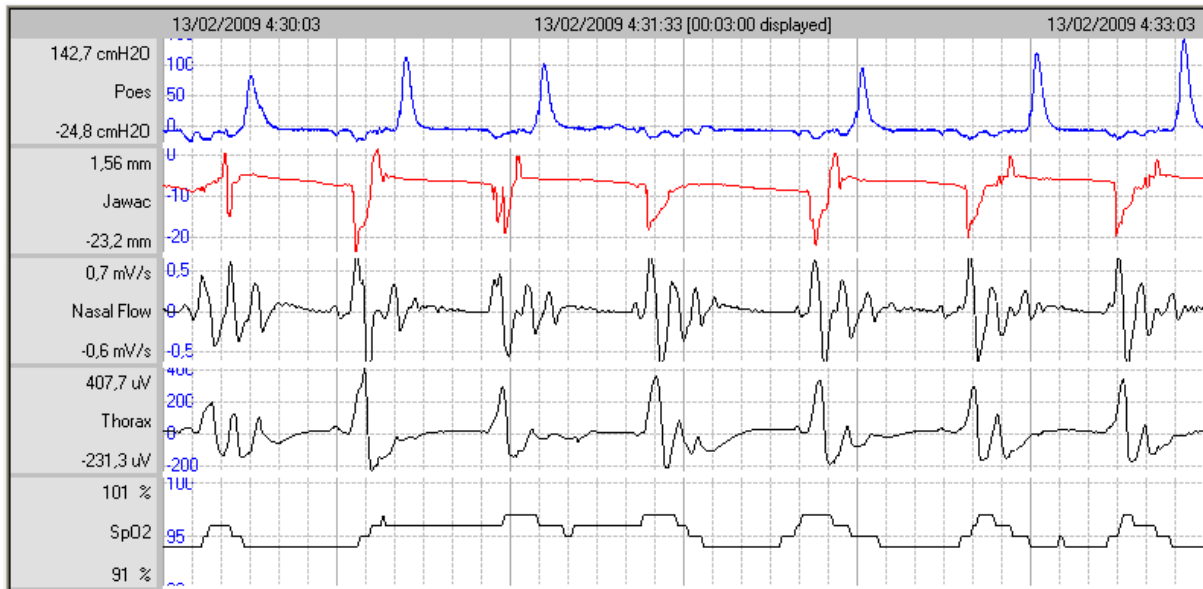
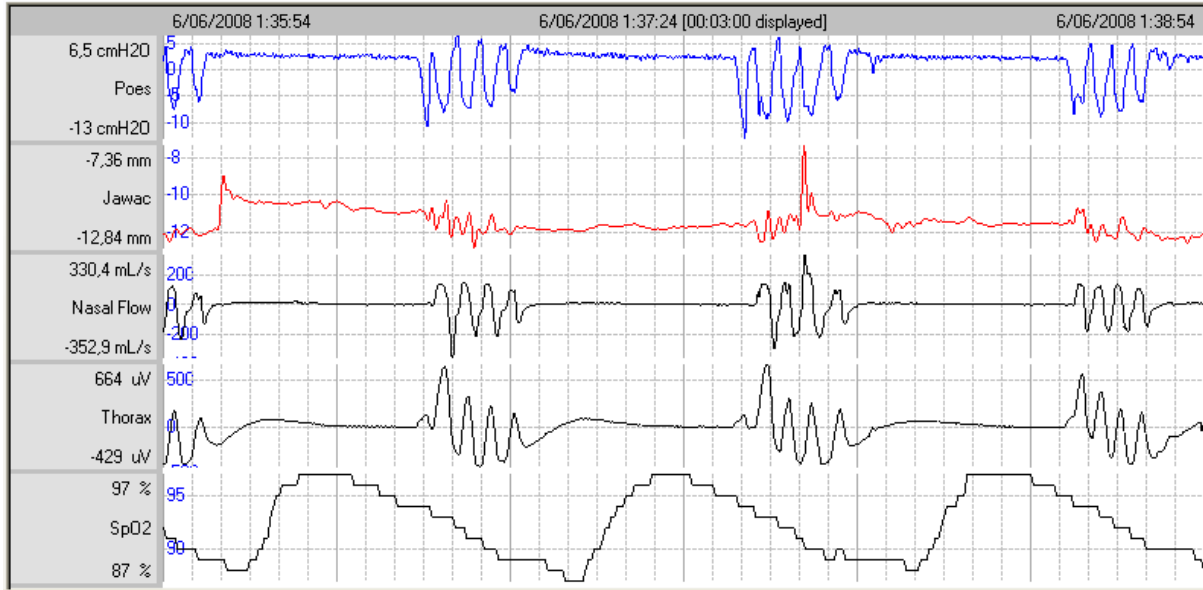
Obstructive Apnea – Examples



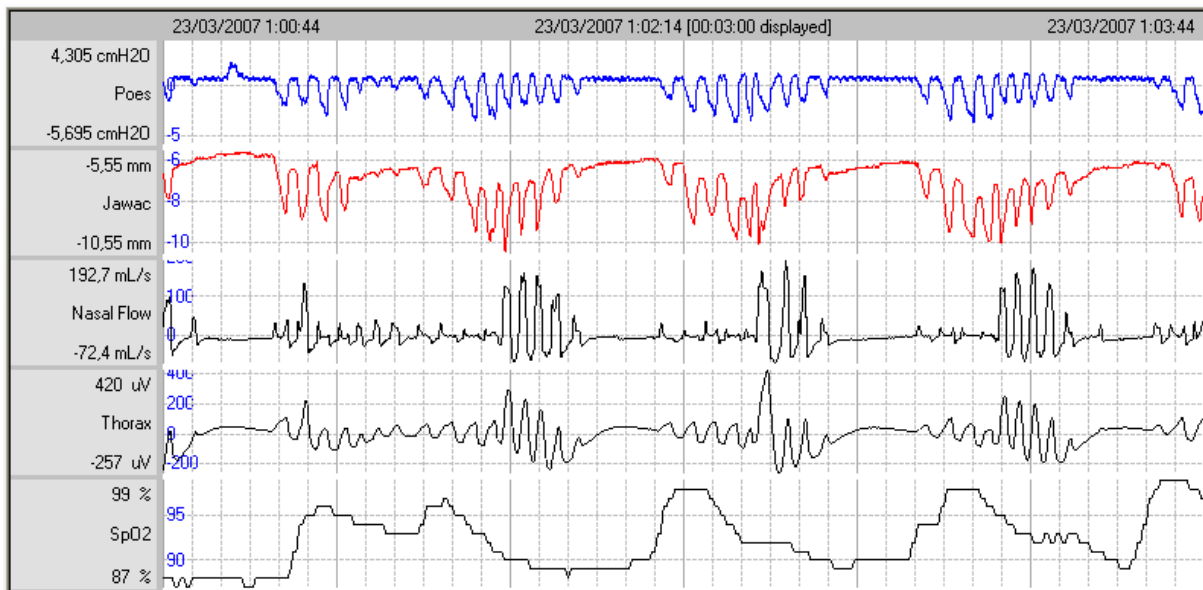
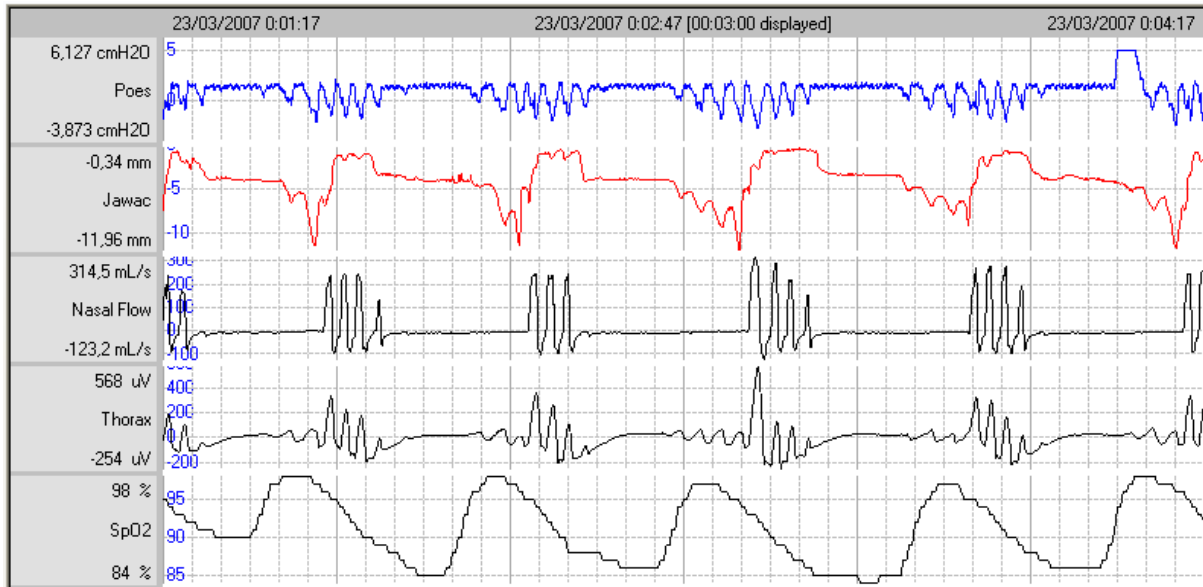
Obstructive Apnea – Examples (continued)



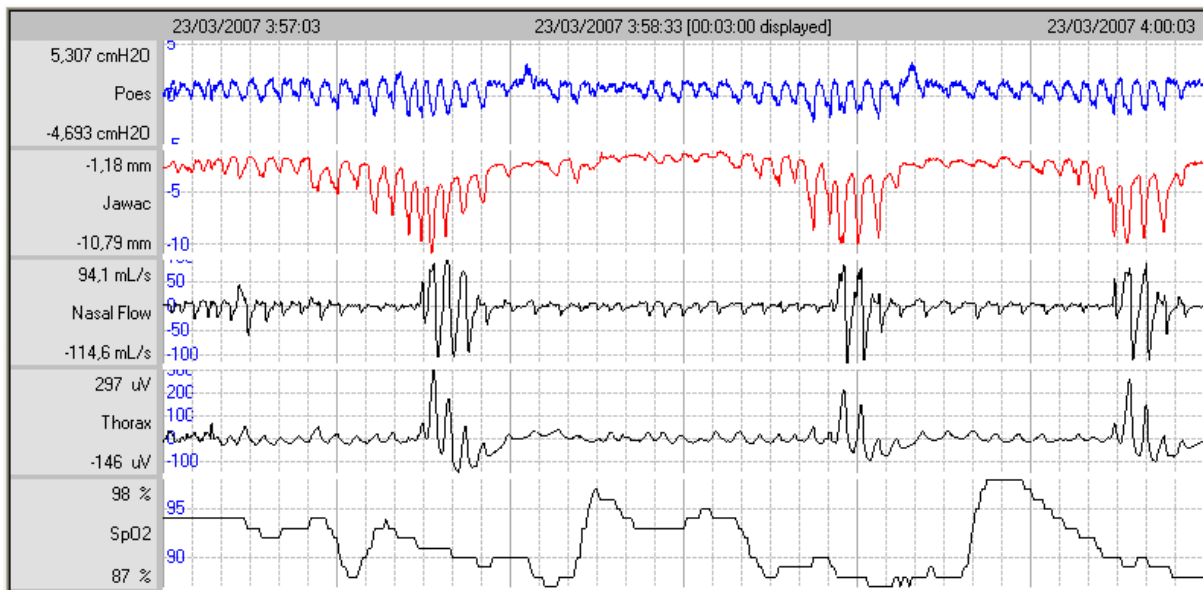
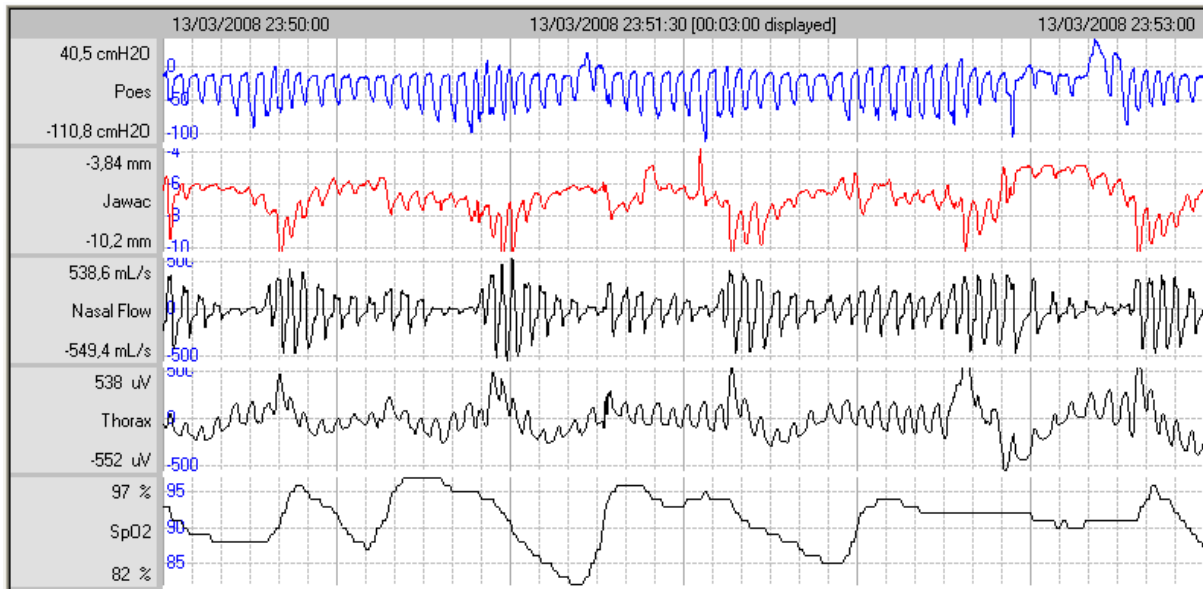
Central Apnea – Examples



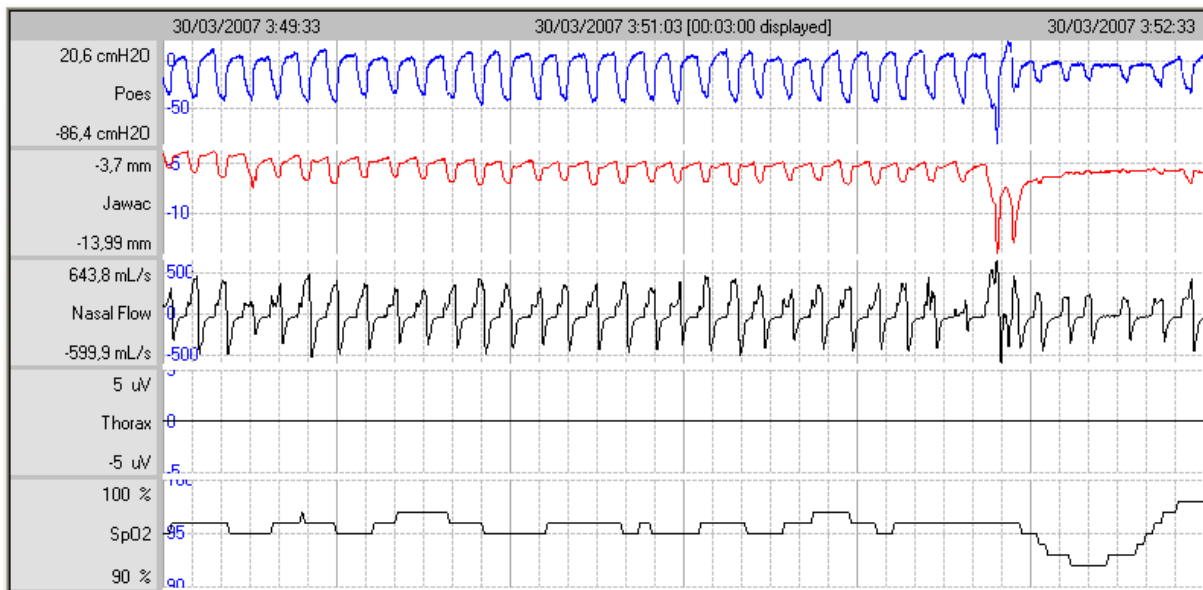
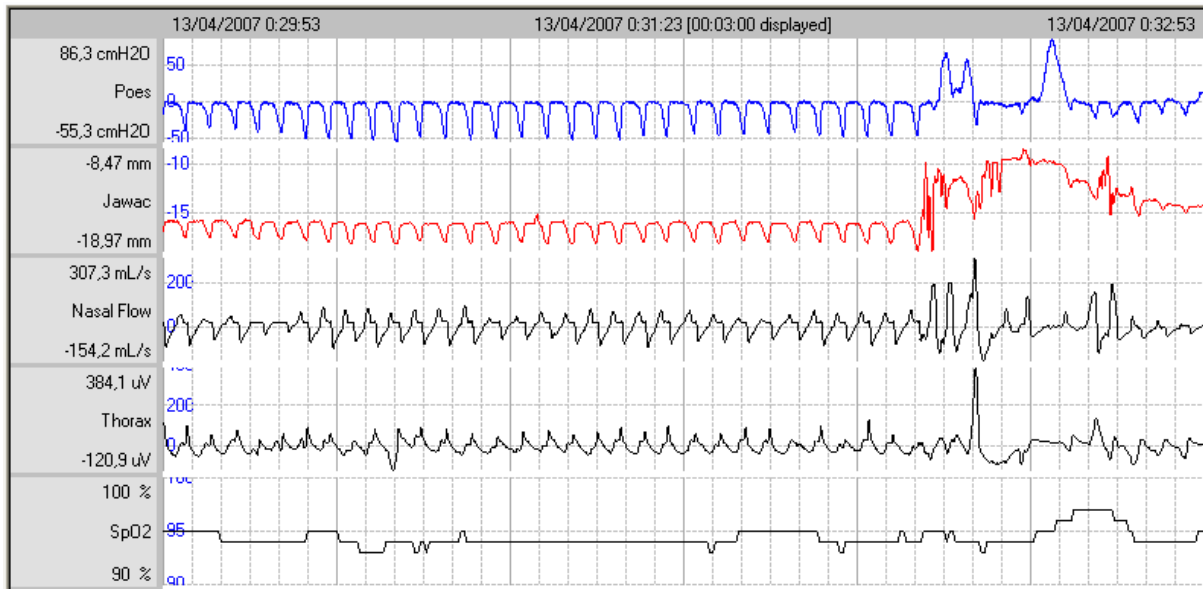
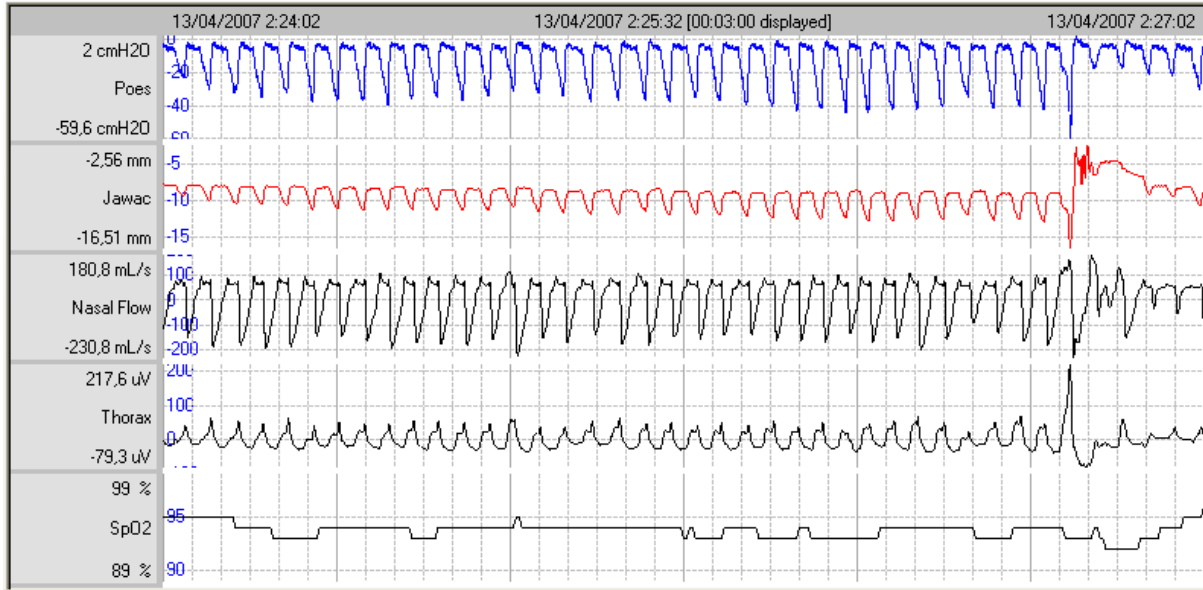
Mixed Apnea – Examples



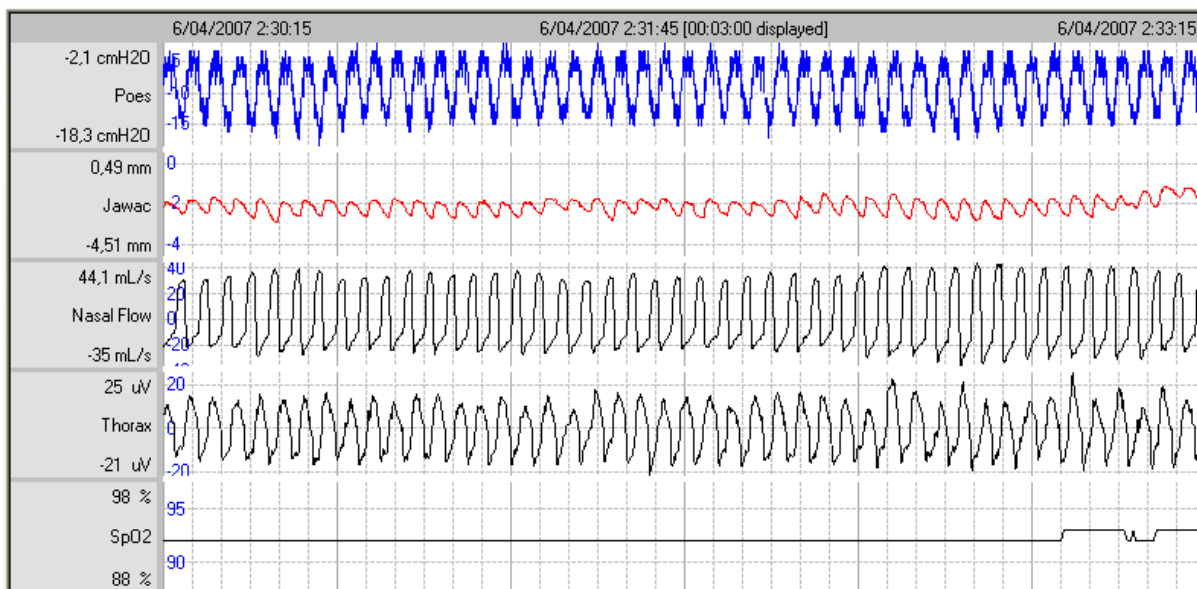
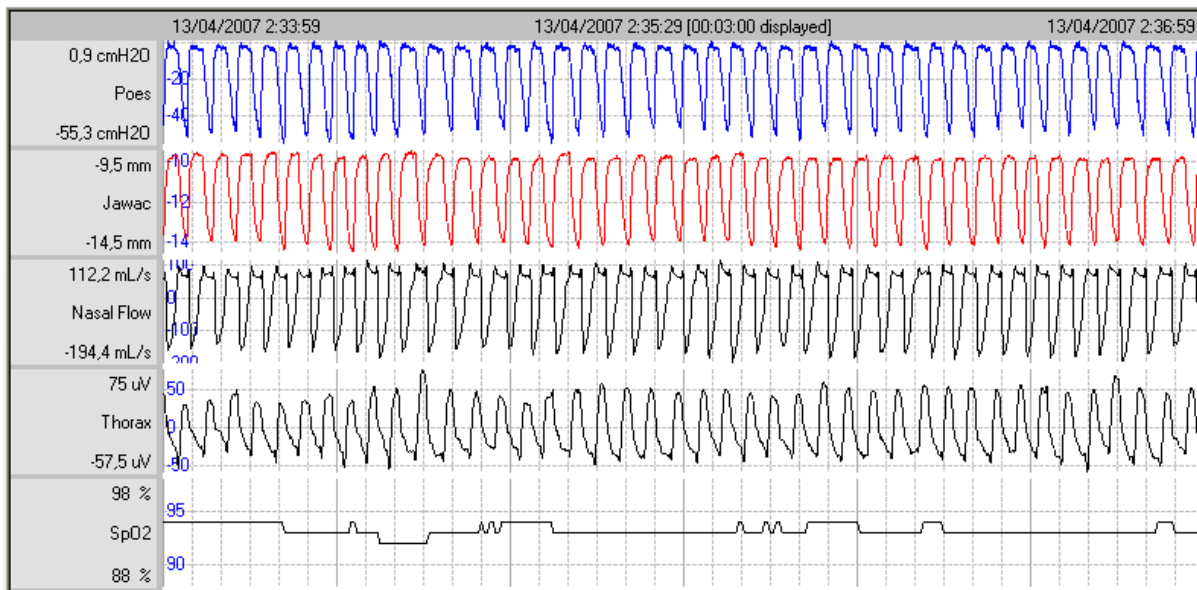
Hypopnea – Examples



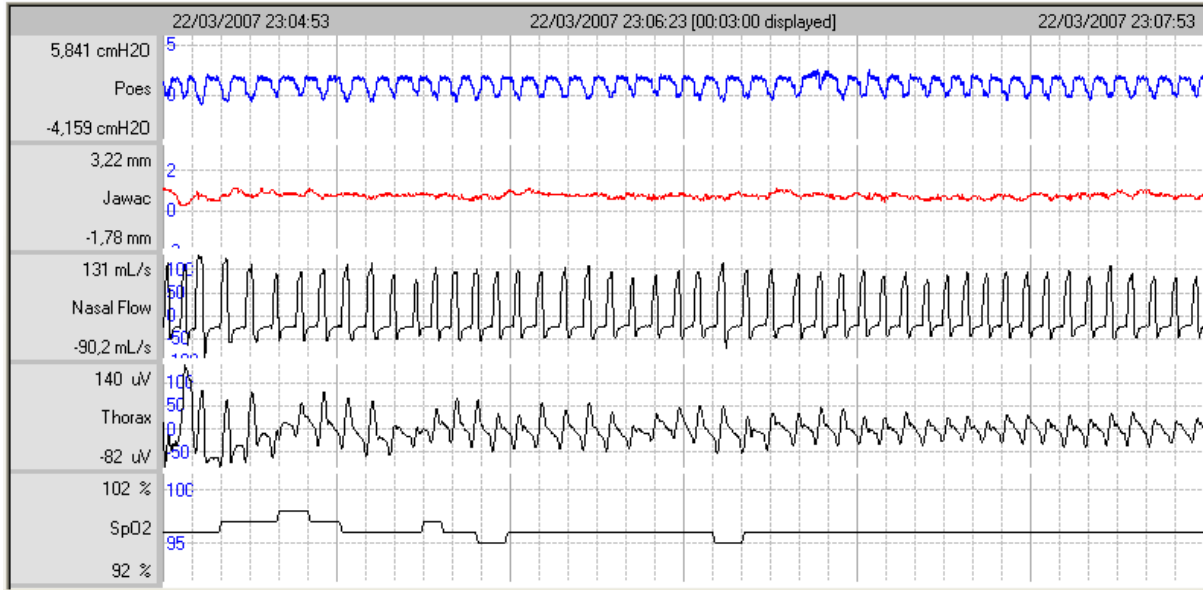
Respiratory Effort Related Arousal (RERA) – Examples



Snoring – Examples



Normal Sleep – Examples



The Jawac technology is integrated into all of Nomics' sleep-dedicated products

Brizzy REF NS21



Up to 4 signals

Type 4 portable monitoring device

Records mandibular movement and body position

(Option 1) oxygen saturation and pulse rate.

(Option 2) Interface module for real time connection to polysomnography (PSG) systems

Provided with extremely powerful automatic analysis software solution

Automatic rejection of wake periods

Combines high accuracy with high convenience and low cost

Somnolter REF NS22



Up to 12 derived signals

Type 3 portable monitoring device

Records mandibular movement and effort, airflow and snoring, respiratory movements (Chest, Abdomen and Sum), oxygen saturation, pulse rate, plethysmographic pulse wave, and body position

Provided with extremely powerful automatic analysis software solution

Automatic rejection of wake periods

Probably the most accurate home testing device on the market

Comfortable and simple

[1] Mandible position and activation of submental and masseter muscles during sleep, *Hollowell and Suratt*, J Appl Physiol 1991;71:2267-2273.

[2] Mandibular posture during sleep in patients with obstructive sleep apnoea, *Miyamoto et al.*, Arch Oral Biol 1999;44(8):657-64.

[3] Jaw movement during sleep, *Le Huquet*, Master Thesis, Queen's University Kingston, Ontario, Canada, 2008.

[4] Measurement of abnormal breathing effort by mouth opening during sleep, *Poirrier et al.*, Oral presentation at the World Congress on Sleep Apnea (WCSA), Seoul, Korea, 2009.

[5] Midsagittal jaw movements analysis for the scoring of sleep apneas and hypopneas, *Senny et al.*, IEEE Trans Biomed Eng 2008;55(1):87-95.