AUSTRALASIAN SLEEP ASSOCIATION

Overnight Oximetry for evaluating Paediatric Obstructive Sleep Apnoea

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Technical Specifications and Interpretation Guidelines

Intention:

Provide a consensus guideline for the practice of paediatric overnight oximetry studies for obstructive sleep apnoea in Australasia. Due to the limitations of oximetry this document refers to children over 12 months corrected gestational age. It focuses on technical performance and interpretation. It is not intended as a guide to the overall evaluation or treatment of obstructive apnoea and ought not be used in isolation.

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Review date: 2024

Contents:

1. **KEY POINTS**

- Oximetry recordings can provide useful information in the assessment and management of children with known or suspected obstructive sleep apnoea.
- Oximetry cannot rule out significant obstructive sleep apnoea.
- Oximetry cannot differentiate obstructive from central respiratory events.
- Appropriate choice of device, settings, software and report format are critical to interpretation.
- An awareness of clinical context including age and potential confounders is crucial. This document is not intended for children under 12 months of age and should be used with caution in those with significant confounders/co-morbidities.
- Oximetry may predict risk of post-operative respiratory compromise and so can aid the planning of post-operative care.
- Oximetry studies may be performed in other contexts but these are outside the scope of this document.

2. **INTRODUCTION**

Since its introduction in the 1970s, pulse oximetry has become a common and valuable clinical tool. Recording continuous overnight oximetry is a more recent application of this technology.

Sleep is a vulnerable time for respiration, involving changes in muscle tone/control, chemoreceptor responsiveness to apnoea and respiratory chemoreceptors, and a fall in functional residual capacity, minute ventilation, and potentially, respiratory control stability. These changes may lead to either sustained or paroxysmal reductions in ventilation/gas exchange and/or repeated arousals resulting in sleep disruption.

The gold standard for the assessment of sleep quality and sleep disordered breathing is polysomnography. However, limited channel studies such as pulse oximetry may still provide useful data. As with all tests, it is critical to understand the indications for pulse oximetry, what the instrument measures and reports, its limitations, and how to interpret results.

Oxygen delivery to tissues is influenced by:
- Cardiac output
- Tissue perfusion
- Haemoglobin (Hb) concentration
- Haemoglobin oxygen capacity (HbO_2)
- Oxygen affinity, and
- Oxygen saturation (SpO_2).

Haemoglobin oxygen capacity is usually approximately 1.39 mL/g (adult Hb). SpO_2 ('functional saturation') refers to the amount of oxygen bound to haemoglobin in the blood expressed as a percentage of its maximal capacity. 'Fractional saturation' (HbO_2), often reported by blood gas analysers and estimated by some pulse oximeters, refers to the percentage of total Hb bound to oxygen and never reaches 100%. The relationship between SpO_2 and HbO_2 varies and they should not be considered interchangeable. Oxygen affinity refers to the relationship between oxygen saturation and oxygen partial pressure (oxygen dissociation curve, see **Figure 1**). The oxygen affinity should be such that haemoglobin reaches almost full saturation in the lungs, yet readily releases oxygen at the relatively lower partial oxygen pressure in the tissue capillaries.
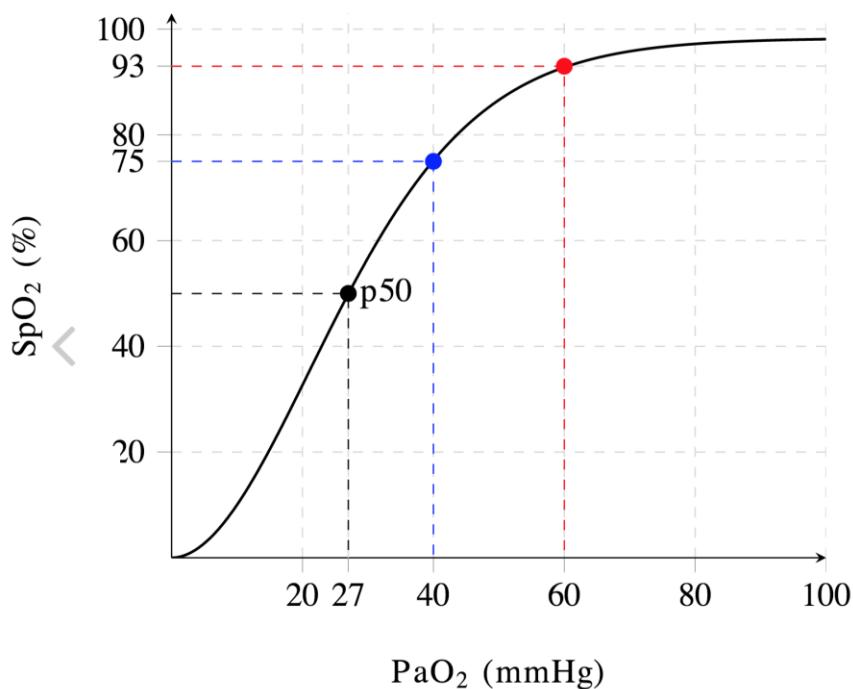
Figure 1. Oxygen dissociation curve

3. OXIMETRY TECHNOLOGY

Pulse oximetry refers to technology which estimates the arterial oxygen saturation based firstly on the detection of pulsatile blood flow and secondly on differing absorption spectra of oxyhaemoglobin and deoxyhaemoglobin. Most commercially available pulse oximeters have two light-emitting diodes (LEDs) that emit light at 660nm (red) and 940nm (infrared). A photoreceptor is positioned opposite to the LEDs with patient tissue, usually a finger, toe or ear lobe, held between. The oximeter signal processor compares the ratio of absorption of the two spectra against a set of stored reference values obtained previously from volunteers. While the signal is sampled frequently (e.g. 25 times per second), the displayed (and recorded) output is usually averaged over a set period (2-16 seconds) or heart beats that is referred to as the **'averaging time.'** Longer averaging times (8-16s) may reduce signal artefact (e.g. from motion) but also reduce the ability to detect the rapid change in saturation often seen with central or obstructive events (apnoea/hypopnoea). In addition, the report may be influenced by the study **'resolution'-** the frequency that the result is saved into the oximeter's memory (commonly once every 2-10 seconds).

Sources of oximetry inaccuracy include
- **Motion artefact.** Motion impairs the oximeter's ability to discern pulsatile blood flow. Manufacturers utilize different signal processing techniques (including the use of long averaging times) to reduce this error. In addition, oximeters may indicate signal strength and/or show a plethysmographic waveform to assist the clinician in identifying artefact.
- **Severe hypotension, low cardiac output, vasoconstriction and hypothermia** reduce pulse volume and consequent signal strength, impairing oximeter performance.
- **The presence of carboxyhaemoglobin, methaemoglobin, fetal haemoglobin, sickle cell haemoglobin, nail polish, false nails and xenon and fluorescent lamps** potentially influence results. Hyperbilirubinaemia and anaemia do not.
- Oximeter technology relies on **reference data** obtained from volunteers. Individual variation and the limits of what values can be safely generated in volunteers results in intrinsic inaccuracy, especially when oxygen saturations fall below 70%. Probes designed for low saturations are available.

- Quality, appropriate size and placement of the **oximetry sensor**. Variations in the frequency output of individual LEDs (individual sensors) can also influence results.

Most pulse oximeters have quoted accuracy of ± 2-3% at saturations above 90%. Oximeters don't require calibration however should be well maintained and used according to manufacturer recommendations.

4. TECHNICAL STANDARD - RECOMMENDATIONS

4.1 Oximeter qualities:

High motion resistance	Recommended
Provides measure of signal quality (ability to exclude artifact)	Recommended
Age appropriate sensors in good condition	Recommended
Sufficient recording capacity (hours) and (if appropriate) battery life	Recommended
Easy to use in varying environments (those with a 'lock out' or 'home mode' may be preferred).	Recommended
Familiar to staff	Recommended

As movement artefact can be a significant challenge in infants and children, choosing an oximeter with good 'motion resistance' characteristics is important. Technology varies between models so experience with individual models aids interpretation. The oximeter ought to be capable of indicating when signal quality is poor (both overnight and on the downloaded recording). Sensor quality, fit and placement have a large impact on study quality. The oximeter must have sufficient recording capacity for overnight studies. As devices do vary, familiarity with the specific device is important.

4.2 Oximeter settings:

SpO$_2$ averaging time	2-3 seconds (or ~ 3 beat)	Recommended
Resolution (frequency data stored)	2 seconds or less	Recommended
Alarms	Disabled or set broadly	Recommended

For the purposes of an oximetry study in the evaluation of suspected OSA, as opposed to other roles including monitoring, a short averaging time is required (<3 seconds at a heart rate of 80bpm). Some oximeters average pulse 'beats' rather than seconds. At a heart rate of 60bpm, 2-3 beat averaging would equate to 2-3 second averaging. At 100bpm, 3-5 beat averaging would equate to 2-3 second averaging (or less). As alarms may themselves disturb sleep, these ought to be disabled or set so broadly that they are unlikely to sound. Where patient safety is a concern a compromise in alarm thresholds may be required.

4.3 Study indication

Study indication and relevant medical history	Collected	Recommended
Standardised sleep questionnaire (eg Chervin PSQ)	Collected	Optional

The indication for the study or question to be answered should be clearly stated prior to the study together with relevant medical history (eg. co-morbitities). This will help ensure the study is appropriate (i.e. can answer the question) and that is performed at the right time and in the right manner. A form may be used to collect this information in a standardised manner.   Whilst not required, routinely having a parent / caregiver complete standardized symptom questionnaire is helpful.

4.4 Study context (status at the time of the study)

Study context – details regarding the child's health, current therapies and the typicality of sleep on the study night.	Collected	Recommended

Ensure that the study is performed at an appropriate time and manner to the clinical question being asked. This will generally be when the child is well and best postponed if the child is immediately post-anaesthetic or suffering an intercurrent illness. Information regarding their current health status (well/unwell), typicality of the sleep that night and any relevant therapies received at the time (nasal steroids, oxygen, etc) should be collected at the time of the study and available to those interpreting the result.

4.5 Staff / parent / caregiver Observations (see example observation sheet below)

Observation chart	Utilised	Recommended

In conjunction with the oximetry study, an overnight observation record of events and the child's status is recommended. Observations may include events (awake, asleep, feeding, crying, alarm soundings, etc), body position and respiratory observations (snoring, increased work of breathing, etc). An example is included in Appendix 8.1.

4.6 Study duration

Study duration	> 6 hours of sleep	Recommended

When utilizing cluster analysis (see Interpretation), some adjustment for study duration may be appropriate. Night to night variability is not uncommon especially in specific conditions (eg Down syndrome).[1] As oximetry is relatively easy and non-invasive a low threshold for repeating studies that are discordant with clinical presentation is recommended.

4.7 Study software, download & editing:

Download software	Systems to ensure correct patient details entered	Recommended
Editing of data	Artefact removal or limiting to period of interest	Optional
Editing documented	Document editing if performed	Recommended

In the same way that the characteristics of oximeter devices vary, so do the download softwares.[2] This impacts on how the indices are calculated and the data displayed. Great care must be taken when downloading. Check that the correct patient details (right patient to right study) and study characteristics are entered into the download software. Some softwares permit editing of data (ie deletion of artefact). This may be appropriate but great care must be taken that the interpreting clinician is aware of what and why data has been removed. Editing undertaken should be noted in the report.

Artefact exclusion / removal:
Artefact, often due to movement, may confound interpretation especially when short averaging times are being used or young children studied. This may impact on software defined indices (e.g. nadir) or on cluster analysis (see below). A practitioner / service ought to have an agreed strategy on how artefact will be managed. This may be up to the interpreter (i.e. the report shows all raw data including a measure of oximeter signal quality) or editing may occur using the download software. In the latter case it is important that any performed editing is described on the report and a raw version of the data ought to be kept. Different strategies are possible with software editing including:
- Manual removal of wake time and judged artefact. This may be identified / suspected either from concurrent carer observation or due to sustained increase in heart rate / heart rate

variability particularly at the beginning or end of the recording. The time taken to perform this and the likely negligible effect on oximetry parameters should be taken into account when deciding whether to undertake this step.[3]

- Software defined implausible results. Software may allow the automated removal of SpO_2 data points that are for example 10 points different from preceding or following data points as this is judged physiologically implausible.
- Oximeter defined poor signal. Software may allow the automated removal of data that the oximeter has determined to be suspect.

4.8 Report Contents & Graph Format

Patient identifiers		Recommended
Study date & duration		Recommended
Name of responsible / requesting clinician		Recommended
Relevant study conditions (health status & therapy on night of study)		Recommended
Oximeter model, averaging time and resolution		Recommended
SpO_2 indices – Mean SpO_2, nadir, % time under 90%, 3% desaturation index*		Recommended
SpO_2 indices – 4% and/or 10% desaturation indices[†]		Optional
Pulse rate indices - mean, maximum and minimum pulse rate		Recommended
Graphical representation	Graph time scale: $\geq$ 3 cm/hour	Recommended
	SpO2 graph - scale: $\geq$1 mm/%[‡]	Recommended
	Pulse rate graph	Recommended
	Signal quality displayed	Recommended
Data editing		Optional
Documentation of editing (if done)		Recommended
Printouts of individual events and bar graphs/histograms		Optional

* A 3% desaturation refers to a drop of 3% or more relative to the preceding baseline.

4.9 Clinician reporting (interpretation)
This may be an integral to the oximetry 'report' or a separate document. Components include:

Clinical indication	Recommended
Summary of relevant overnight staff/carer observations	Recommended
Comment on study context (duration, well/unwell, concurrent therapy)	Recommended
Comment on study quality	Recommended
Summary of pertinent results	Recommended
Clinical interpretation / conclusion	Recommended

Making recommendations:
It is always appropriate for an oximetry report to include recommendations relating to technical aspects and clinical limitations of oximetry in this context. Examples may include:

- "Repeat study is recommended" in the context of a study that is too short or has excessive artefact.
- "Obstructive sleep apnoea is not excluded. Proceed as clinically indicated." or "Obstructive sleep apnoea is not excluded. Consider further assessment with polysomnography" to highlight that oximetry cannot be used to rule out obstructive sleep apnoea.

[†] The 3% desaturation index is recommended as most commonly used now in polysomnography. 4% desaturation criteria are used in cluster analysis (see below) as this was the practice at the time the scoring was developed.

[‡] These are recommended on the paper report if analysis is to be done from that and may not apply to practitioners whom perform analysis 'on-screen' in the download software where they have the ability to zoom in and out to confirm the nature of events.

- "Consider polysomnography to better define the nature of observed desaturation events." in the context of a child with significant risk factors for confounding central apnoea (eg. infant, Down syndrome, Prader Willi syndrome).

It is also appropriate to highlight features of an oximetry study that indicate greatly increased post operative risk (see 5.2.7 below). Specific recommendations regarding what action should be taken to manage that risk depend on the clinical / service context and are beyond the scope of this document.

Unless the interpreting clinician is highly familiar with the clinical context of the specific child in question, clinical recommendations regarding therapy (eg. "Adenotonsillectomy is recommended") should not be included in the oximetry report.

5.0 INTERPRETATION STRATEGIES

Oximetry studies present a great deal of data. A systematic approach to interpretation is recommended:

5.1 GENERIC STRATEGY - CAGE

C for CONTEXT:
Clinical context - What is the question? What are the pre-test probabilities? *Study context* - What happened during the study (awake / asleep, feeding, crying, etc)? Is the child on oxygen or other respiratory support? *Technical context* - What model of oximeter (any peculiarities to be aware of)? What averaging time? What resolution? What report format?
A for ARTEFACT:
Identify and exclude obvious artefact. Is the study of adequate quality overall? If not do not proceed further (repeat the study).
G for GAS EXCHANGE:
Estimate the average saturation from the indices and graphical representation. While summary statistics provided by the oximeter such as mean and nadir may be useful, they may be skewed by artefact. For some indications, estimating the time spent below 90% may also be useful.
E for EVENTS:
Consider averaging time again - is it possible to report on events? Consider the graphical representation. Note frequency and severity of desaturation. Do they occur in clusters? Is there recovery between? If appropriate, apply 'scoring' systems such as the McGill score outlined below.

5.2 Cluster analysis for obstructive sleep apnoea syndrome (OSAS)

Whilst polysomnography remains the gold standard for diagnosis and exclusion of obstructive sleep apnoea and for the titration of respiratory support, oximetry can be a useful tool. Conceptually it may be seen as a very limited channel sleep study relying on the presence of desaturations to herald respiratory events and making the assumption they are obstructive. Oximetry can add strong support to clinical suspicion of OSAS, provide a crude estimate of OSAS severity, assist in triaging urgency of surgery, and contribute to peri-operative risk assessment. Oximetry is limited by the fact that obstructive apnoea and hypopnoea may occur without significant desaturation and that desaturation may occur for other reasons. Interpretation requires caution in patient populations with high prevalence of central apnoea (eg infants, Down syndrome). If there is doubt about interpretation the opinion of a paediatric sleep specialist should be sought.

Strategies focus on the visual examination of a graphical representation of the SpO_2 using 'cluster' analysis. This approach involves
   a) Performing a study as outlined above. General recommendations for set-up, quality, report format, and interpretation apply.
   b) Cluster analysis, which involves systematically scoring the study based on the presence of clusters of desaturation using the rules/definitions below. This approach is largely defined by Brouillette 2000 and referred to as a 'McGill Oximetry Score'.[4]

5.2.1 Definitions[4]

Baseline	This generally refers to the 'typical' saturation for that patient and in this context during non-obstructed breathing. The reported mean is generally a reasonable guide unless there is significant artefact or very frequent/prolonged desaturation in which case it may be better to estimate it from the graph.
Desaturation	≥ 4% fall from preceding baseline (any duration)
Cluster	≥ 5 desaturations within a 10-30 minute period of sleep
D90%	A fall in SpO_2 to < 90%
D85%	A fall in SpO_2 to < 85%
D80%	A fall in SpO_2 to < 80%

5.2.2   The McGill Oximetry Score (Brouillette 2000, Nixon 2004) is the most common cluster analysis method used in Australasia.[4,5]

In children over 1-2 years in age with clinically suspected obstructive sleep apnoea, adenotonsillar hypertrophy and no confounding co-morbidities, a positive McGill Oximetry Score has a 98% positive predictive value for the presence of OSA. However the McGill Oximetry Score only has a sensitivity of 43%. Always bear in mind that a child can have severe OSAS, as defined by PSG, without desaturation events.

		Clusters	D90%		
'McGill'/(Brouillette / Nixon)	*Inconclusive*	Not positive			
'McGill'/(Brouillette / Nixon)	*Positive*	≥ 3	≥ 3		

5.2.3 Alternate cluster analyses:

Suarez (2013) provided an alternative cluster analysis strategy based on shorter studies that uses the same rules to define a cluster but requires fewer- just two.[6]

The table below defines both the McGill and Suarez Oximetry scores. The McGill Oximetry Score may also be used to estimate severity. It should be noted that it is possible to have PSG defined severe OSA with an 'inconclusive' oximetry result and that neither oximetry nor PSG defined severity necessarily correlates with clinical impact in an individual.

Criteria (Brouillette 2000, Nixon 2004, Suarez 2013)[4–6]

		Clusters	D90%	D85%	D80%
'McGill'/(Brouillette / Nixon)	*1 – Inconclusive*	Not positive			
'McGill'/(Brouillette / Nixon)	*2 – Positive*	≥ 3	≥ 3		
'McGill'/(Brouillette / Nixon)	*3 – Positive moderate*	≥ 3		> 3	
'McGill' (Brouillette / Nixon)	*4 – Positive severe*	≥ 3			> 3
Suarez	*"Negative"*	Not positive			
Suarez	*"Positive"*	≥ 2	≥ 1		

5.2.4 Cluster analyses validation:

	Positive / suggestive study	Clusters /hr	Positive predictive value	Negative predictive value	Sensitivity
'McGill' Brouillette, 2000[§]	≥ 3 clusters + > 3 D90%	0.4/hr	97%	57%	43%
Suarez, 2013[**]	≥ 2 clusters + ≥ 1 D90%	0.4/hr	98%	90%[††]	87%

5.2.5 Cluster analysis in young and/or complex patient groups

Cluster analysis may still be used those with relevant co-morbidities (e.g. Down syndrome) but greater caution is needed for interpretation due to an increased incidence of confounding central respiratory events.[7]

5.2.6 Adjuvant data / heart rate analysis:

Pulse rate variability / rises are commonly seen in association with obstructive respiratory events on PSG and oximetry heart rate analysis (visually or automated) may add to SpO_2 interpretation. Analogous to the desaturation index, the pulse rate rise index (PRI), but not pulse rate standard deviation, has been validated with a PRI-15 (rise of 15bpm) of >35/hr having a 97% specificity for OSA in children.[8]

5.2.7 Adenotonsillectomy risk:

Pre-operative oximetry has been validated as a tool to help predict respiratory compromise post-operative risk (airway compromise) in children having adenotonsillectomy for OSA. OSA in general increases peri-operative risk and the risk rises with increasing McGill Oximetry Score.[5] Those with a McGill Oximetry Score of 3 or 4 are at highest risk and their post-operative care plan ought reflect this. A detailed review of appropriate post-operative care is beyond the scope of this document but recommendations for those with a McGill Oximetry score of 3 or 4 include: [5,9–14]

- Overnight admission in a facility with after-hours expertise in paediatric airway management.
- Appropriate caution with opiate administration.
- Continuous oximetry monitoring (including in the post-anaesthetic care unit).

These recommendations only consider pre-operative oximetry findings and other risk factors such as age and co-morbidities also require consideration.

See section 8.2 for worked reporting examples involving the use of this scoring

5.2.8 Automated analyses:

The ASA notes a number of research groups have been developing various forms of automated analysis for the prediction of OSA based on oximetry. However the ASA is not aware (now) of any that are commercially available or in widespread clinical use and no recommendation can be made at this time.

5.3   Oximetry for suspected OSA in infants

[§] *The Brouillette study used a Nellcor N-200 oximeter and studies were 8 hours in duration.*

[**] *The Suarez study used a Nonin oximeter and studies were typically 5 hours in duration.*

[††] *The Suarez study's PSG methodology may have under-estimated mild OSA and consequently over-estimated sensitivity and negative predictive value.*

Obstructive sleep apnoea can occur in infants, often due to enlargement of the adenoids or secondary to conditions such as laryngomalacia, choanal atresia, or other congenital upper airway conditions. Whilst OSA in infancy may be associated with desaturation events as for any other child, interpretation of oximetry results is more difficult in infants given that oximetry is unable to distinguish the aetiology of desaturation.[15] Central apnoeas may confound the interpretation of oximetry, especially in neonates in whom respiratory control is immature and in whom periodic breathing may cause clusters of desaturation. Central apnoea and periodic breathing may co-exist with obstructive conditions, or even be the major cause of desaturation in children with symptoms of obstruction, and so oximetry cannot be relied upon to reliably determine which children have severe OSA. Polysomnography may be indicated in this age group to determine the aetiology of desaturation events. See the Australasian Sleep Association clinical practice guidelines for performing sleep studies in children 2017, https://www.sleep.org.au/documents/item/2984[16]

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7. GLOSSARY

BPM   Beats per minute

CAHI   Central apnoea hypopnea index

CPAP   Continuous positive airway pressure

'Dip'   A brief desaturation

'Desat' A brief desaturation

D10I   Desaturations or dips of 10% or more from preceding baseline per per hour

D3I   Desaturations or dips of 3% or more from preceding baseline per per hour

D4I   Desaturations or dips of 4% or more from preceding baseline per per hour

D80%   Desaturations below 80%

D85%   Desaturations below 85%

D90%   Desaturations below 90%

Hb   Haemoglobin concentration

HbO2   Haemoglobin oxygen capacity

Hr   Hour

OAHI   Obstructive apnoea hypopnea index

OSA   Obstructive sleep apnoea

PRI   Pulse rise index

PSG   Polysomnography

RDI   Respiratory disturbance index

SpO2   Oxygen saturation (peripheral capillary)

8.1 Appendix – Example of Oximetry Observation Record Sheet:

Name of person having study: . . . .   **Date of Study** . . . .

Name and role of person completing observation record: . . . .

Time	Comment (awake, asleep, feeding, crying, snoring, on back, etc)	Support Room air, oxygen (include flow), CPAP, etc as applicable
example "6pm"	*example "asleep, snoring"*	*example "room air"*

8.2 Appendix: Worked examples with reports

These worked examples were performed in different centres using different software packages.

The graphical representations have been re-scaled to fit on the page and without patient / date identifiers. They may not include the full recording or the software provided summary statistics that would usually be available to the reporter.   Note in practice, interpretation may be done directly within the download software or from paper/electronic reports produced by the download software.

Some oximetry examples include PSG indices derived from a study the same night.
OAHI – obstructive apnoea hypopnoea index, CAHI – central apnoea hypopnoea index, RDI – respiratory disturbance index.

Examples of written interpretations are provided for each.

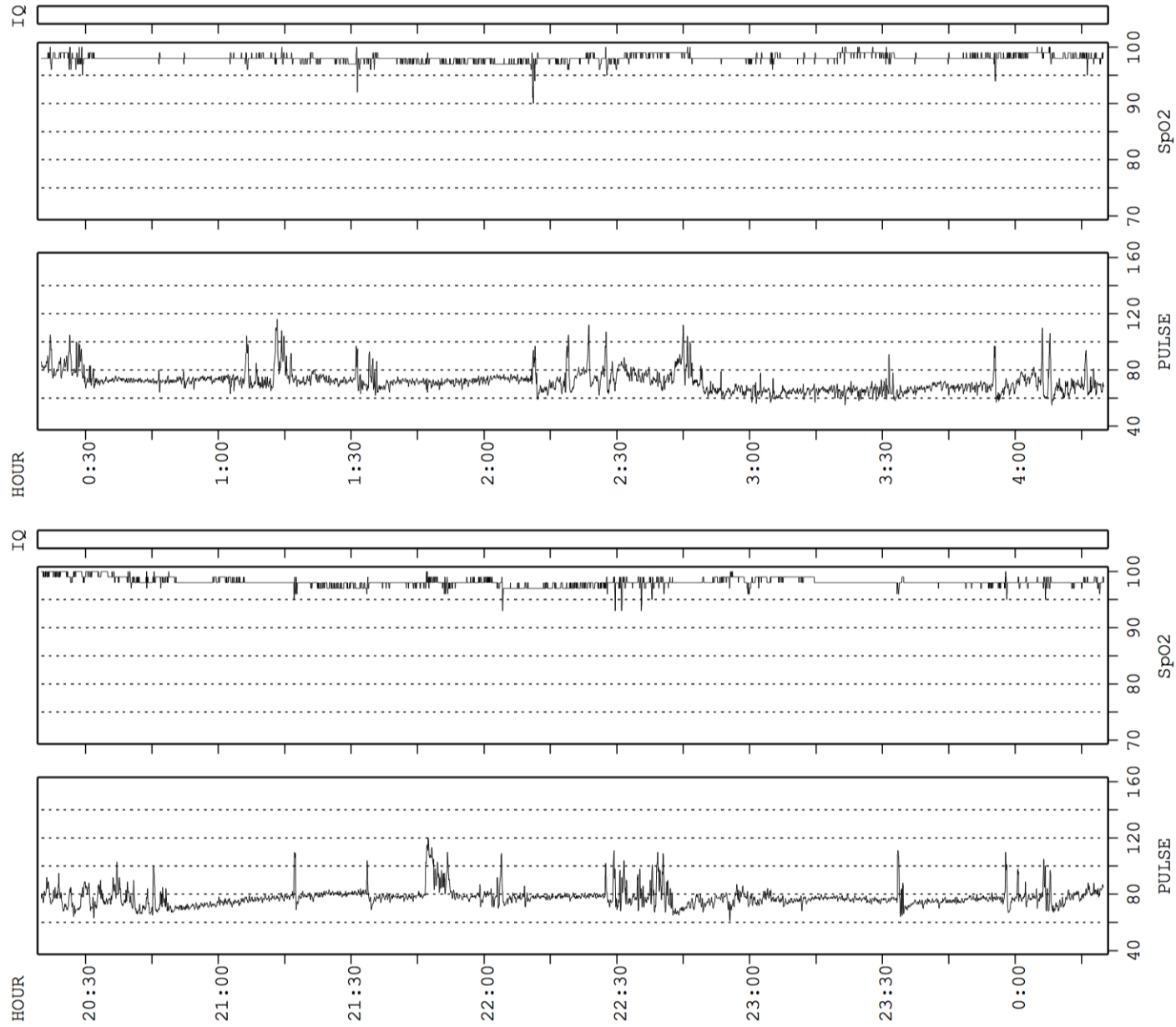**Example 1:** Ten year old with habitual snoring.
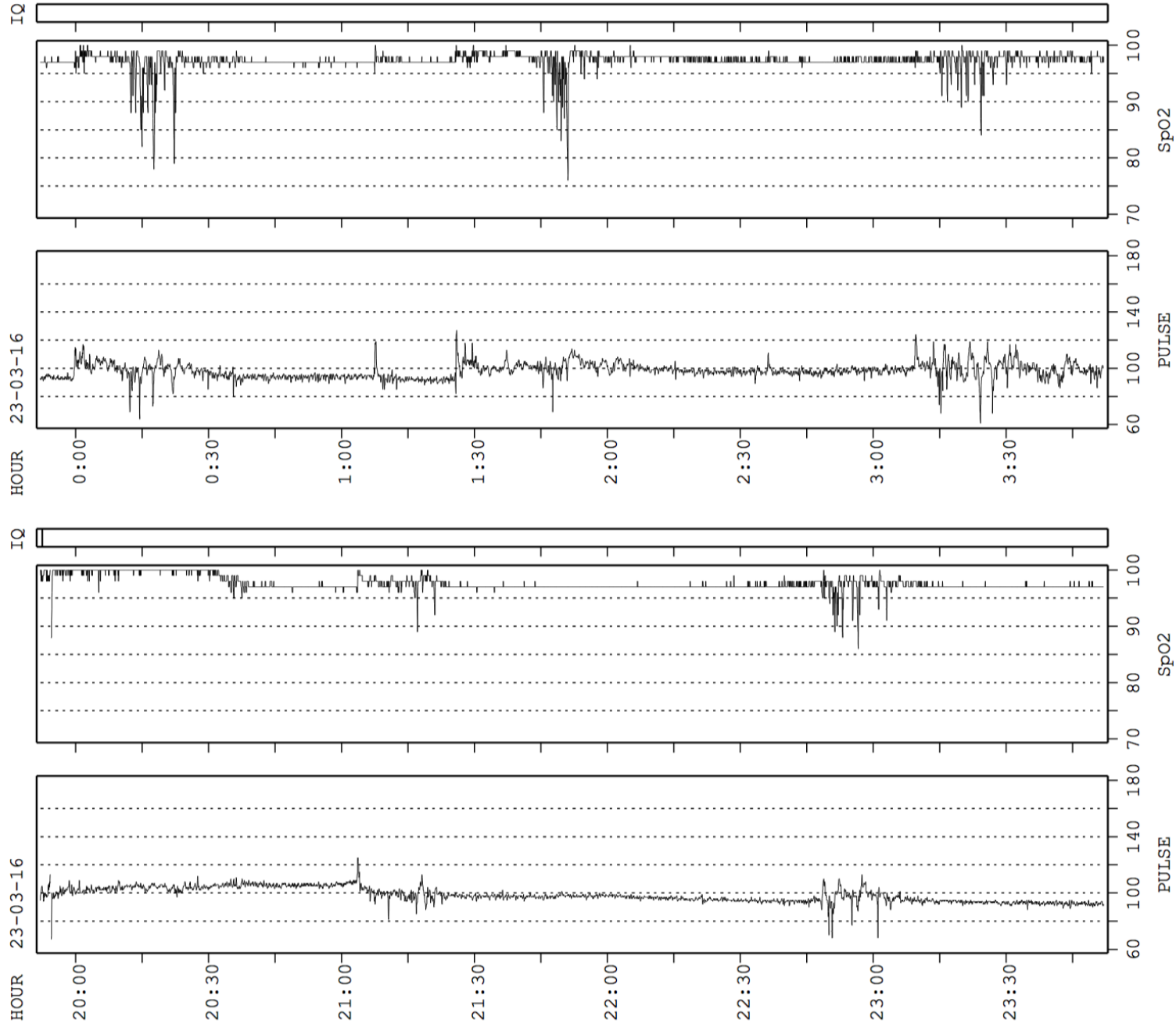
Example 2: Healthy 6 year old child with history of snoring awaiting adenotonsillectomy.
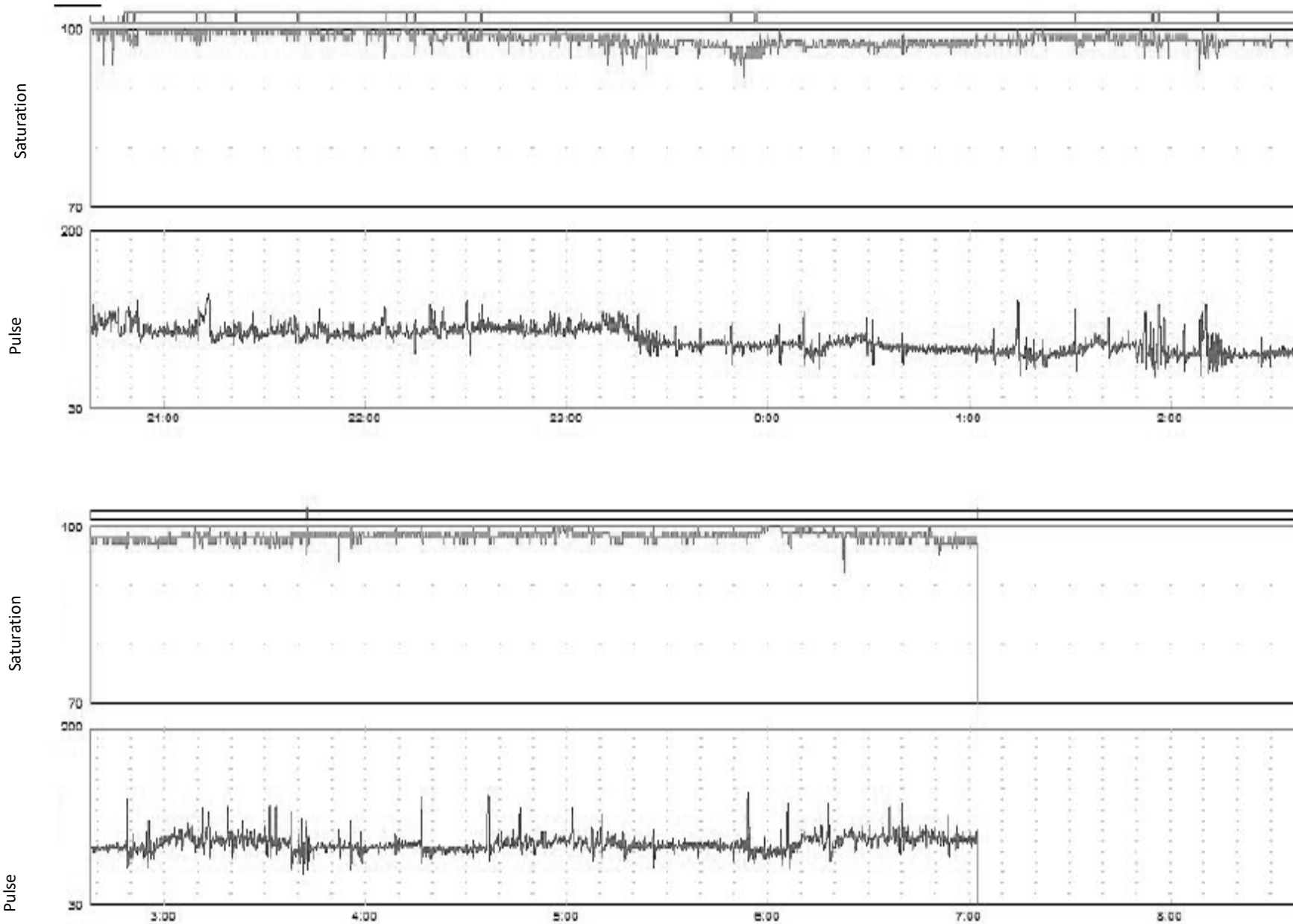
Example 3: Healthy 3 year old child with habitual snoring after adenoidectomy.
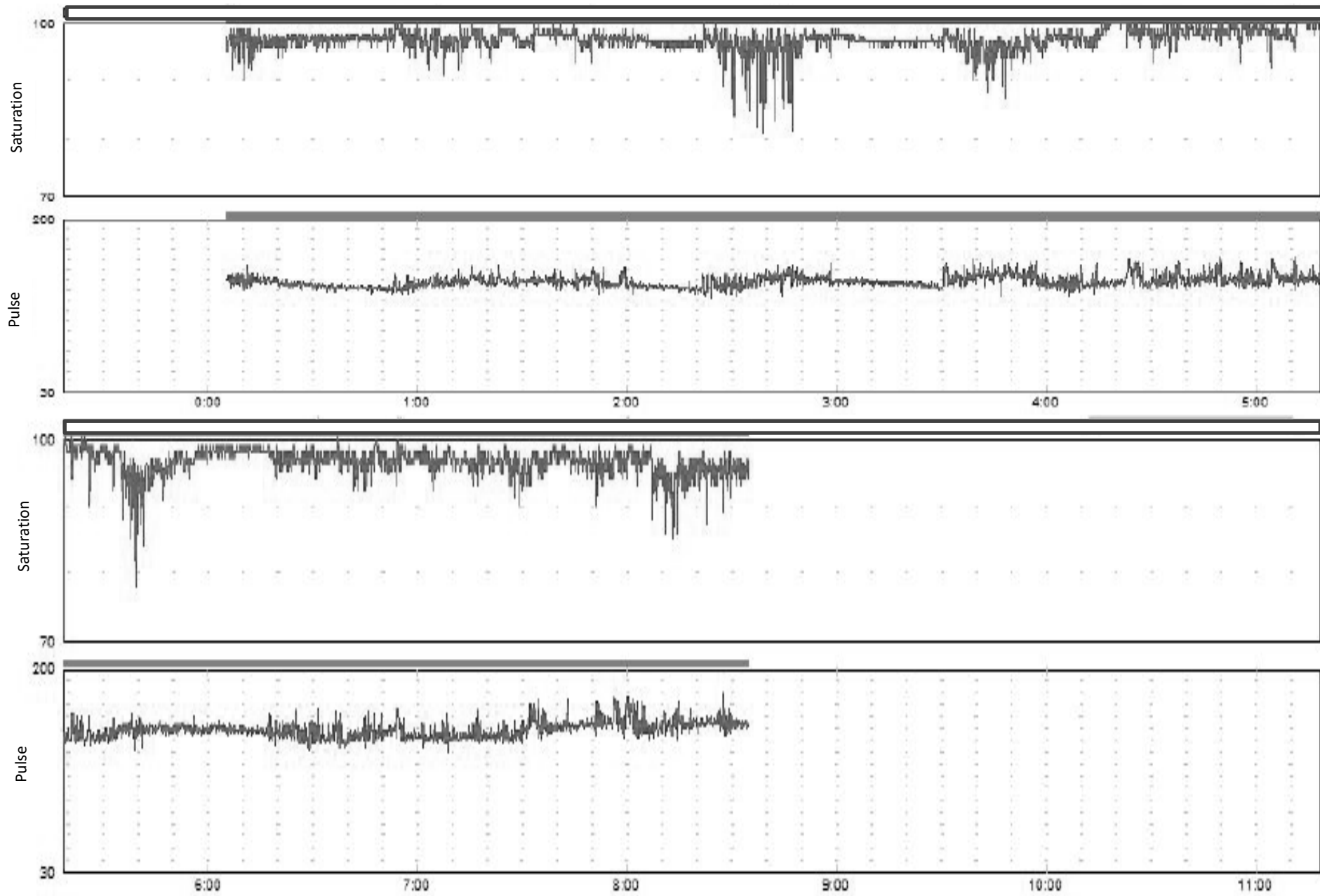
Example 4: Fourteen year old with snoring and tiredness.

Suggested Reports:

Example 1

Indication:	Ten year old. Snoring. Grade 3 tonsils.
Observations:	Well. Slept as usual. Snoring all night.
Study:	Eight 1/2 hours recording on a Masimo Radical oximeter with two second averaging. Satisfactory signal quality. No editing.
Results:	Mean saturations of 98% with 0.6% time below 90%. 3% desaturation index 10.3/hr. Four desaturation clusters identified with >3 individual desaturations below 85% and 3 individual desaturations below 80%. McGill Score 3.
Interpretation:	Highly suggestive of obstructive sleep apnoea. Significantly increased risk of post-operative respiratory compromise following adeno-tonsillectomy. Recommend that post-operative care is in a centre with expertise in paediatric airway management and minimum of overnight stay with oximetry monitoring.

[Polysomnography result: Moderate OSA with an OAHI of 8.4/h, CAHI of 3.1 and REM RDI of 48/hr.]

Example 2

Indication:	6 year old child with no comorbidities. Habitual snoring without other concerns during sleep. Possible obstructive sleep apnoea.
Observations:	Well. Slept as usual.
Study:	11h15m recording on a Masimo Radical oximeter with two second averaging. Good signal quality apart from brief signal loss at the start of the night.
Results:	Mean saturation of 98% with 0.1% time below 90%. 3% desaturation index 3/hr. McGill Oximetry Score 1.
Interpretation:	Study is inconclusive for a diagnosis of obstructive sleep apnoea. Obstructive sleep apnoea is not excluded.

Example 3

Indication:	3 year old child with no comorbidities. Previous adenoidectomy and grommets. Ongoing snoring and large tonsils. Possible obstructive sleep apnoea.
Observations:	Well. Slept as usual. Two brief awakenings at approximately 4.30am and 5am with loss of signal.
Study:	8h 30 minutes recording on a Masimo Radical oximeter with two second averaging. Good signal quality.
Results:	Mean saturation of 97% with 1% time below 90%. 3% desaturation index 28/hr. McGill Oximetry Score 3, with at least 4 clusters and multiple dips below 85%. SpO_2 nadir 78%.
Interpretation:	Consistent with severe obstructive sleep apnoea. Significantly increased risk of post-operative respiratory compromise following adeno-tonsillectomy. Recommend that post operative care is in a centre with expertise in paediatric airway management and minimum of overnight stay with oximetry monitoring.

Example 4

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Indication:	Fourteen year old girl. Habitual snoring and mouth breathing. Daytime tiredness.
Observations:	Well. Slept as usual. Snoring for periods.
Study:	8 ¼ hours of recording on a Masimo oximeter with 2 second averaging. Good quality. No editing.
Results:	Mean saturations of 98% with 0% time below 90%. 3% desaturation index 4.1/hr. No desaturation clusters. Nadir 90%. McGill Score 1.
Interpretation:	Equivocal result for obstructive sleep apnoea with normal baseline saturations and minor individual desaturations. Obstructive sleep apnoea is not excluded. Proceed as clinically indicated.

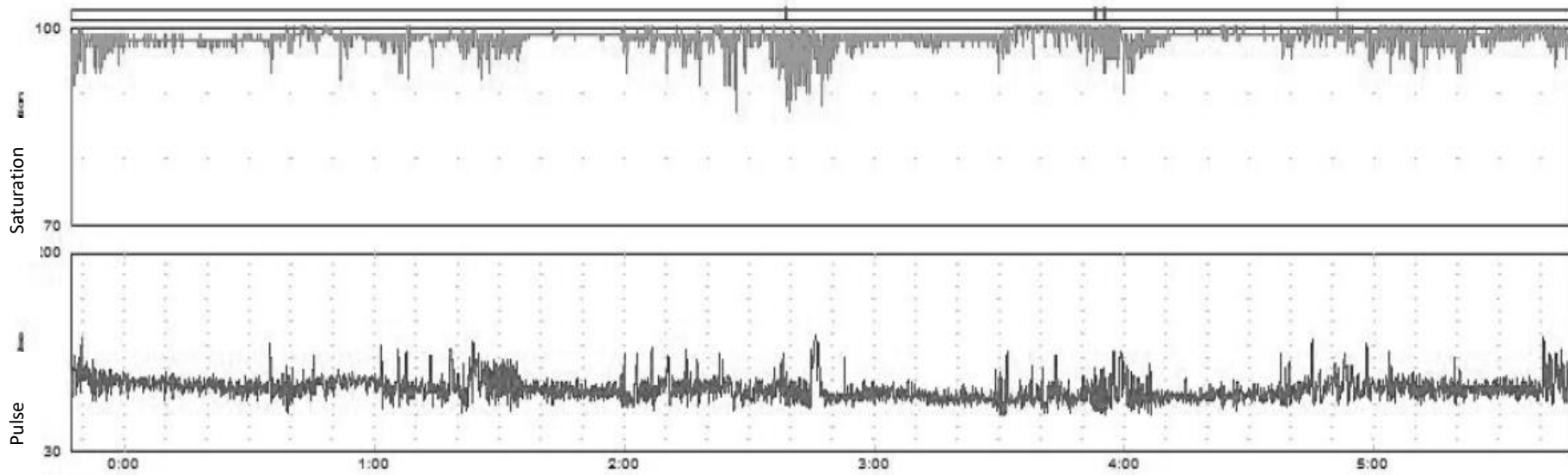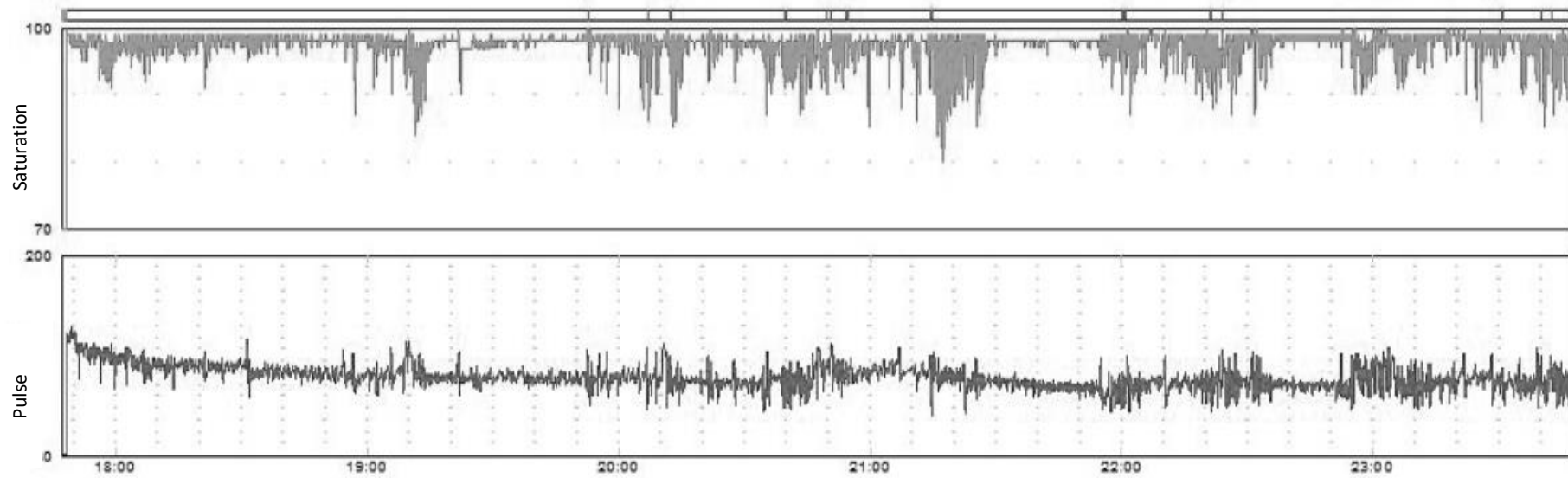*[Polysomnography result: OAHI 0.9/hr, CAHI 1.6/hr.]*

Example 5: 16 year old with Down Syndrome and recurrent snoring after adenotonsillectomy**.**
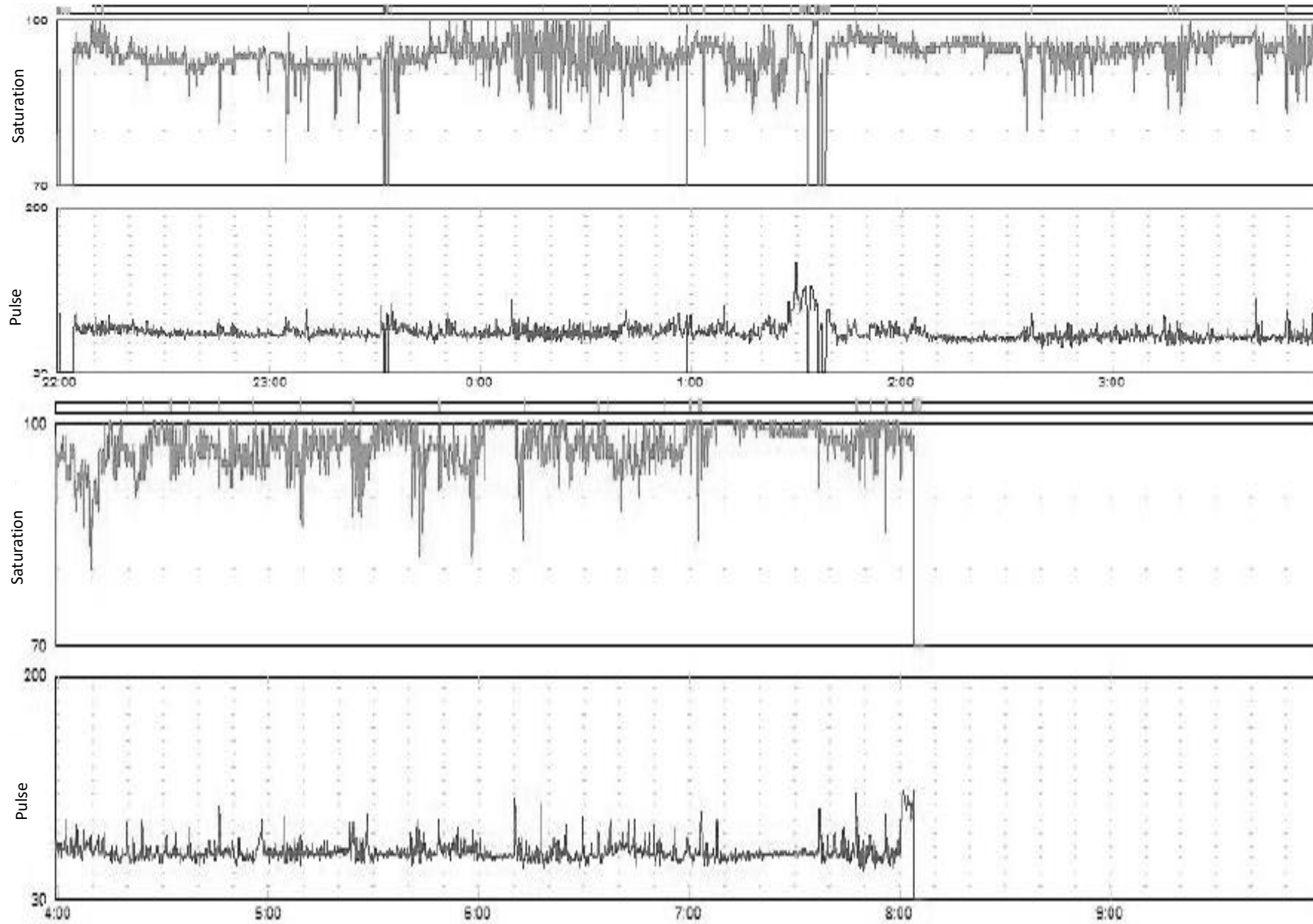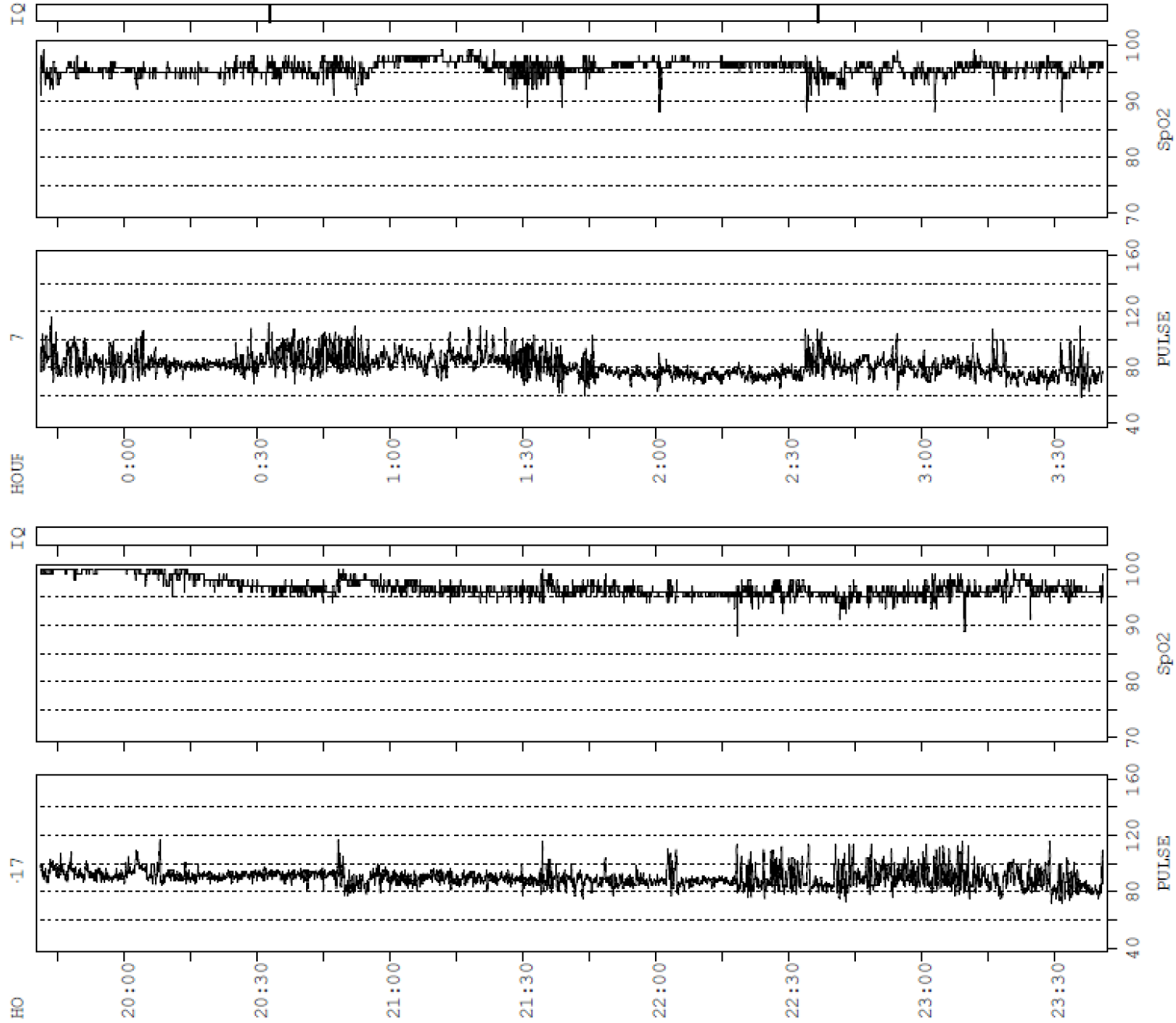
Example 6: Two and a half year old boy with snoring.
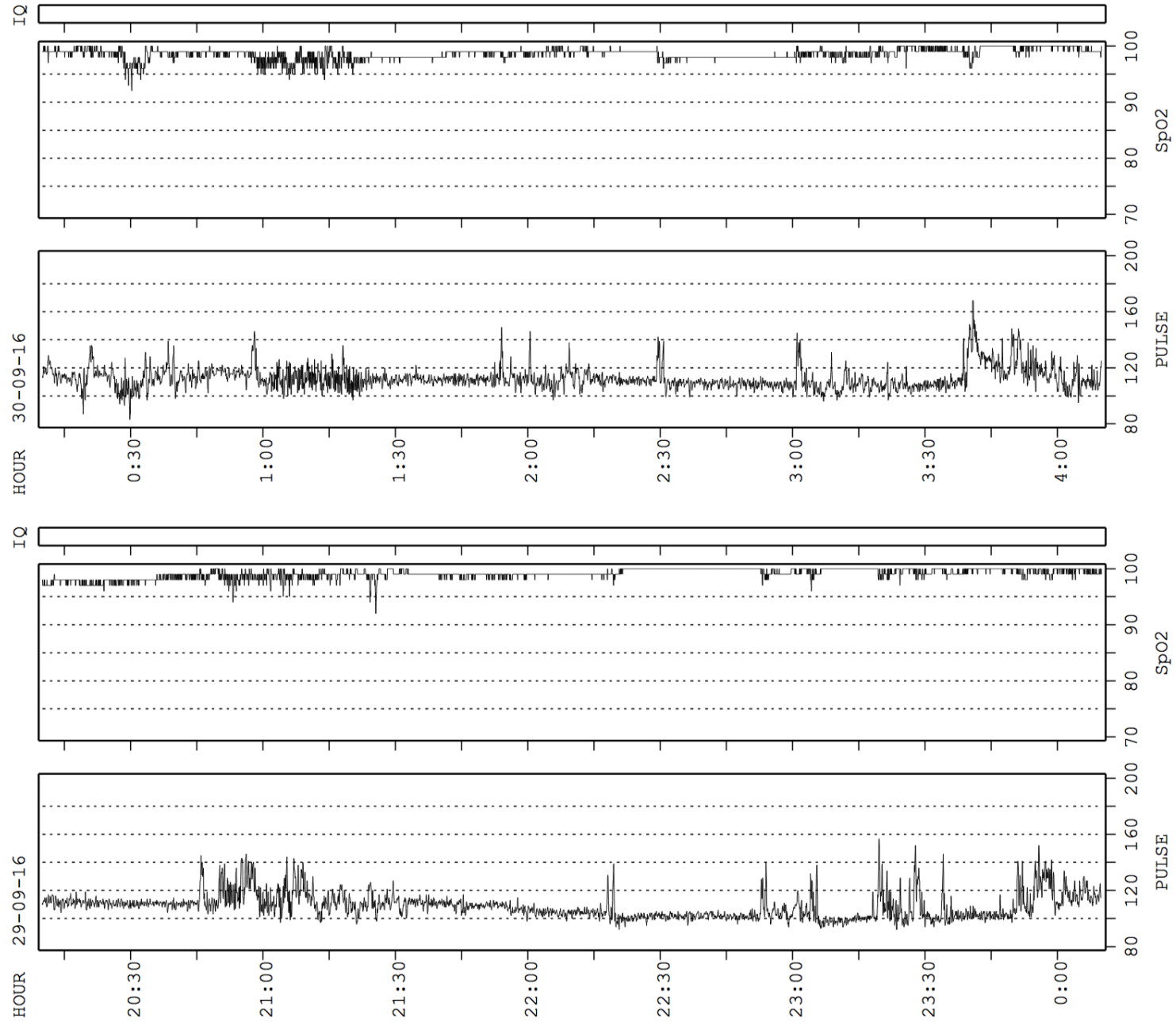
Example 7. Three year old with headaches and witnessed apnoea during sleep.

Example 8: Ten year old boy with obesity, habitual snoring and reported breathing difficulties during sleep. Previous adenotonsillectomy.

Example 5

Indication: 16 year old with Down Syndrome and previous adenotonsillectomy. Habitual snoring, increased work of breathing and restless sleep.

Observations: Well. Slept as usual. Brief awakenings at 1:35am.

Study: Ten hours recording on a Masimo Radical oximeter with two second averaging. Good signal quality.

Results: Mean saturation of 95% with baseline SpO_2 in the low 90's for the first two hours of the recording. 3% time below 90%. 3% desaturation index 45/hr. McGill Oximetry Score 3, with one long and several short clusters and multiple dips below 80%. SpO_2 nadir 74%.

Interpretation: Consistent with severe obstructive sleep apnoea. Given the comorbid Down Syndrome, low baseline SpO_2 and recurrent dips, a central or respiratory cause of lowered SpO_2 cannot be excluded. Polysomnography would be helpful to further delineate the cause of sleep-disordered breathing in this context.

Example 6

Indication: Two and a half year old. Snoring post adenoidectomy and adenotonsillectomy

Observations: Well. Slept as usual.

Study: Nearly nine hours recording on a Masimo oximeter with two second averaging. Satisfactory signal quality overall.

Results: Mean saturations of 99% with 0.0% time below 90%. 3% desaturation index 6.9/hr. 10% desaturation index 0.0/hr. One cluster with no desaturations below 90% - McGill Score 1.

Interpretation: Equivocal finding for obstructive sleep apnoea. Normal oximetry baseline without defined clusters. Some instability noted at 01:00 with associated heart rate variability.

[Polysomnography result: Moderate OSA with OAHI of 6.4 per hour. Events were largely confined to a period of REM sleep at 01:00.]

Example 7

Indication: 3 year old child with headaches, possible seizures and history of witnessed apnoeas during sleep. No obstructive symptoms.

Observations: Well. Slept as usual. No significant awakenings.

Study: 12 hours recording on a Masimo Radical oximeter with two second averaging. Good quality signal.

Results: Mean saturation of 98%. <1% time below 90%. 3% desaturation index 36/hr. Repetitive clusters of desaturation with frequent dips into the 90's and 80's. SpO_2 nadir 80%.

Interpretation: Recurrent dips in SpO_2. Given the lack of obstructive symptoms, polysomnography is suggested to determine the aetiology of these dips in SpO_2.

[Subsequently found to be severe central sleep apnoea associated with Chiari type 1 malformation.]

Example 8

Indication: Ten year old boy with symptoms and risk factors for obstructive sleep apnoea.

Observations: Well. Slept as usual. Snoring all night.

Study: Over nine hours recording on a Masimo Radical oximeter with two second averaging. Satisfactory signal quality.

Results: Mean saturations of 96% with 0.1% time below 90%. 3% desaturation index 26/hr. 10% desaturation index 0.2/hr. Only one definitive cluster identified (multiple clusters of more mild desaturation associated with spikes in heart rate noted however) with multiple desaturations below 90%.

Interpretation: This study is equivocal for OSA using the McGill Oximetry Score criteria.

[Polysomnography result: Severe OSA with an OAHI of 11.6/h together with sustained upper airway obstruction and increased work of breathing.]
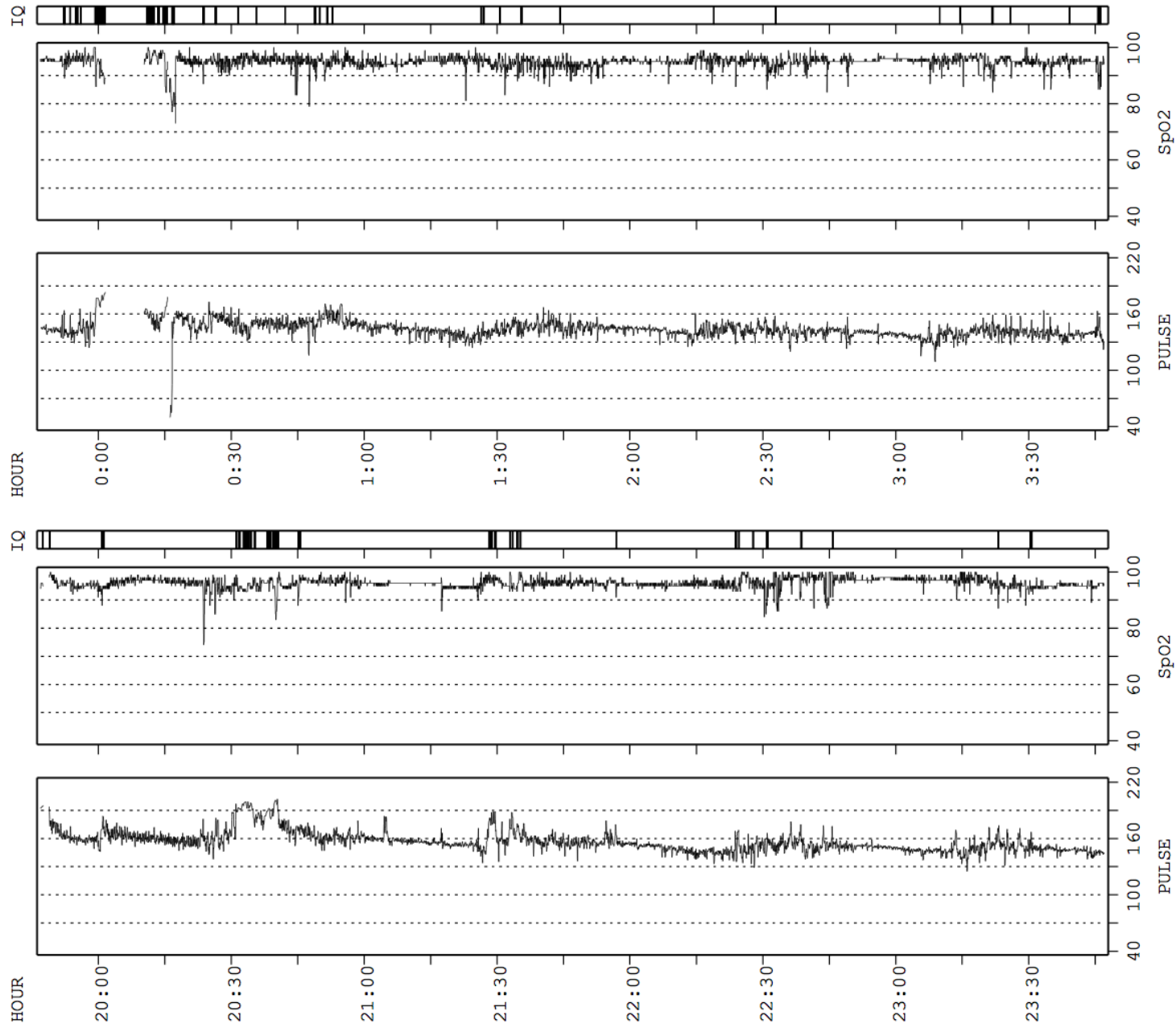
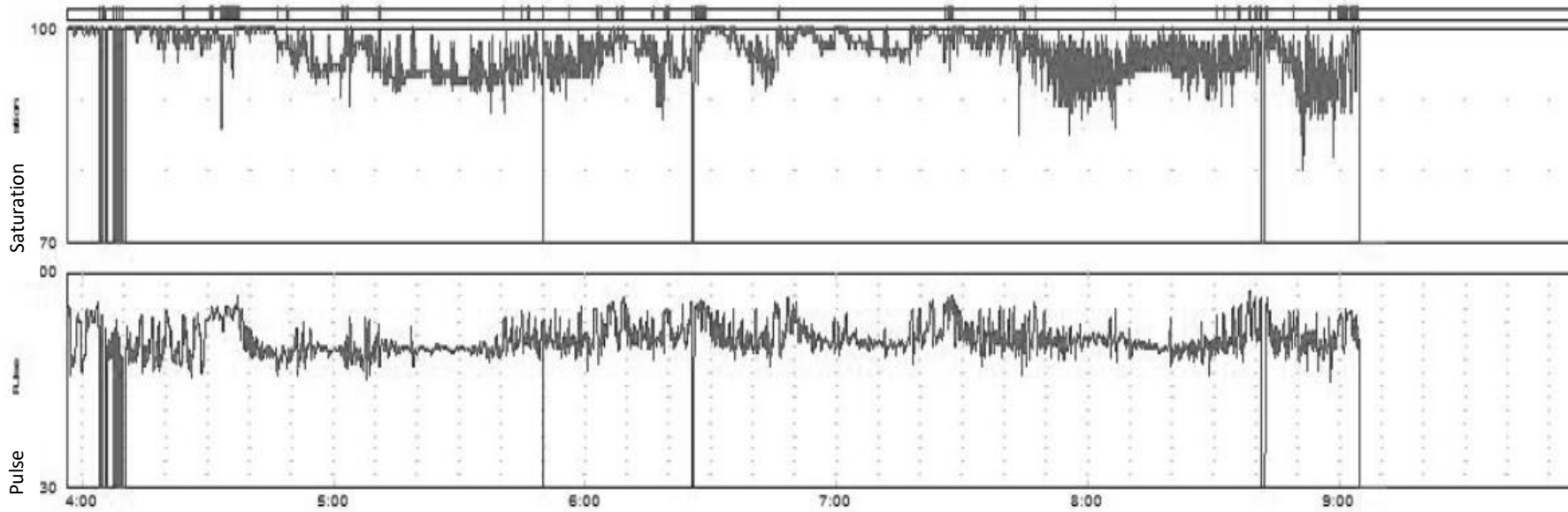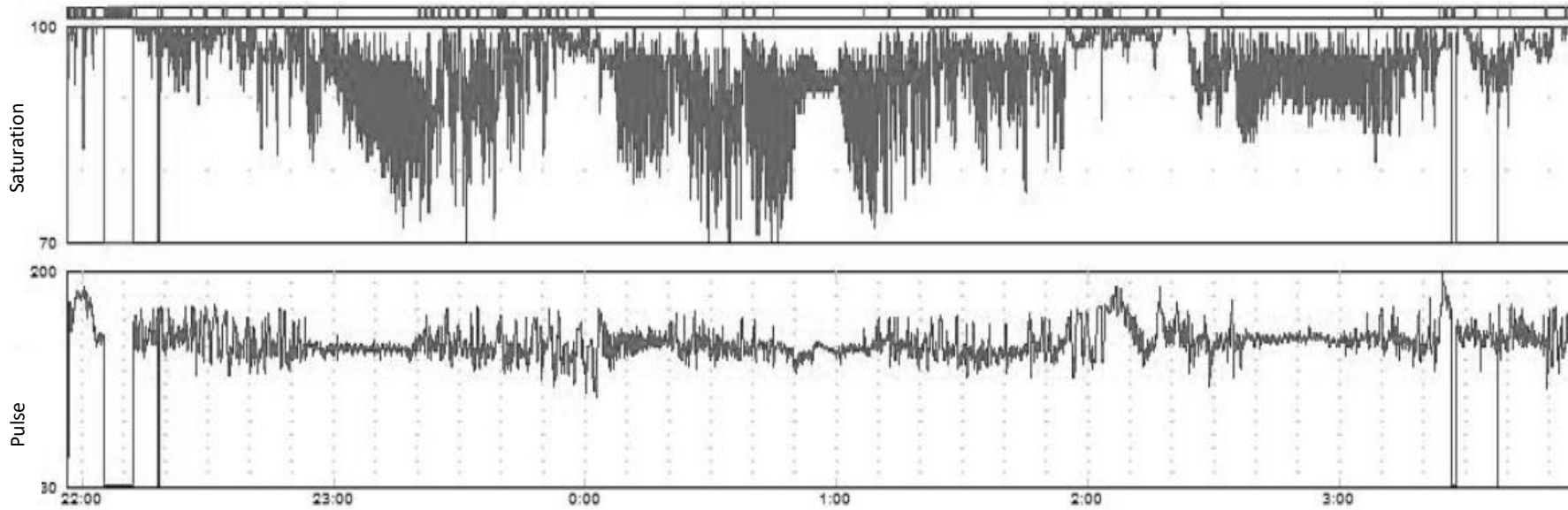**Example 9:** Seven year old girl with snoring and daytime tiredness.
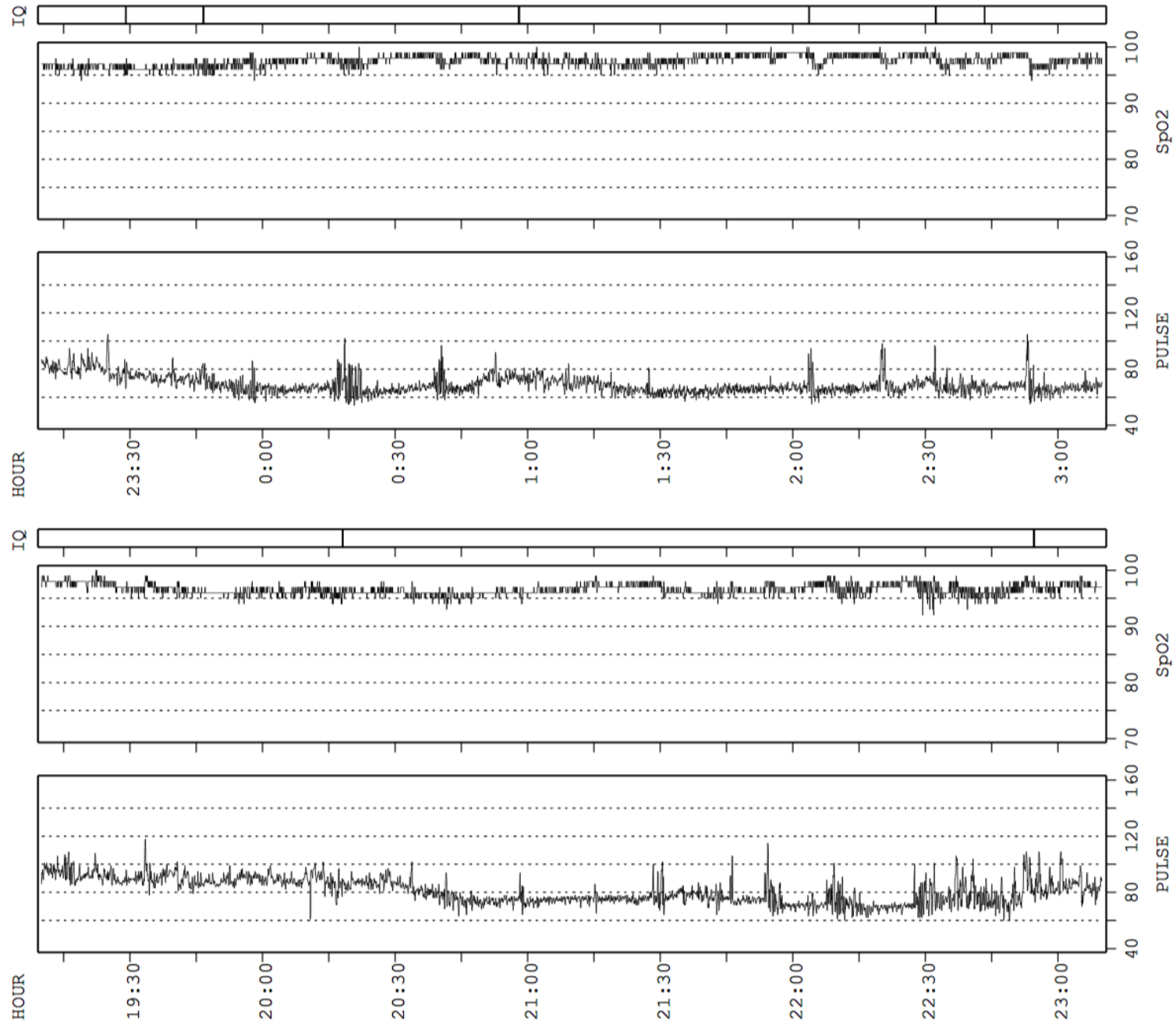
Example 10: A five year old child with history of snoring and increased work of breathing during sleep
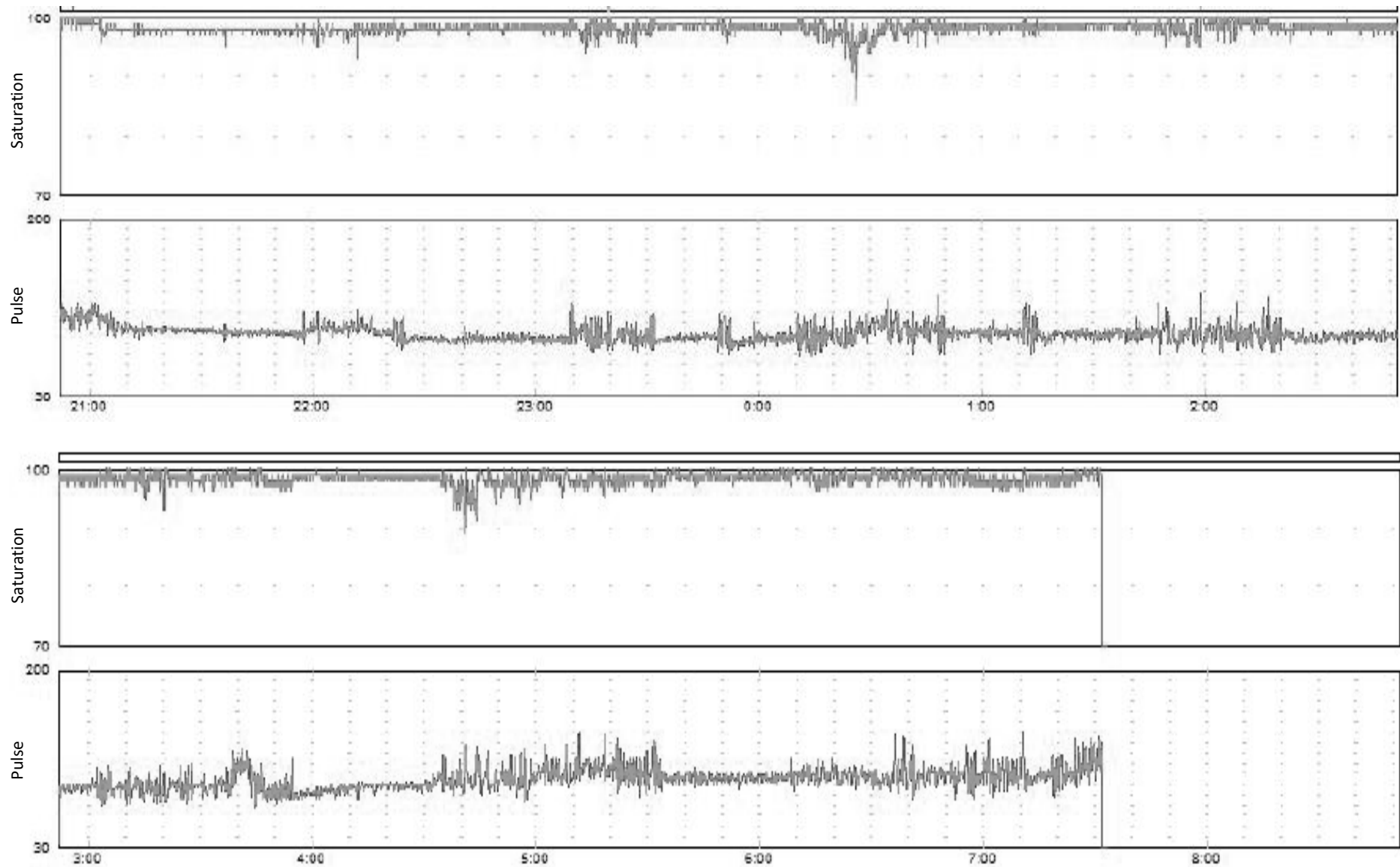
Example 11: Ten week old infant with laryngomalacia.

Example 12: One month old infant with witnessed apnoea during sleep.

Suggested Reports. Examples 11 and 12 are in infants demonstrating the more limited utility in this context.

Example 9

Indication:	Seven year old with snoring and tiredness.
Observations:	Well at time. Slept slightly less than usual. Periods of soft snoring and observed 'apnoea'.
Study:	9 hours of recording [only 8 shown in excerpt] on Masimo oximeter with two second averaging. Satisfactory signal quality overall. Minimal artefact (no editing).
Results:	Mean saturations of 97% with 0% time below 90%. 3% desaturation index 15/hr. One desaturation cluster (22:30). Nadir 90%.
Interpretation:	Equivocal result for obstructive sleep apnoea with normal baseline saturations and minor individual desaturations. McGill Score 1. Obstructive sleep apnoea not excluded. Proceed as clinically indicated. *[Polysomnography result: OAHI 2.4, CAHI 13.4]*

Example 10

Indication:	Healthy 5 year old child with habitual snoring, increased work of breathing, restless sleep and frequent wakings. Large tonsils.
Observations:	Well. Slept as usual. Awake briefly at 22:40 for toilet.
Study:	Twelve hours recording on a Masimo oximeter with two second averaging. Good quality recording apart from reduced signal quality from 22:10 to 22:40.
Results:	Mean saturation of 98%. 0.02% time below 90%. 3% desaturation index 13.5/hr. McGill Oximetry Score 1. Multiple clusters of desaturation, with only 2 dips below 90%.
Interpretation:	This is a borderline result by McGill oximetry score, not quite meeting criteria due to <3 desaturation events below 90%. It would however be positive by Suarez criteria and the desaturation clusters seen in association with repetitive surges in heart rate is highly suggestive of obstructive sleep apnoea.

Example 11

Indication:	Ten week old with laryngomalacia and noisy breathing.
Observations:	Slept as usual. Episodic wakenings for feeding (times not given). Intermittent noisy breathing.
Study:	Ten ½ hours recording [Only eight hours in excerpt shown] on a Masimo oximeter with two second averaging. Satisfactory signal quality. Some artefact (IQ bar) excluded from interpretation (especially 20:30 and 00:00) but not edited from recording. Note change in SpO_2 scale.
Results:	Mean saturations of 95% with 2.1% time below 90%. 3% desaturation index 62/hr. 10% desaturation index 6.3/hr. Infant is too young to utilize McGill scoring. Frequent brief desaturations are scattered throughout the sleep period, sometimes in clusters.
Interpretation:	Normal baseline saturations with frequent desaturations of indeterminate significance. Given the infant's age/immaturity these could be normal central sleep apnoea / periodic breathing however in the context of noisy breathing polysomnography may be indicated. *[Polysomnography result: OAHI 3.3, CAHI 13.0/hr, REM RDI 38/hr.]*

Example 12

Indication:	One month old term infant admitted to hospital with mild upper respiratory tract infection. Desaturation during sleep and apnoeas noted on ward monitoring. No obstructive symptoms.
Observations:	Well. Slept as usual. Woke and was fed at 2 and 4am.
Study:	11h15m recording on a Masimo Radical oximeter with two second averaging. Multiple brief periods of signal loss.
Results:	Mean saturation of 95%. 9% time below 90%. 3% desaturation index 119/hr. Repetitive clusters of desaturation between the start of the study and 3:30am and then from 7:40am to the end of the study. The reason for the improvement between 3:30 and 7:40am is not apparent from diary. SpO_2 nadir 69%.
Interpretation:	Recurrent dips in SpO_2. Given the child's age and the absence of history of upper airway obstruction, a central cause of SpO_2 dips such a periodic breathing or central hypoventilation is most likely. Polysomnography may be indicated to better define this.