Oxygen Therapy & Monitoring in Newborn Intensive Care Unit (NICU)

Guideline Responsibilities and Authorisation

Department Responsible for Guideline	NICU
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Document Owner Title	Head of Department
Target Audience	NICU Staff

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Guideline Review History

Version	Updated by	Date Updated	Summary of Changes
4	David Bourchier	2015	Original version
5	Arun/Jutta	Sept 2023	New format, complete review of guideline Withdrawal of #0441 Newborn resuscitation – oxygenation OxyGenie® setup Histogram interpretation

Oxygen Therapy & Monitoring in Newborn Intensive Care Unit (NICU)

Contents

1 Overview

1.1 Purpose

The provision of varying levels of supplemental oxygen is a frequent and necessary requirement in the management of sick neonates. The use of oxygen requires an understanding of the fine balance which must be maintained and the impact of tissue hypoxia on the one hand, the oxygen toxicity on the other.

This guideline outlines the management of oxygen therapy for newborn babies cared for in the neonatal unit and discharged home on domiciliary oxygen.

1.2 Staff group

Waikato staff working in NICU, Neonatal Community Nursing.

1.3 Patient / client group

Babies and infants in NICU.

1.4 Definitions and acronyms

CCHD	Congenital Cyanotic Heart Disease
CDH	Congenital diaphragmatic hernia
CLD	Chronic Lung Disease
CPAP	Continuous Positive Airway Pressure
CWS	Clinical Work Station (a patient management programme)
FiO_2	Fraction of Inspired Oxygen
GA	Gestational Age
HFOV	High Frequency Oscillation Ventilation
NICU	Neonatal intensive care unit
NIPPV	Non-invasive/nasal intermittent positive pressure ventilation
NLS	Newborn Life Support
OSAS	Obstructive Sleep Apnoea Syndrome
Oxygenie	The OxyGenie® algorithm is a closed loop proportional-integral-derivative (PID) controller. Once a second this algorithm uses the patient's SpO2 (measured using Massimo SET sensors) to calculate the appropriate FiO2 setting to maintain SpO2 within the target range
$paCO_2$	Partial Pressure of arterial CO_2
paO_2	Partial Pressure of arterial O_2

PPHN	Persistent pulmonary hypertension of the newborn
ROP	Retinopathy of Prematurity
SIQ	Signal Identification and Quality. The SIQ indicator waveform shows the acquired measurement confidence and timing of each detected pulse relative to the Pleth. The ventilator displays the indicator waveform as a vertical line. The taller the line the better the signal quality, as the quality drops the line decreases in height. The quality is also indicated by a good quality signal being coloured blue and a poor quality signal being coloured orange.
SMO	Senior Medical Officer
SpO_2	O_2 Saturation by pulse oximetry

2 Clinical management

2.1 Roles and responsibilities

- Nurse Practitioners/Clinical Nurse Specialists/Registrars, SMOs
- Registered midwife
- Registered nurse who has completed NICU Level 2 orientation
- Enrolled Nurse under the directions and delegations of an RN

2.2 Guideline

2.2.1 Delivery Suite

Please follow instructions as per NLS recommendations

2.2.2 Oxygen Saturation Targets in NICU

Oxygen saturation targets (SpO2) are determined by postmenstrual age.

Aim for the appropriate SpO2 and find the necessary FiO_2 to achieve this. Do not allow the saturation to remain at 100% unless the baby is in air or a minimum FiO2 concentration is set (see Appendix A and B).

When FiO2 is 0.21 (air), use only the lower limits of the set target saturations.

Postmenstrual Age	SpO2 target	Alarm limits
< 36 weeks	90% - 94%	89% - 95%
≥36 weeks	93% – 97% (for PPHN ≥95%)	92% - 98%

Table 1: Oxygen Saturation (SpO2) and alarm limits for babies needing oxygen

An individualised approach may be taken for babies if it is deemed appropriate by the SMO (e.g.in CCHD or CDH)

2.2.3 Monitoring of babies in NICU

Saturation targets should be set for all babies in particular those ventilated or those requiring oxygen.

Pulse oximetry (SpO2)

This is a high priority in initial monitoring, and oximetry along with cardiac monitoring should be instituted before other procedures such as umbilical catheterisation and elective tracheal intubation are undertaken.

The probe should be place preferably on the right upper limb, i.e. pre-ductal.

Results from pulse oximetry machines can only be useful if the heart rate display matches with that seen on the cardiac monitor, and if the pulse wave is being reliably and consistently detected over the preceding few seconds. Given these circumstances they are reliable, and oxygen therapy can be adjusted accordingly.

They give no indication of the acid base status, $PaCO_2$ levels and blood gas sampling may be required.

Blood Gases

These should be seen predominantly as evaluating pH and $PaCO_2$. The oxygen status of the small babies is better monitored by pulse oximetry.

In infants with persistent pulmonary hypertension, the PaO_2, preferably measured via an arterial blood sample, assumes greater importance.

2.2.4 Adjustments of FiO2

In acute situations the SpO2 will fluctuate but the aim is to keep it as stable as possible within the target range:

For adjusting the FiO2 while on the Ventilator/CPAP/NIPPV/High Flow (Appendix A)

For adjusting the FiO2 while on low flow oxygen (Appendix B)

Oxygenie –SLE 6000

For more details, please refer to the SLE 6000 manual and https://www.youtube.com/watch?v=tLsQTsv3qV0

- On the SLE 6000, the OxyGenie® system is intended to control the inspired oxygen delivery to keep the SpO2 of the patient within a predefined range during mechanical ventilation, nCPAP, Non Invasive Respiratory Support and High Flow Oxygen Therapy.
- The OxyGenie® algorithm is a closed loop proportional-integral-derivative (PID) controller. Once a second this algorithm uses the patient's SpO2 (measured using Masimo SET sensors) to calculate the appropriate FiO2 setting to maintain SpO2 within the target range.

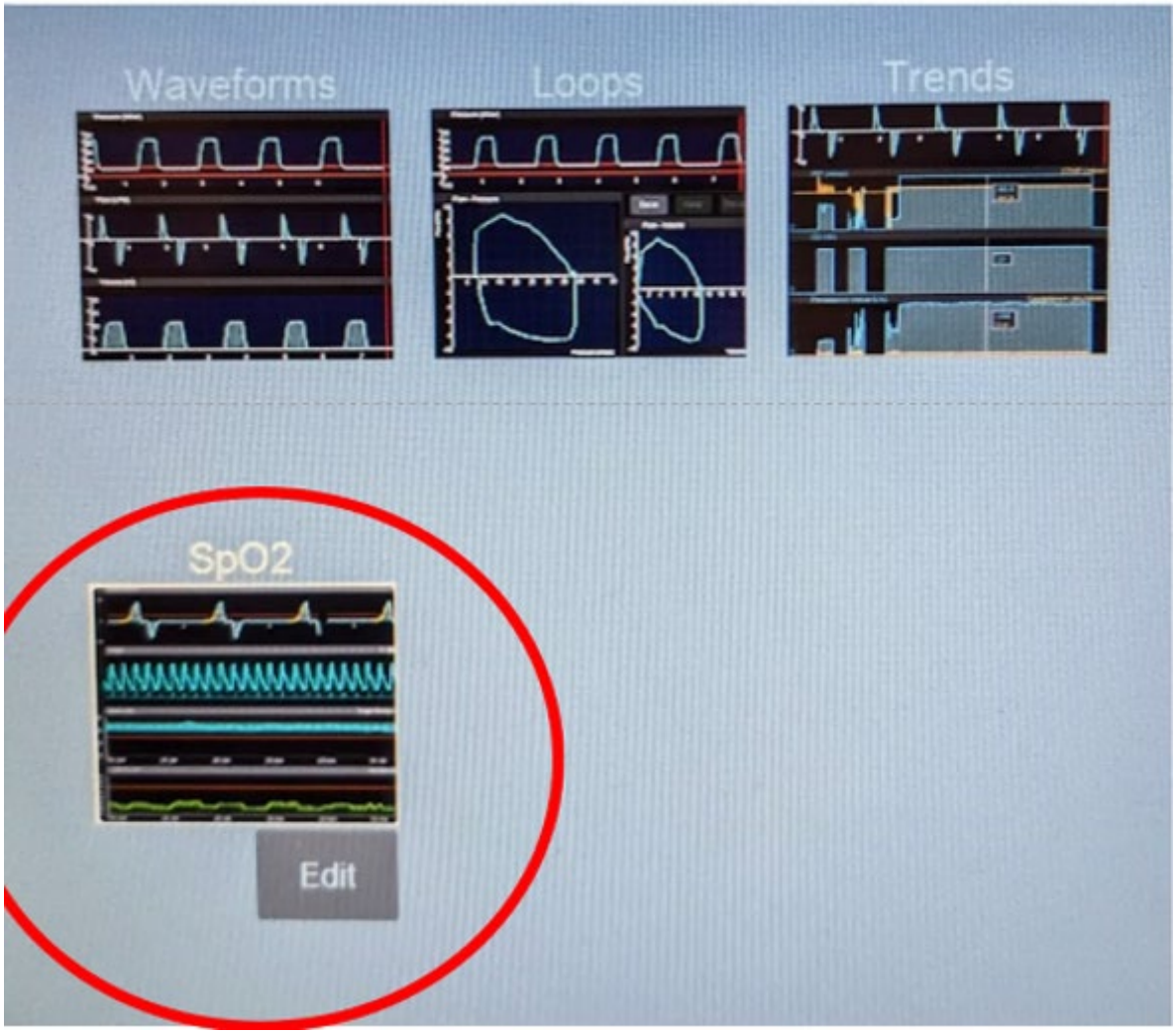
- The OxyGenie® is not to be used during resuscitation situations.
- De-activate OxyGenie® function during recruitment manoeuvre. See High frequency oscillation ventilation - Nursing care of infants on HFOV Ref 0396
- Place **two saturation probes**, one pre-ductal (this one should preferably be the OxyGenie® lead), and a second one for safety reasons if OxyGenie® fails, as there is no alarm on the ventilator.
- Ensure optimal SpO2 probe placement and site selection.
    - One of the critical success factors in using OxyGenie® is to have a quality SpO2. Users should be aware of this and ensure correct SpO2 placement and the need to change the site periodically and use the SIQ as an indicator of a good signal quality.

Oxygen Reference Value ***Important***

- The OxyGenie® algorithm requires at least 30 minutes of SpO2/ FiO2 readings to use as a baseline. This will produce a patient specific **oxygen reference value.**
- The **oxygen reference value** updates every 30 minutes based upon SpO2 values inside the selected SpO2 range in the preceding hour of data. This is then used to calculate the new reference value.
- If the SpO2 is highly variable and outside of the target ranges then those values are not used in the next **oxygen reference value** calculation.
- In case the **oxygen reference value** seems to be inconsistent with the clinical condition of the patient, consider turning off OxyGenie®, especially during cares or probe/site changes, and manually tune the FiO2 to achieve SpO2 in target range. Turn on Oxygenie® once finished with cares. Within 30 minutes the oxygen reference value should have stabilised.

Important ventilator displays:

Figure 1 and 2: Layout to review the Reference range:



Setting a minimum FiO2 when on CPAP or high flow

In babies who are stable but with increased desaturation episodes, with a long tail for SpO2 below target SpO2 on histogram or oximetry, a minimum FiO2 may be ordered.

With this approach the upper limit of SpO2 target cannot be set, so it is important therefore to make sure that minimum FiO2 does not cause the baby to remain in SpO2 of 100% most of the time. This needs to be reviewed at least daily.

If the baby requires the FiO_2 to be increased above the prescribed minimum FiO2, the alarm limits on the transcutaneous oxygen monitor must be set according to the target saturation for respective gestational age.

Transition to and weaning from low flow oxygen

Low flow oxygen is used for a flow of ≤ 1L/min, delivered either directly from the wall or from an oxygen cylinder (which is not humidified).

- To be tried only on babies with corrected age of ≥36 weeks with no or mild increased work of breathing. If there is increased work of breathing check pCO2 levels.
- Use humidification if needing ≥ 0.5L/minute.
- Start on a flow rate that seems appropriate
- To determine level of oxygen needed - initially wean in steps of 50-100 ml/min every 30-60 min.
- Obtain overnight oximetry once stable FiO2, do not adjust FiO2 during oximetry. If there is a need to increase FiO2, stop the oximetry run.
- For interpretation of oximetry please refer to **sec.2.3**

Weaning from Low flow oxygen

Aim to wean at a rate of 50-100ml/min according to oximetry results.

2.3 Interpretation of histograms and oximetry runs

Histograms and oximetry are used for monitoring and adjusting FiO2 while the baby is on respiratory support, or to assess the respiratory function while the baby is self-ventilating in air.

Interpretation of a histogram and oximetry can only be reliably undertaken when there is a steady oxygen requirement over a longer period of time, e.g. the length of the observed time period.

Histograms can be used to determine minimum FiO2 (e.g. while on CPAP or more likely highflow)

2.3.1 Histograms

Histograms should be reviewed for babies that are ventilated, and those on respiratory support <36 weeks gestation on a daily basis.

1. For babies with CGA <36 weeks who are unstable requiring supplemental oxygen
   a. Mean SpO2 90-94%
   b. <20% time below SpO2 of 90
   c. <10% time below SpO2 of 80

2. For babies =/>36 CGA OR babies <36/40 who do NOT require supplemental O2
   a. Mean SpO2 =/>93%
   b. <10% time below SpO2 of 90

3. Born at term babies
   a. Mean SpO2 >/= 93%
   b. <5% time below 90%

For occasional babies and situations, modified targets may be required. These should be clearly documented in the medical notes by the SMO.

2.3.2 Oximetries

Set up

Oximetries are done closer to discharge for babies' ≥ 36 weeks gestation, to determine the need for home oxygen.

Oximetries should only be undertaken while the FiO_2 is stable, e.g. no change in FiO2 in the last 24h, and should be abandoned if there is a need to increase FiO2. There should be no apnoea, bradycardias and desaturations needing intervention in the preceding 24h.

While long averaging times (8-16s) may be adequate for monitoring or for oxygen titration, an **averaging time of 2-4s is recommended for most studies** and is mandatory for the investigation of obstructive sleep apnoea syndrome. Correspondingly, a high recording resolution is required (every 2 seconds) and motion artefact and signal quality function must be enabled.

The minimum time for an oximetry should be 6 hours, and include feeding and sleeping.

It is very useful for staff / parents to make a record of events / observations during the oximetry study recording. This helps correlate patient circumstances with oximetry results. Observations should include events (awake, asleep, feeding, crying, alarm soundings, etc) and respiratory observations (snoring, increased work of breathing, etc). see Appendix C.

Report

All oximetry runs must be reviewed by an SMO.

All oximetries are to be uploaded via Profox to CWS. Instructions on how to upload to CWS are found in Appendix D.

As a minimum, the report should include

- **patient identification**
- **date, time, study duration**
- **the name of the responsible / requesting clinician**
- **relevant study conditions** (such as oxygen flow)

A graphical representation (time vs. saturation) of the overnight recording is the single most useful output. It is recommended that the output be >3 cm/hr and >1mm/%. Signal quality should be displayed on the printout.

Summary statistics such as mean SpO2, mean pulse rate and percentage time below 90% are useful.

Printouts of individual events (desaturation or poor signal), bar graphs and descriptions of time during other percentage ranges are not usually necessary.

Clinical Interpretation

Below template is to be used by means of a sticker placed in clinical notes or as a progress note in CWS for outpatients.

Clinical interpretation For babies with corrected GA ≥36 weeks/ CLD		
Indication		
Relevant overnight observations		
Adequate oxygen as determined by oximetry run		
Is the baseline saturation in the target range?	Mean SpO2 >93%	Yes/no
Is the percentage time below 90% excessive?	Time with SpO2 <90% for <5% of the time (meaning 89% or below)	Yes/no
Is the baseline stable?	Frequent desaturation may represent obstructive or central events (apnoeas) or hypoventilation. They may be associated with undesirable cardiovascular instability or sleep disturbance.	Yes/no
Summary of study's quality and findings		
Conclusion and recommendation		
Date and name/signature		

For examples see Appendix E

Obstructive Sleep Apnoea Syndrome (OSAS)

Oximetry studies cannot exclude Obstructive sleep apnoea syndrome (OSAS) and therefore are not screening tests. Oximetry may, however, support the diagnosis of OSAS, provide a crude estimate of severity, assist in triaging, and contribute to peri-operative risk assessment.

Please see the National Paediatric Sleep Medicine Network guideline (Assessment of Sleep Disordered Breathing in Childhood) for further discussion regarding the investigation and management of OSAS.

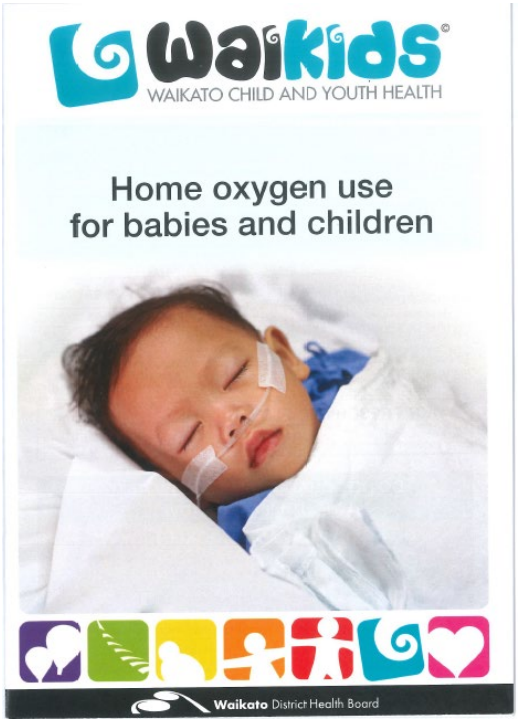
The McGill Oximetry Score provides a validated approach to oximetry studies for OSAS – for further information, please refer to the Starship guideline on oximetry.

https://starship.org.nz/guidelines/oximetry/

3 Home Oxygen Therapy

For all infants with a diagnosis of CLD or infants with any form of respiratory support, approaching discharge.

Brochure on home oxygen



Infants suitable for home oxygen therapy should:

1. Be clinically stable or improving – no significant cyanotic or apnoeic episodes in the preceding two weeks
2. Have no other significant cardio-respiratory co-morbidity contributing to their oxygen requirement - May need to exclude pulmonary hypertension (ECG/ECHO/recent CXR prior to discharge) See Persistent Pulmonary Hypertension of the Newborn (PPHN), Management of Ref 6503

3. Demonstrate satisfactory weight gain on current management (average 20-40 grams/day assessed over 7 days)
4. Meet the oxygen targets at flows of ≤0.5 L/min nasal cannula oxygen for at least 6h as documented by oximetry
5. Decision to be made if going home on 62.5mls (oxygen regulator only) or >100mls (oxygen concentrator)
6. Have competent caregivers and appropriate home environment –
   - Social worker can do home assessments and refer to social services when necessary,
   - Consider pre-discharge assessment by Social Work and Neonatal Community Nursing Team.
7. Have undergone multi-disciplinary discharge planning (including community nursing and SMO) including discussion of oxygen therapy goals, safety issues (smoking, open fires, etc), and implications for flying.
8. Have completed ROP screening
9. An 'air challenge', aiming for a minimum SpO_2 of ≥ 80% is maintained for 30 minutes off oxygen before discharge. This can be assessed by an oximetry run with baby in room air (with no nasal cannula)
10. Completed an oximetry positioned in car seat for 1hr to assess ability to maintain SpO2 >90%.
11. Completed an oximetry for 8hrs on equipment to be used at home and assess ability to maintain SpO2 >90% for desired period (discussed earlier).
12. Discuss if appropriate for Disability Allowance and Child Disability allowance and Mobility parking forms to be completed.

Table 2: Expected range on 6 hour oximetry analysis**, after clearing of artefact**

Parameter	**Target**
Mean SpO_2	93-95%*
SpO2 < 90%	< 5% of the time
Desaturations	Minor/Infrequent

* Aim for a mean SpO2 > 94%, if there is pulmonary hypertension and/or evidence of right ventricular hypertrophy

3.1 Weaning of home oxygen

There is no available evidence to guide the titration or weaning of supplemental oxygen in infants. However, the prevailing principle is to maintain the child within the SpO2 targets whilst recognizing changes in their underlying disease status (usually improving CLD, maturity and size).

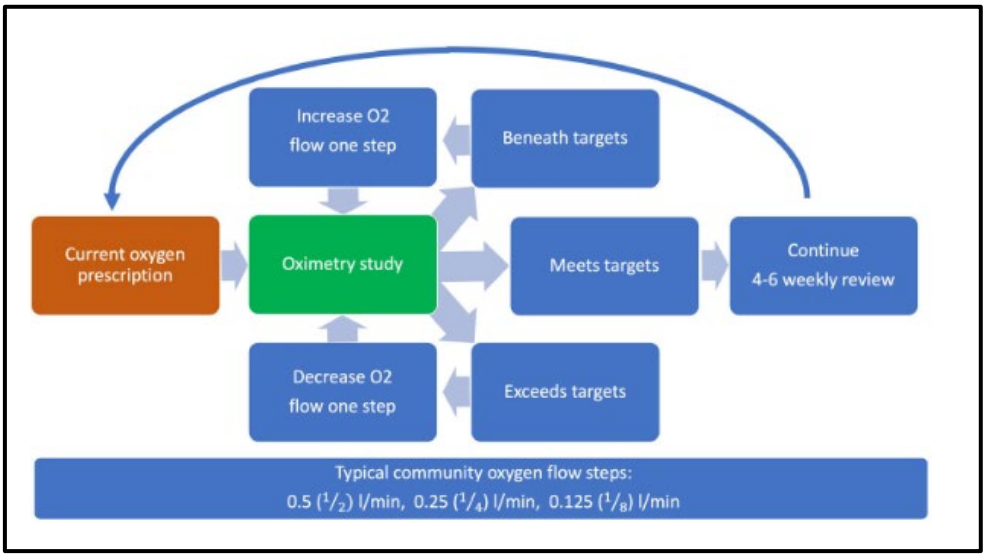


Figure 3: Oxygen weaning recommendation (adapted from Kapur, N)

3.2 Discharge planning

- Complete Paediatric Home Oxygen request form (G3757HWF)
- See Discharge and Follow-up Process for Neonatal Services Ref 6230
- Complete Nursing Referral form (R1098HWF) for Neonatal Community Nursing team.
- Refer to nominated Paediatrician for follow up

4 Patient information

- Going Home on Oxygen
- Neonatal Community Nurses

5 Evidence base

5.1 Bibliography

- Balfour-Lynn IM, Field DJ, Gringras P, et al. BTS guidelines for home oxygen in children, Thorax, 2009:64(suppl II)
- Hayes Jr D, Wilson K C, Krivchenia K et al (2019) Home Oxygen Therapy for Children. Am J Respir Crit Care Med Vol 199(3) pp e5-e23
- https://starship.org.nz/guidelines/oximetry/ - accessed 23rd of August 2022
- Kapur N, Nixon G, Robinson P, Massie J, Prentice B, Wilson A, Schilling S, Twiss J, Fitzgerald DA. Respiratory management of infants with chronic neonatal lung disease beyond the NICU: A position statement from the Thoracic Society of Australia and New Zealand. Respirology. 2020 Aug;25(8):880-8.SLE 6000 Instructions for use, V2.0

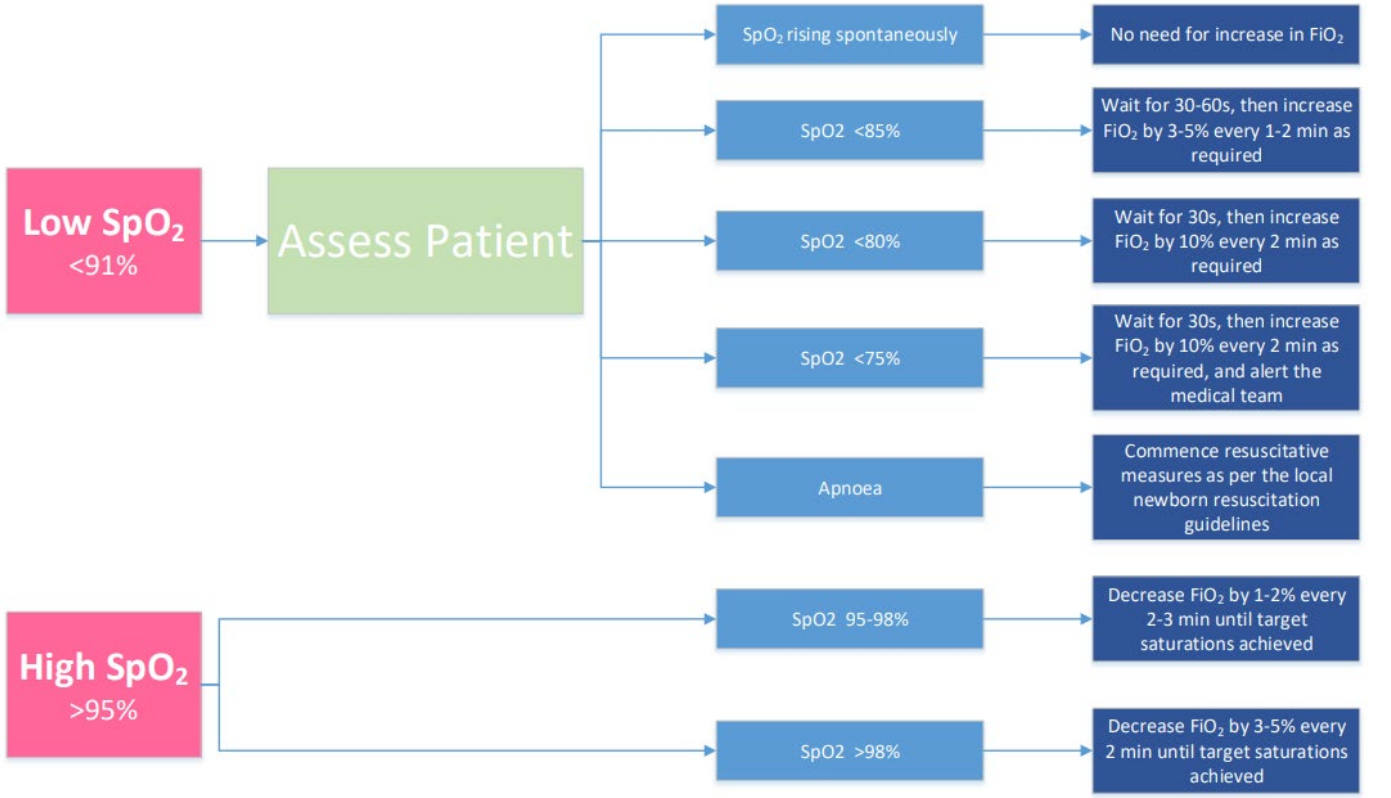
- Neonatal Unit Handbook Christchurch Womens Hospital (2020). Oxygen Saturation Targets- NICU Inpatients
- Newborn Clinical Network Guideline (2015) Oxygen saturation targets for newborns cared for in New Zealand neonatal units, Practice Recommendation for Oxygen Saturation Targets for Newborns cared for in neonatal units, New Zealand
- Pirr S & Peter C (2020) Home Oxygen Therapy after hospital discharge. Seminars in Fetal and Neonatal Medicine. https://doi.org/10.1016/j.siny.2020.101082
- Royal Cornwall Hospitals NHS Trust UK (2017). Clinical Guidelines V3 Oxygen Therapy & Saturation Monitoring of the neonate.
- Sola A & Golombek S (2016) Oxygen Saturation monitoring in Neonatal Period. Springer International Publishing Switzerland. Neonatology Ed.

5.2 Associated Te Whatu Ora Waikato Documents

- Admission to Level II Special Care Nursery (Ref. 4946)
- Admission to Level III Intensive Care Nursery in NICU (Ref. 4571)
- Care of Ventilated Infant (Ref. 0432)
- Consultation Process and Transfer of Care for Neonates (Ref. 2290)
- Continuous Positive Airway Pressure (CPAP) - Management in NICU (Ref. 4939)
- High frequency oscillation ventilation - Nursing care of infant on HFOV (Ref. 0396)
- High Frequency Ventilation of Neonates (Ref. 2625)
- Nitric Oxide Usage in NICU (Ref. 1553)
- Respiratory Support Clinical Guideline- Premature Infants in NICU (Ref. 0441)

Appendix A

Responding to SpO_2 Alarms in babies on oxygen by blender (IPPV/CPAP/NIPPV/High Flow)

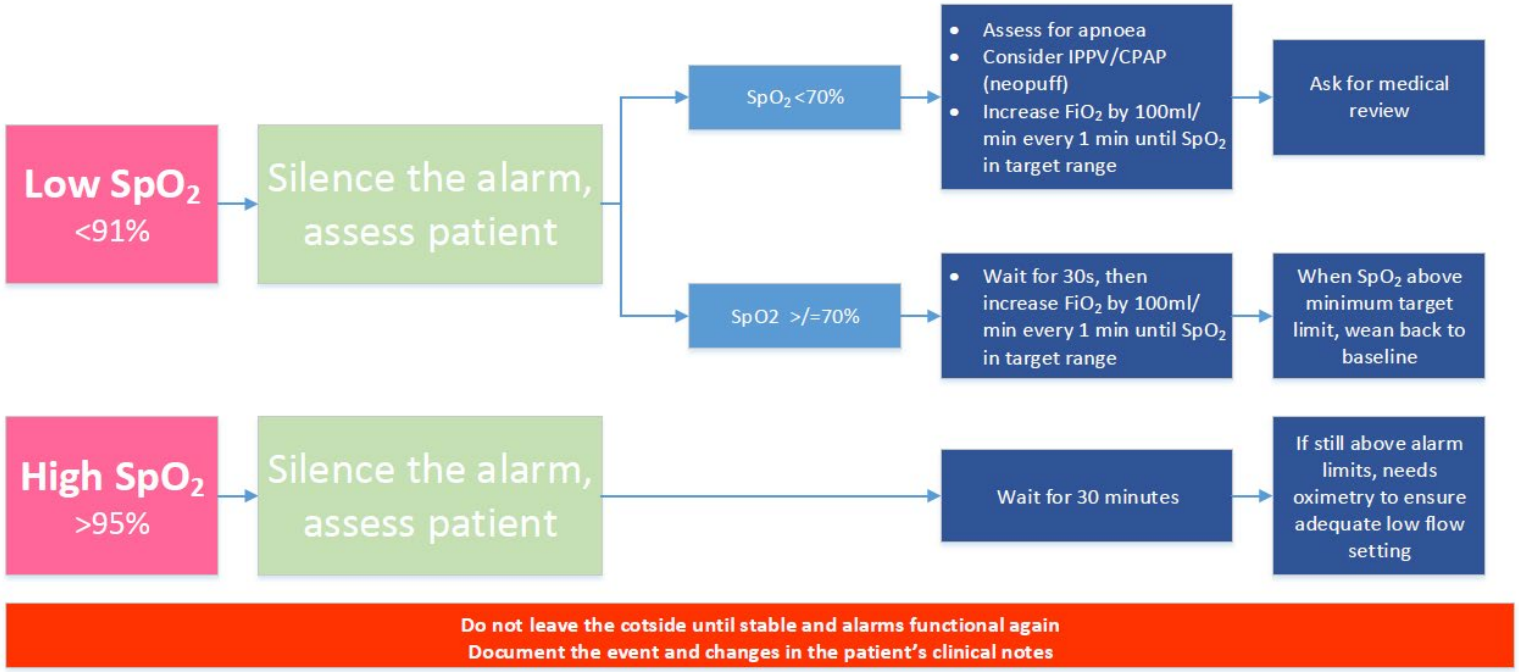


NOTES

- For infants who are unable to be stabilised within the target saturation range of 91-95%, please aim for saturations as close to target range as possible, and inform medical team
- There will be some neonates who have altered target saturations as per the medical team (eg PPHN, congenital cardiac conditions), these infants will have a sign on their cot.

Appendix B

Responding to SpO_2 Alarms in babies on low flow oxygen



NOTES

- Check if alarm settings and alarm silence time are correctly set at 2 minutes
- For infants who are unable to be stabilised within the target saturation range of 91-95%, please aim for saturations as close to target range as possible, and inform medical team
- There will be some neonates who have altered target saturations as per the medical team (eg PPHN, congenital cardiac conditions), these infants will have a sign on their cot.

Appendix C

Observation sheet for oximetry study.

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

Time	Oxygen Flow (If applicable)	Comment	Awake	Asleep

Please comment on noise and work of breathing (e.g. “quiet”, “snoring”), any events that occur (e.g. “apnoea monitor alarmed”, “crying”, “feeding”, “went to toilet”) and any changes.

Was the night typical for your child? Yes / No.

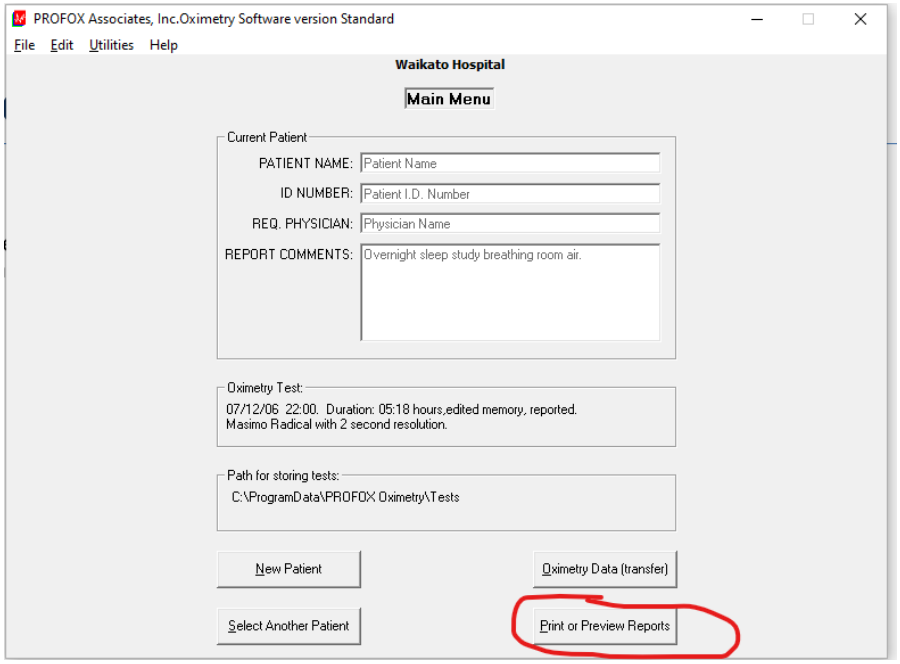
If No, why not ……

Name of care-giver:……..Signature:……..

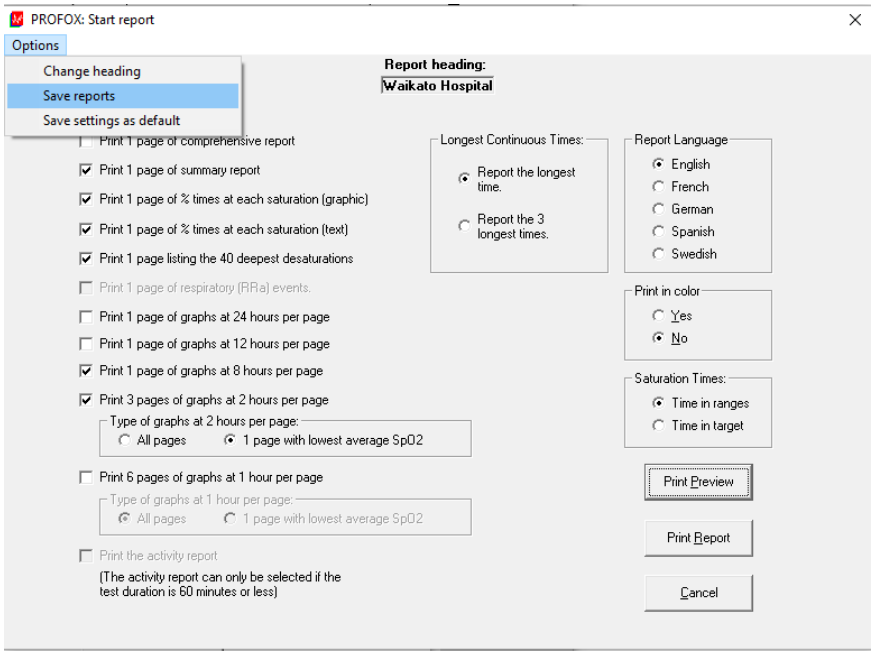
Appendix D

How to create and upload a Profox report to CWS

Once you have finished downloading the patients' recordings from the Rad device, open 'Print or Preview Reports'

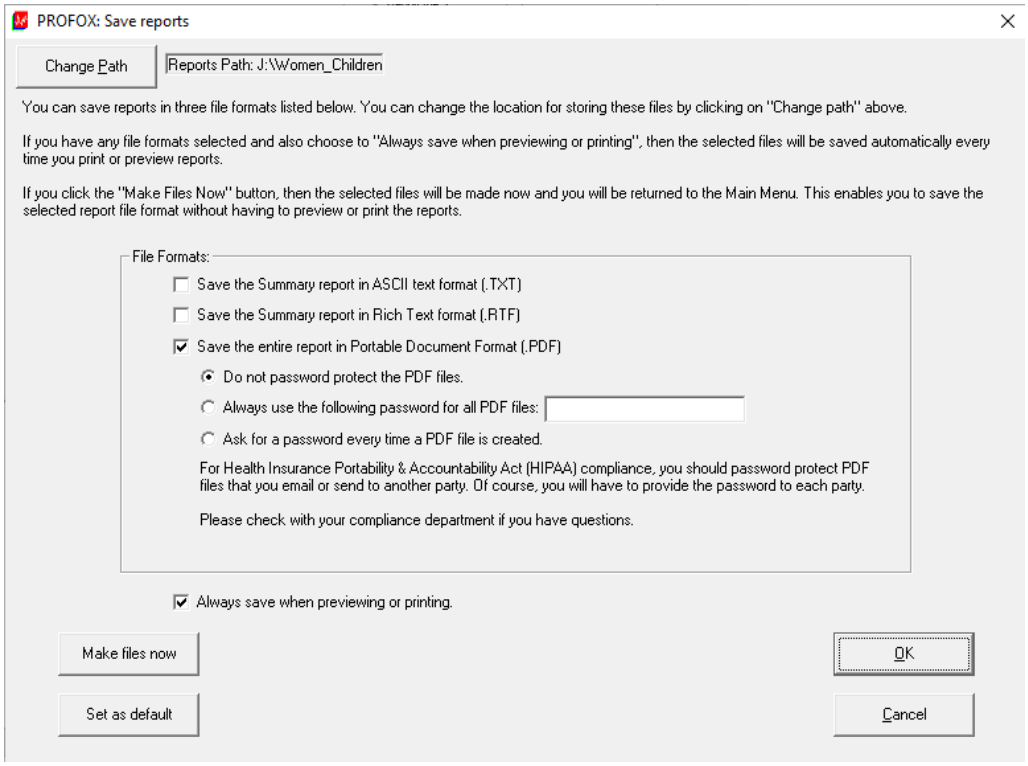


Click on Options > Save reports



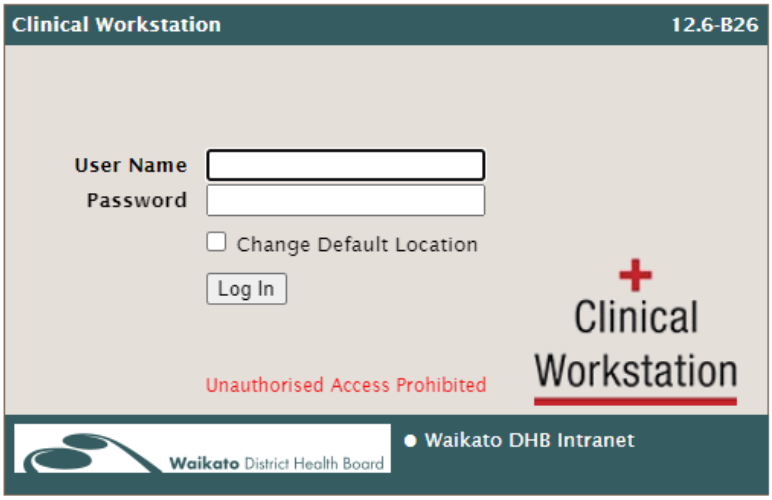
Ensure the following (These should be the default settings) –

1. Change Path is 'J:\\Women_Children\Profox Reports to CWS'
2. 'Save the entire report in Portable Document Format (.PDF)' is ticked
3. 'Do not password protect the PDF files is selected
4. 'Always save when previewing or printing' is ticked
5. Click on 'Set as default', this should mean that the above settings are retained the next time you download a patients recording.

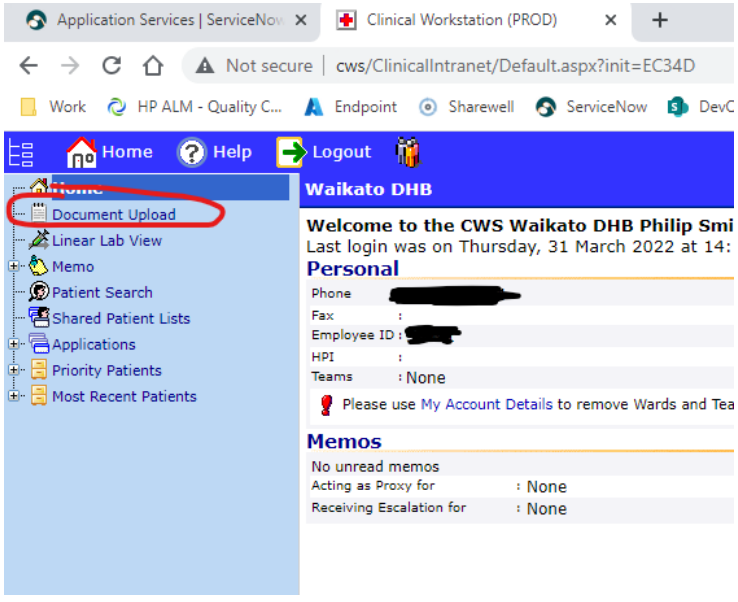


Click on 'Make files now'. This will save the report to the Profox Reports folder.

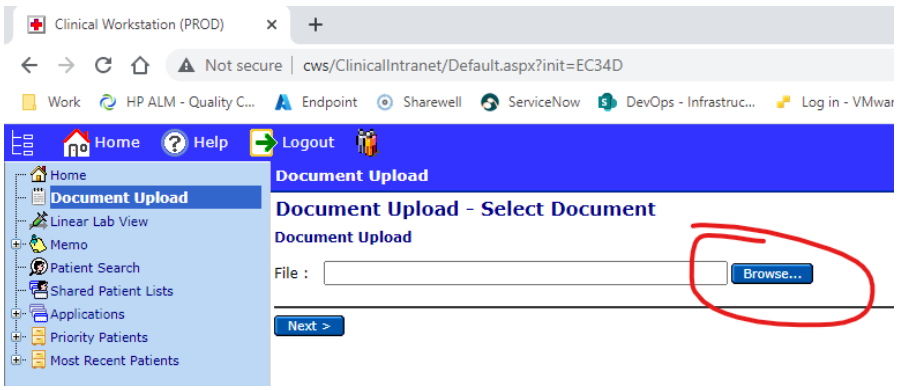
Open Clinical Work Station (CWS) and logon –



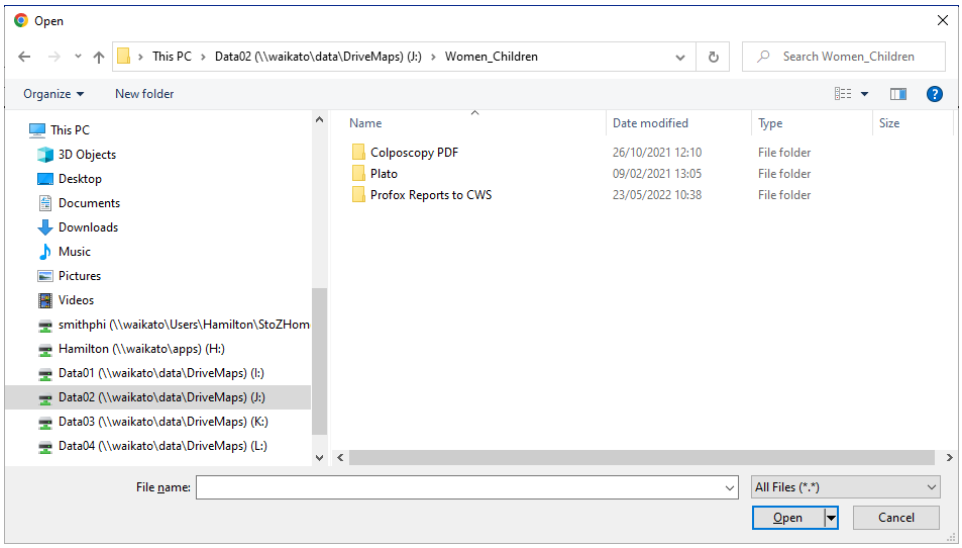
Navigate to Document Upload & click to open –



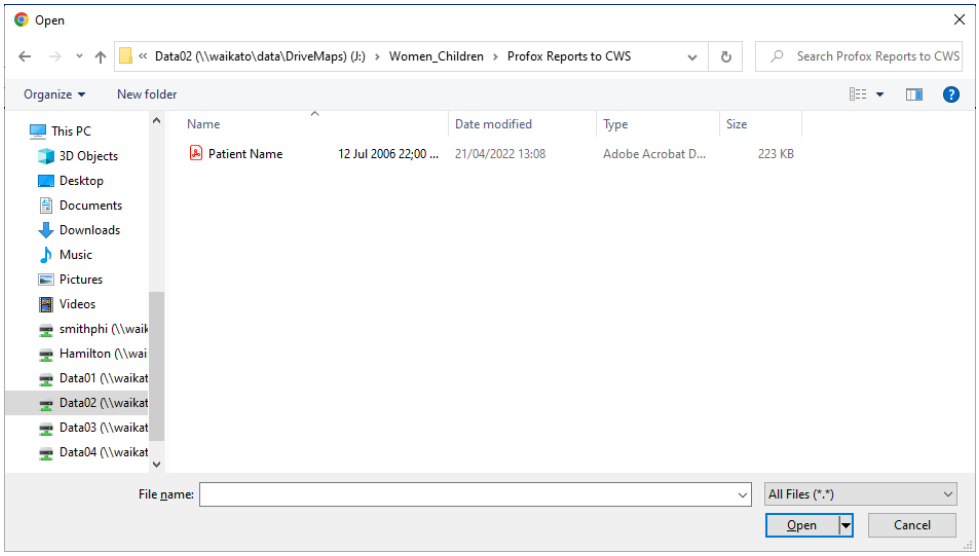
Click on Browse –



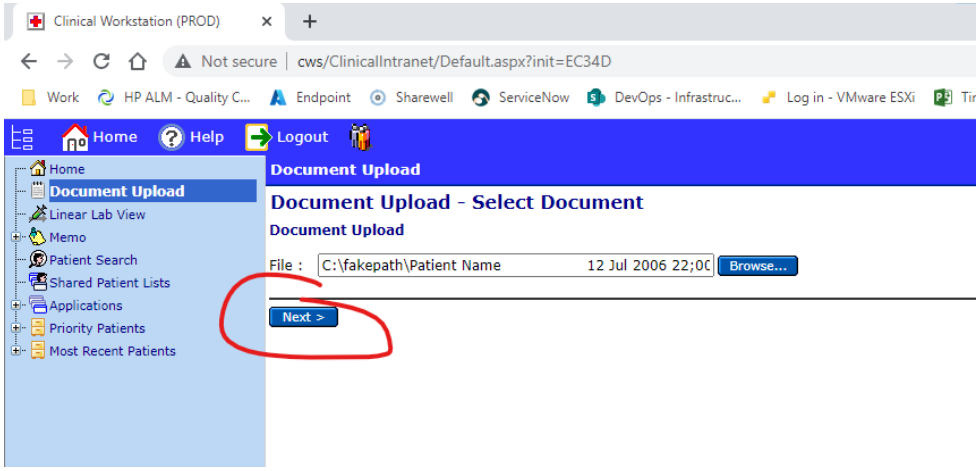
Navigate to Data02 - (J)\Women_Children\Profox Reports to CWS)



Select your patients report & click on Open–

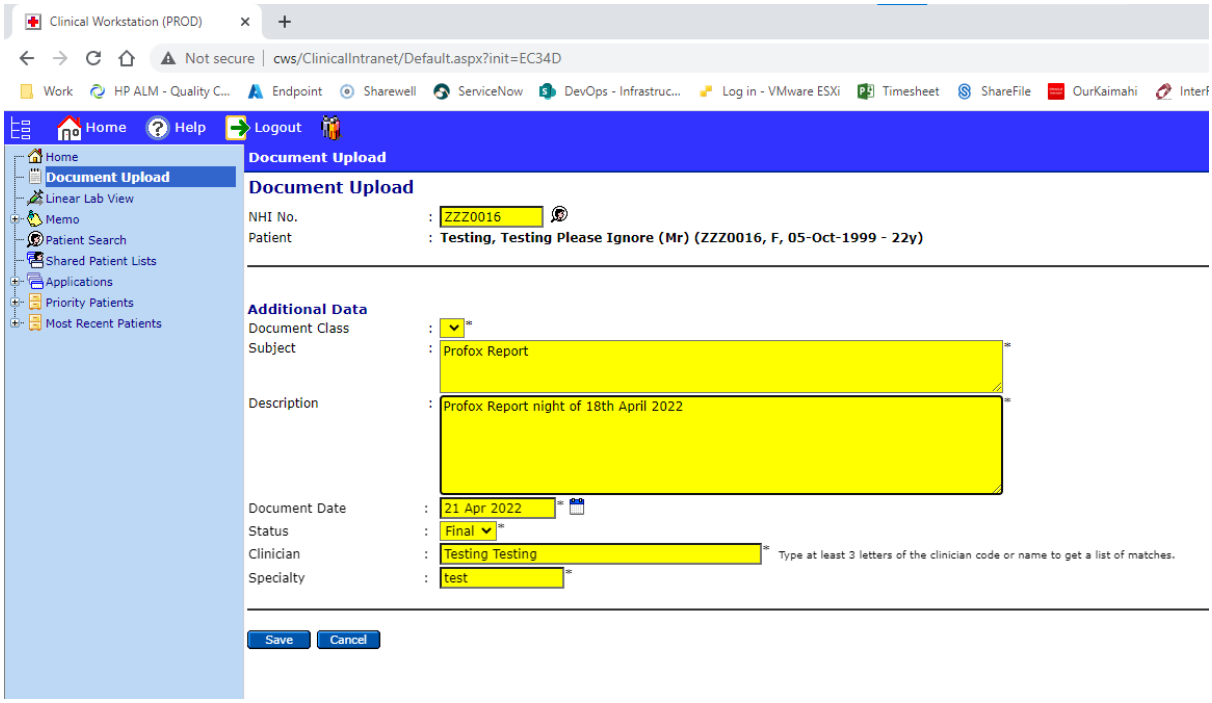


Click Next –



Complete the fields and click on Save –

(If the actual report opens at this stage, close it)



NHI No. Enter your patients NHI number

Description Expanded explanation of the report

Document Date Date report created *(Click on the calendar icon to open and select the date)*

Status Document status

Clinician Clinicians name

Speciality Clinicians speciality

The document will now be stored against your patients' details within CWS.

Appendix E

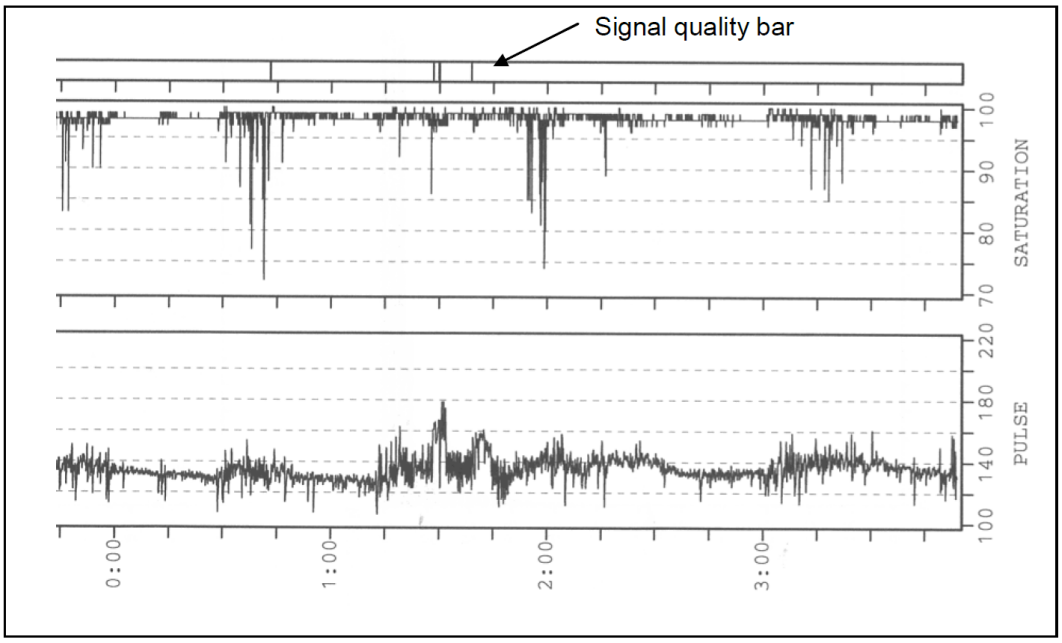
OXIMETRY

Worked Examples:

Figures show portions of graphical reports at either full or reduced scale.

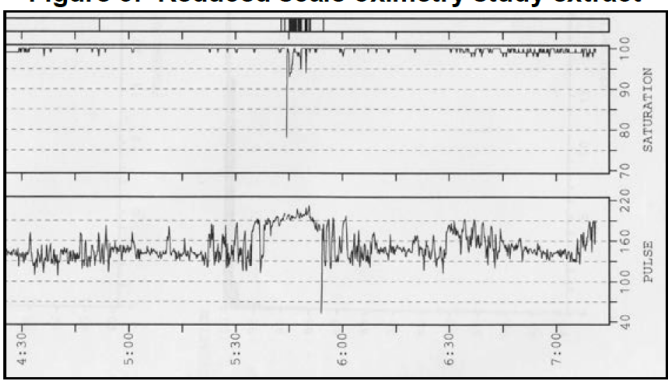
Example 1: **Recommended graphical report format.** Time scale is at least 3cm per hour, vertical scale is 1mm per % saturation and poor signal quality is indicated by lines in the quality ba (see figure 2 below).

Figure 2: Full scale oximetry study extract



Example 3: **Indication: Oxygen titration. Infant with Chronic Neonatal Lung Disease on 0.25 l/min oxygen at home (figure 3).**

Figure 3: Reduced scale oximetry study extract



Report: *"Nearly eleven hours of recording available on a Masimo oximeter with two second averaging time. Some artefact is evident however recording is of adequate quality. The baseline is normal (mean 99%) and above target saturations. No significant desaturation is seen. Consider repeating study on 0.125l/min oxygen. Please return infant to 0.25l/min until the oximetry on the lower flow rate has been reviewed."*