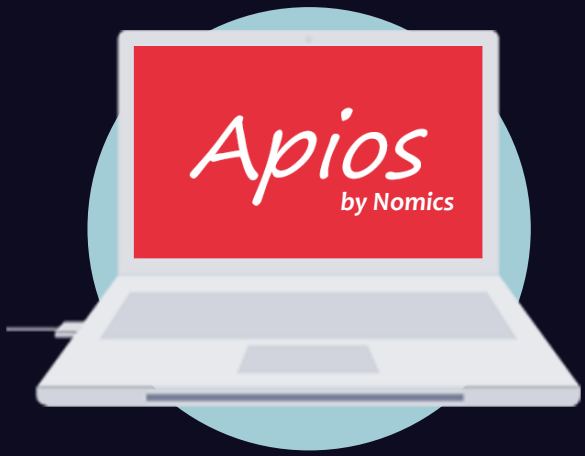


Definitions and algorithmic principles

NS500 - Apios

DEFINITIONS

PRELIMINARY NOTE

.[ ]	The values enclosed in square brackets [ ] can be configured by the user. The values enclosed in square brackets below are the default values used by the automatic analysis.

SIGNS

Depending on the device and accessories you used, your recording may include the signals identified below. If the signal corresponding to a sensor you connected is not present, the sensor is defective or has been connected incorrectly.

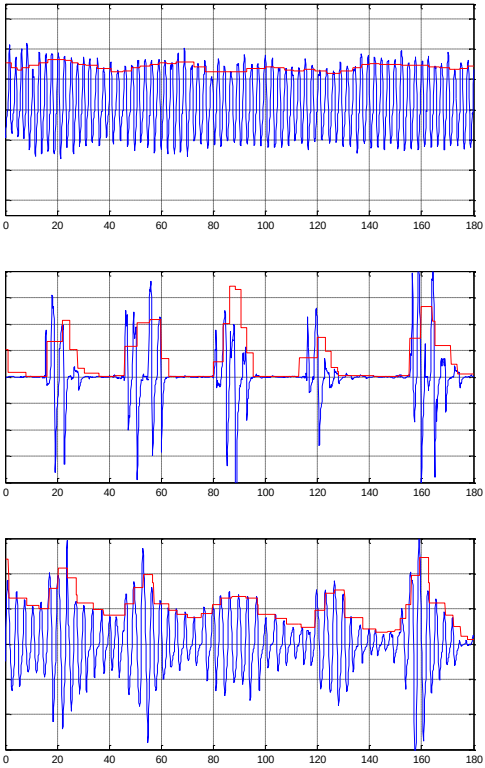
Jawac	JAWAC stands for Jaw Activity. Distance measurement (electromagnetic sensor).
Jawac Effort	Signal derived from the Jawac that best represents the characteristic variations in the force it contains.
Nasal Flow	Airflow (nasal cannula and pressure sensor).
RIP Abd / Chest	*RIP stands for Respiratory Inductance Plethysmography (belts).* Chest movements (RIP Chest) and abdominal movements (RIP Abd).
RIP Sum	Signal obtained by summing the RIP Chest and RIP Abd signals.
Respi. movements	Representation of device movements in the direction of greatest variation. This signal shows movements caused by breathing, regardless of the patient's position, but is of course subject to artifacts caused by patient movement.
SpO2	Peripheral oxygen saturation measured using the "4-beat averaging" option on the Nonin Medical oximeter.
Pulse Rate	Heart rate measured using the "4-beat averaging" option on Nonin Medical oximeters.
Plethy Pulse	Pulse plethysmographic waveform provided by the Nonin Medical oximeter.
Body Position	Body position (3D accelerometer). *Standing* – standing *Prone* – on stomach *Left* – on left side *Right* – on right side *Supine* – on back
Nasal Vibration	Estimation of the amplitude of vibrations present in the nasal pressure signal in the frequency band from 25 to 450Hz.
ECG	Electrocardiogram measured by NS922 or NS965 auxiliary sensors.
Heart Rate	Heart rate calculated from the ECG signal.

CPAP pressure	Continuous component of the pressure measured on the nasal cannula, when placed under the mask or connected to the CPAP air tube, and a pressure greater than 2.5 cmH2O is observed for more than 20 minutes or 15% of the recording.
Mask pressure	Continuous component of the pressure measured at the mask side inlet of the pneumotachograph sensor.
Respiratory flow	Respiratory frequency component of the air flow measured using the pressure difference between the two ports of the pneumotachograph sensor. It represents the inspired and expired flow.
Global leak	Average air flow rate per respiratory cycle measured using the pressure differential between the two ports of the pneumotachograph sensor. It represents the continuous flow provided by CPAP, i.e., the total leak.
NI leak	Unintended component of the overall leakage, equal to the overall leakage minus the leakage specified in the mask characteristics at the corresponding pressure (Mask pressure).
Tidal volume	Estimated tidal volume by integration over each respiratory cycle of the portion of the flow signal above the average
Respiratory rate	Respiratory rate calculated from respiratory flow

GENERAL CONSIDERATIONS

Analysis area	The analysis zone is the portion of the recording between the start and end points of analysis defined by the algorithm (and modifiable by the user).
Sleeping area	Sleep zones are portions of the analysis area that are not masked by exclusion zones.
Exclusion zone	Exclusion zones are the masked portions of the recording. In the analysis zone, exclusion zones correspond to periods of wakefulness detected by automatic analysis (see algorithmic principles) and, if any, periods during which all signals are invalid. Exclusion zones can also be defined manually.
Reference level (Jawac)	The Jawac signal reference level ('0mm' level) corresponds to the level of the mandible in the "mouth closed" position. This level is automatically established by the software as the level below which almost all mandibular activity observed during the first two hours of recording takes place.
Reference value (Flow)	The reference value of the flow signal is the signal used in all flow reduction estimates for event detection according to the definitions on page 6. To avoid aberrant amplitudes during periods of unstable ventilation and rapid exhalations, it is determined from the quasi-peak-to-peak[1] amplitude of the ventilation cycles. An average is then calculated over two successive cycles

[1] The difference between the maximum and minimum signal values is not considered as such, but sharp peaks are ignored by analyzing the 95th percentile on the estimation window.

In blue: Flow signal. **In red:** Reference ventilation signal.	to obtain a more consistent result during ventilatory recovery. 
Effort	Periods of mandibular movements (MM – Jawac and Jawac Effort signals) synchronized with the respiratory frequency with a peak-to-peak amplitude >= [0.3 mm] indicate ventilatory effort (noted MML). MML: A period of at least [20] seconds in which the peak-to-peak MM amplitudes are >= [0.3 mm] (see [a], [b], [e] and [g]).
Activation	An activation corresponds to a discontinuity in the Jawac signal that meets the amplitude and irregularity criteria set out in [a] and [b].
Respiratory activation	This is an activation associated with an MMO or MML as defined in [e] and [f], and graphically represented in Figure 1.
Obstructive Event	This is an event consisting of a period of ventilatory effort (MML) and ending with respiratory activation.

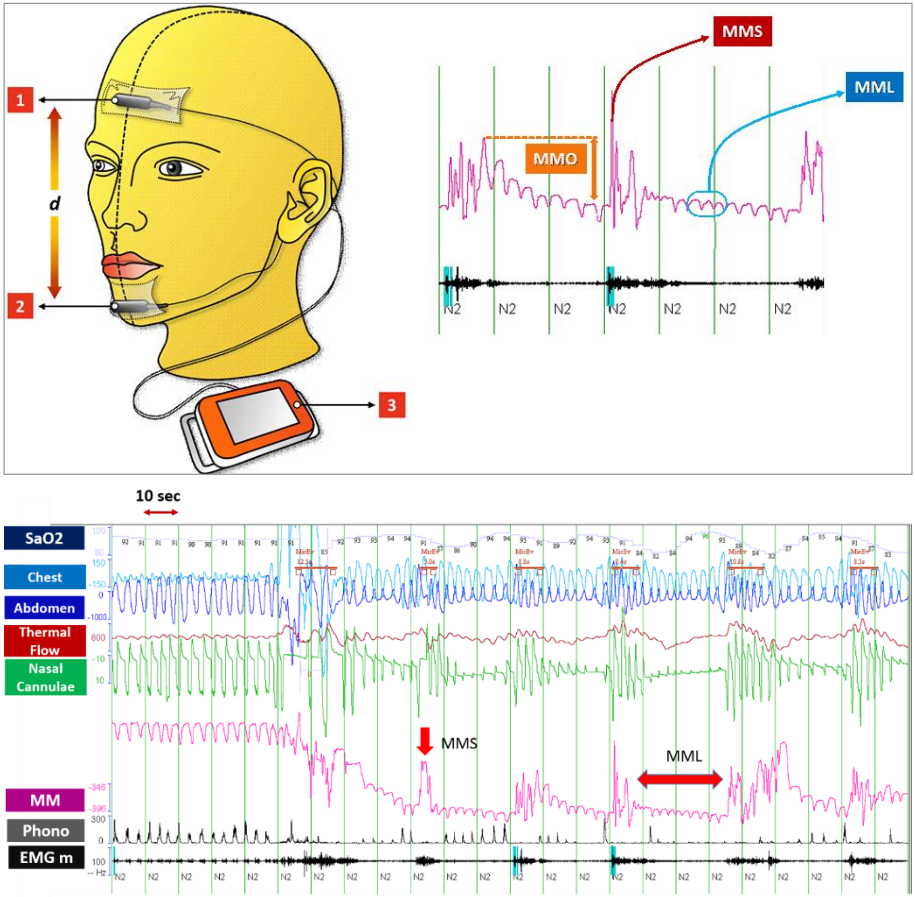


Figure 1 : Extract from a polysomnography sleep study showing various signals useful for detecting and classifying respiratory events, for comparison with the JAWAC (MM) signal.

REGISTRATION INFORMATION

Jawac signal validity	Percentage of the analysis area where the Jawac signal is valid, i.e., where the sensor is not saturated and where the signal value is between +10mm and -45mm relative to the reference level. Areas of frequent transitions between validity and invalidity are classified by majority in the 30 seconds preceding and following each moment. Periods of invalidity lasting less than 60 seconds are then deleted, and periods of validity lasting less than 60 seconds are reclassified as invalid.
Validity of the flow signal and RIP signals	Percentage of the analysis area where the flow signal/RIP signal is valid. To tolerate the very low amplitudes possible on these signals, validity is defined by a frequency analysis that checks whether a predominant signal exists in the 0.125 to 1.2Hz frequency band in which respiration occurs (7.5 to 72

	cycles/min), with rare exceptions, compared to disturbances found in frequencies above 2Hz. There are cases where the patient barely breathes between fairly long periods of apnea. Periods of invalidity lasting less than 180s or 2x[120]s (the maximum duration allowed for an event, if it exceeds 90s) are therefore reclassified as valid. Periods of validity of less than 60s are then reclassified as invalid.
Validity of the oximetry signal	Percentage of the analysis zone where the SpO2 signal is valid, i.e., where its value is between 1% and 100%. Areas of frequent transition between validity and invalidity are classified by majority in the 15 seconds preceding and following each moment. For oximetry signals, there may be very brief periods of invalidity, or even a single outlier value. In this case, the 1-second periods around these isolated cases are noted as invalid.
Heart Rate Signal Validity	Percentage of the analysis zone where the heart rate signal obtained from the ECG (R-R intervals) is valid, i.e., where its value is between 30 and 240 bpm. Frequent transition zones between validity and invalidity are classified by majority in the 15 seconds preceding and following each moment. In the R-R intervals, there may be very brief periods of invalidity, or even a single outlier. If this is the case, the 1-second periods around these isolated cases are noted as invalid.
Total analysis time	Duration of the analysis zone.
Total sleep time (TST)	Total duration of sleep zones in the analysis area.
Time in bed (TIB)	Total duration of the analysis zone[2] spent in a lying position.

EVENTS – AASM 2012 AND RF 2010 RECOMMENDATIONS

Obstructive sleep apnea (OSA)	Event lasting ≥ [10 seconds] with: • flow reduction ≥ [90%] • and chest (RIP) and/or jaw (Jawac) movements throughout the event.
Central Apnea (CA)	Event lasting ≥ [10 seconds] with: • flow reduction ≥ [90%] • and jaw movements < [0.18 mm] throughout the event. • and absence of chest movements (RIP) throughout the event.
Mixed Apnea (MA)	Event lasting ≥ [10 seconds] with: • flow reduction ≥ [90%] • and a period without chest movements (RIP) or jaw movements (Jawac < [0.18mm]) at the start of the event, followed by a period with movements.
Hypopnea associated with desaturation (Hyp_d)	Event lasting ≥ [10 seconds] with: • flow reduction ≥ [30%]

[2] Please note that individual signal invalidity zones may prevent the automatic analyzer from marking events there, but they are not removed from the TST or TAL since other signals may provide information there.

	• and desaturation ≥ [3%].
Hypopnea associated with visible activation on the Jawac (Hyp_j)	Event lasting ≥ [10 seconds] with: • flow reduction ≥ [30%] • and respiratory activation (Jawac signal).
Hypopnea with 50% reduction in flow (Hyp_50)	Event lasting ≥ [10 seconds] with a reduction in flow ≥ [50%] as described in the French RF 2010 recommendations.
Ventilatory effort associated with activation (RERA)	Event lasting ≥ [10 seconds] with: • a period of effort — during which the peak-to-peak amplitude of mandibular oscillations is ≥ [0.3 mm] — followed by respiratory activation • and not corresponding to the definition of apnea/hypopnea.
Ventilatory Effort (RE)	Period of duration ≥ [20 seconds] with effort, during which mandibular oscillations are stable and have a peak-to-peak amplitude ≥ [0.3 mm].
Desaturation (Desat)	SpO2 drop ≥ [3%] within 30 seconds.

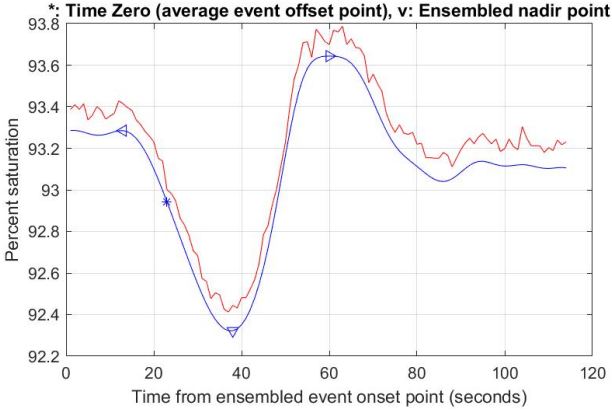
SEVERITY ANALYSIS

The definitions of the ratings for the events listed in the index calculations below are those presented on page 6. Depending on the parameters selected by the user (see the relevant section of the user manual), those indicated in [ ] may or may not be included.

Apnea-Hypopnea Index (AHI)	Number of apneas and hypopneas per estimated hour of sleep AHI = (nOA+nCA+nMA+nHyp_d+[nHyp_j]+[nHyp_50]+[nRERA])/TST
Respiratory Event Index (RDI)	Number of apneas, hypopneas (desaturating and/or respiratory activation) and RERA events per estimated hour of sleep RDI = (nOA+nCA+nMA+nHyp_d+nHyp_j+nRERA)/TST
Ventilatory effort: Proportion of time spent ventilating	Cumulative duration of all periods of ventilatory effort over the estimated duration of sleep. Expressed as a %.
Snoring: Percentage of time	Cumulative duration of the number of respiratory cycles associated with snoring out of the total number of respiratory cycles during sleep. Expressed as a %.
Respiratory event index	Number of respiratory activations per hour of sleep (estimated based on the number of MMS).
Sleep fragmentation index	Estimated number of activations per hour of sleep, regardless of their origin.

OXYMETRY ANALYSIS

Oxygen Desaturation Index (ODI)	Number of desaturations per hour of sleep = nDesat/TST.
Cumulative time below 88% SpO2 (TC90)	Sleep time during which SpO2 < 88%. Also expressed as a percentage of total sleep time.

Cumulative time below 80% SpO2 (TC80)	Sleep time during which SpO2 < 80%. Also expressed as a percentage of total sleep time.
Cumulative time below 70% SpO2 (CT70)	Sleep time during which SpO2 < 70%. Also expressed as a percentage of total sleep time.
Minimum saturation	Minimum SpO2 signal (excluding extreme values), calculated during sleep zones.
Average saturation	Average SpO2 signal, calculated over sleep zones.
Average heart rate	Average number of beats per minute, calculated based on sleep zones.
Time spent below 30 bpm / above 90 bpm	Sleep time during which Pulse Rate < 30 bpm or > 90 bpm, respectively.
Hypoxic load	Index calculated according to the reference Kate Sutherland, Nadi Sadr, Yu Sun Bin, Kristina Cook, Hasthi U. Dissanayake, Peter A. Cistulli and Philip de Chazal, "*Comparative associations of oximetry patterns in Obstructive Sleep Apnea with incident cardiovascular disease*", Sleep, 2022, DOI: 10.1093/sleep/zsac179 The calculation requires the definition of areas delimited vertically by a baseline specific to each event and the part of the SpO2 curve that lies below this baseline, and horizontally by delays relative to the end of each respiratory event. These delays are adapted to the patient by calculation based on an average SpO2 curve near each identified event, as follows. **Red trace: ensembled SpO2 signal** **Blue trace: filtered ensembled SpO2 signal** **<|: search window start, |>: search window end** ***: Time Zero (average event offset point), v: Ensembled nadir point**  As a result, to calculate the hypoxic load, at least one event of type OA, CA, MA, Hyp_d, Hyp_j, or Hyp_50 is required, or their equivalent events if the events were defined based on Jawac, around which SpO2 is valid. In particular: • Valid SpO2, > 50% and no awakening within 100 seconds before the end of the event, in order to calculate a baseline. • Valid SpO2, > 50% and below baseline, and no awakening within the time limits defined by the graph above, which can be up to 90 seconds after the event.

	All events that do not meet these criteria will be ignored in the calculation of the index.
McGill score	Index calculated according to the reference Gillian M. Nixon, Andrea S. Kermack, G. Michael Davis, John J. Manoukian, Karen A. Brown, and Robert T. Brouillette, "*Planning Adenotonsillectomy in Children With Obstructive Sleep Apnea: The Role of Overnight Oximetry*," Pediatrics, Vol. 113 No. 1 January 2004. It records desaturations based on their minimum value and their grouping into clusters (at least 5 desaturations over a 30-minute period) and assigns a severity score from 1 to 4 according to: **TABLE 1.** The McGill Oximetry Scoring System Devised in Phase 1 and Validated in Phases 2 and 3 It should be noted that a cluster is defined over a fixed period of 30 minutes. Consequently, for example, 10 or 15, 20, 50, etc. desaturations evenly distributed over 1 hour therefore constitute 2 clusters. After evaluating the number of clusters and counting the number of desaturations falling below 80%, 85%, and 90%, we arrive at a score of **4** if there are more than 3 desaturations below 80%, otherwise **3** if there are more than 3 desaturations below 85%, otherwise **2** if there are at least 3 desaturations below 90%[3], or at least 3 clusters, otherwise **1**

Oximetry Score	Comment	Criteria				Recommendation
		No. of Drops in SaO_2 <90%	No. of Drops in SaO_2 <85%	No. of Drops in SaO_2 <80%	Other	
1	Normal study/ inconclusive for OSA	<3	0	0	Baseline: stable (<3 clusters of desaturation) and >95%	Additional evaluation of breathing during sleep required to rule out OSA
2	OSA, mild	≥3	≤3	0	Three or more clusters of desaturation events[14]	Recommend T&A on the waiting list
3	OSA, moderate	≥3	>3	≤3	Three or more clusters of desaturation events[14]	Recommend surgery within 2 wk
4	OSA, severe	≥3	>3	>3	Three or more clusters of desaturation events[14]	Recommend urgent surgery (within days)

[3] The table in the publication takes into account the fact that, for example, a desaturation falling to 84% is counted under both 85% and 90%.

LEAK ANALYSIS

The use of a Pneumotachograph Module (NS960), in combination with a pneumotachograph sensor inserted between the CPAP tube and the mask of a patient undergoing treatment, makes it possible to detect leaks that occur during the night. Apios' analysis of the contexts in which these leaks occur makes it possible to infer the most likely causes in order to attempt to remedy them.

This context analysis focuses on the following criteria

- a mouth opening (Jawac signal) greater than the median calculated during sleep periods
- the presence of respiratory effort (Jawac Effort signal)
- CPAP pressure (CPAP pressure signal) above the median calculated during sleep periods
- back or non-back position (Body Position signal)

It uses the statistical technique of Odds Ratios to estimate the influence or lack thereof of each of these factors.

The Odds Ratios method is based on the number of occurrences of the four possibilities

- True/True: there is a leak and the criterion exceeds the threshold (or is true)
- True/False: there is a leak but the criterion does not exceed the threshold (or is false)
- False/True: there is no leak and the criterion exceeds the threshold (or is true)
- False/False: there is no leak and the criterion does not exceed the threshold (or is false)

In order to provide a result, each of these cases must occur at least once mathematically. In particular, the two corresponding signals (leak and criterion) must be valid at the same time and in each of the configurations.

In practice, for greater statistical reliability, the analysis is also indicated as uncalculable if there is not at least 10% and at most 90% of sleep time spent with unintentional leaks. Similarly, it is also declared uncalculable if there is not at least 10% and at most 90% of sleep time spent with a criterion that exceeds the threshold (or is true).

The calculation of unintentional leakage is based on the intentional leakage characteristics of the mask as declared by the manufacturer. Make sure you have entered the correct mask.

To perform these counts, signal amplitudes are evaluated by their median over 10-second intervals.

ALGORITHMIC PRINCIPLES

DISTINCTION BETWEEN WAKING AND SLEEPING

During automatic analysis, all regions that are recognized as awake become exclusion zones.

The user can configure the automatic analysis to choose which method is used to distinguish between wakefulness and sleep:

NONE

The analysis areas can be restricted manually by defining the start and end of the analysis, as well as by defining exclusion areas, and by specifying in the confirmation window when launching the analysis that these areas should not be recalculated.

BASED ON BODY POSITION ONLY

When standing, the patient is considered to be awake. The 3 minutes preceding and following the "standing" periods are also considered to be awake.

BASED ON THE JAWAC SIGNAL

The frequency content and structure of the Jawac signal are analyzed taking into account the following observations (see [b] and [c]):

1. If mandibular activity is rapid, disordered, or chaotic, then the patient is considered awake. Even when we are calm, the inevitable swallowing and tongue movements are sufficient to detect this wakefulness.
2. Conversely, if mandibular activity is calm, then the patient is considered asleep.
3. Periodic mandibular activity is a sign of effort or bursts of respiratory events, and therefore of sleep.

BASED ON MULTI-SIGNAL ANALYSIS

Wakefulness periods are initially determined based on body position.

When the patient is lying down, the result is determined by analysis based on the Jawac signal, excluding periods when desaturation is observed, which are classified as sleep.

Methods that use mandibular activity as an indicator of wakefulness/sleep require the Jawac signal to be recorded accurately in order to ensure reliable detection of wakefulness and sleep.

Multi-signal analysis is recommended in most cases. However, in specific cases, such as in patients with COPD (Chronic Obstructive Pulmonary Disease), it can lead to poor performance because bursts of desaturation are considered by the method to be an indicator of sleep.

In general, it is important for physicians to keep a critical eye on the results of automatic analysis.

DELIMITATION AND CLASSIFICATION OF RESPIRATORY EVENTS

Events can be identified and delimited based on the Nasal Flow or RIP Sum signal, if present or valid, according to the AASM 2012 definitions mentioned above. It should be noted that when the SpO2 signal is absent or invalid, no Hyp_d can be marked.

Alternatively, events can be delimited on the Jawac ([a], [b], [d] and [f]). In this case, we do not refer to apneas or hypopneas, since we cannot compare them to the AASM definitions, but rather to respiratory events in the broad sense.

Events are then classified as obstructive, central, or mixed using the Jawac and/or RIP Chest/Abd signals. The Multi-Signal classification checks for the absence of movement on all three signals before concluding that an event is central in nature.

There are therefore six possible delimitations/classifications by automatic analysis, selected according to the availability and validity of the signals:

- The default settings delimit events based on Nasal Flow and classify them using all Jawac and RIP signals available and valid at that time.
- If the validity of Nasal Flow is less than 30% of the TST, delimitation is performed on RIP Sum, if available, according to AASM recommendations.
- And if the RIP_Sum signal is absent or has a validity of less than 30% of the TST, the delimitation and classification of events are performed based on Jawac.

Adults/Children: Since the thresholds for indices (IAH, etc.) are very low in children, the automatic analysis offered if the recording comes from a child (< 18 years old) is based on stricter event detection criteria.

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[c]	*The sleep/wake state scoring from mandible movement signal; Senny et al.; Sleep and Breathing 2011; DOI 10.1007/s11325-011-0539-4.*
[d]	*Added value of a mandible movement automated analysis in the screening of obstructive sleep apnea, Maury et al., Journal of Sleep research, Vol 22, 1, DOI: 10.1111/j.1365-2869.2012.01035.*
[e]	*Mandibular Movements Identify Respiratory Effort in Pediatric Obstructive Sleep Apnea; Martinot J B, Senny F, Denison S, Cuthbert V, Gueulette E, Guénard H and Pépin J L; Journal of Clinical Sleep Medicine, Volume 11, Issue 05, 2015*
[f]	*Mandibular position and movements: Suitability for diagnosis of sleep apnoea; Martinot J-B, Borel J-C, Cuthbert V, Guénard H, Denison S, Silkoff P, Gozal D and Pepin J-L; Respirology, Volume22, Issue3, 2016*
[g]	*Mandibular Movements As Accurate Reporters Of Respiratory Effort During Sleep : Validation Against Diaphragmatic Electromyography; Martinot J-B, Le-Dong NN, Cutheberg V, Denison S, Silkoff P, Guénard H, Gozal D, Pepin J-L and Borel J-C; Front. Neurol., 2017 Jul.*