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Title: Accuracy of Pulse Oximeters with Profound Hypoxia (NIHO18)  
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Determination of SpO<sub>2</sub> and PR accuracy specifications at rest  
**ACCURACY OF PULSE OXIMETERS WITH PROFOUND HYPOXIA NIHO 18**  
**Pulse Oximeter Accuracy Evaluation Protocol**

Study Site: The UCSF Hypoxia Research Laboratory, 513 Parnassus Ave San Francisco, CA 94133

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Study Period: April 10-12, 2023

Signature of Principal Investigator: \_\_\_\_\_

### Breathe-down Test at Rest

#### 1. Objective

This study is intended to evaluate performance of the following pulse oximeter (test devices: recorded oximeters), shown in Table 1, manufactured by Nihon Kohden Corporation (1-31-4, Nishiochiai, Shinjuku-ku, Tokyo, 161-8560, Japan) sufficiently to support performance claims for an FDA 510K submission or ISO technical file. These claims include accuracy at rest.

Table 1. Test devices: \*recorded oximeters

Device name	Model name
Pulse oximeter	OLV-4000 series, OLV-4202 (SW version: 01-15)
SpO <sub>2</sub> Connection Cord	JL-400T
*SpO <sub>2</sub> Probe	TL-052S
Attachment tape	- (option for TL-052S)
*Multi-site Y probe	TL-260T
Attachment tape	Type L/ Type S (option for TL-260T) Trained Nihon Kohden personnel select Type L or Type S according to the size of the volunteer's fingers.

This study is also to evaluate performance of the following pulse oximeter sensors shown in Table 2 (test devices: unrecorded oximeters):

Table 2. Test devices: \*\*unrecorded oximeters

Device name	Model name
**Finger probe	TL-201T-BLK2
**Finger probe	TL-201T-BLK4
**Finger probe	TL-201T-BLK5
**SpO <sub>2</sub> probe	TL-273T3-BLK1
**SpO <sub>2</sub> probe	TL-273T3-BLK2
**SpO <sub>2</sub> probe	TL-273T3-BLK3
**Multi-site Y probe	TL-260T
TL-260T clip adapter	- (option for TL-260T)
**Ear probe	TL-Ear9
**Forehead sensor	TL-571T-P3

Description of the tested devices is attached as Appendix A.

Bedside monitor, PVM-4763 (SW version 01-10) will be used for monitoring heart rate for reference.

The following requirements are to be met at rest:

- SpO<sub>2</sub> value range 70% to 100%
- At least 10 subjects, with 3 of dark pigment (Fitzpatrick Scale Type IV, V or VI)
- At least 200 data points

Success criteria is as follows:

Primary outcome measure	
SpO <sub>2</sub> accuracy	Rms of within $\pm 2$ [%SpO <sub>2</sub> ] (70 to 100 [%])
Pulse rate accuracy	Rms of within $\pm 3$ [1/min.] (30 to 300 [1/min.])

Secondary outcome measure	
SpO <sub>2</sub> accuracy	Rms of within $\pm 2$ [%SpO <sub>2</sub> ] (80 to 100 [%]) Rms of within $\pm 3$ [%SpO <sub>2</sub> ] (70 to 80 [%])

Safety of the test devices will be evaluated by assessing adverse events occurred to subjects.

This test is designed in response to the 2013 FDA Guidance on Pulse Oximeters – Premarket Notification Submissions and by ISO 80601-2-61:2017 on Pulse Oximeters, specifically the sections listed below.

- 2013 FDA Guidance on Pulse Oximeters – Premarket Notification Submissions:
  - o 4.1 Accuracy of Pulse Oximeters
    - o 4.1.1 In vivo testing for SpO<sub>2</sub> accuracy under laboratory conditions
    - o 4.1.5 Testing for Pulse Rate Accuracy claims
- ISO 80601-2-61:2017 Annex EE.2 and clause 201.12.1.101.2
  - o 201.12.1.101 SpO<sub>2</sub> accuracy of pulse oximeter equipment
  - o 201.12.1.101.2 Determination of SpO<sub>2</sub> accuracy
  - o 201.12.1.104 Pulse rate ACCURACY

NOTE: This study has been designed per ISO 80601-2-61:2017, and it has been also designed to respond to the recommendations on subject safety added on ISO 80601-2-61:2011. Since ISO 80601-2-61:2011 has been updated as ISO 80601-2-61:2017 with no changes in the requirements for conducting the study and demonstrating SpO<sub>2</sub> and PR accuracy, this study results can be referred for demonstrating SpO<sub>2</sub> and PR accuracy per ISO 80601-2-61:2011 as well as per ISO 80601-2-61:2017.

This study will be conducted in accordance with this protocol and the ethical principles that have their origin in the Declaration of Helsinki, ISO 14155: 2011 and :2020. The study will not begin until the UCSF IRB approval is received.

## 2. Subjects

This study is performed on volunteers who have previously been determined to be healthy enough for this study, have signed an informed consent form and met the following IRB requirements. These volunteers are compensated by the laboratory for their participation. Point of enrolment is defined as time at which subjects sign and date the informed consent form and screening based on subject demography and inclusion/exclusion criteria is complete. Expected enrolment period is 1 week. Expected duration of each subject's participation will be about 45 minutes. The total expected duration of this study is 2 days.

The inclusion criteria for the test subjects are:

1. Both male and female subjects who can give written informed consent
2. Healthy subjects capable of undergoing controlled hypoxemia to the levels outlined in the desaturation profile below
3. Meeting the demographic requirements listed above.

The exclusion criteria for the test subjects are:

1. Age below 18 or over 50
2. Pregnant women
3. Significant arrhythmia
4. Blood pressure above 150 systolic or 90 diastolic
5. Carboxyhemoglobin levels over 3%
6. Subjects whom the investigator consider ineligible for the study.

At least 10 subjects will be recruited to complete the test. Of these 3 will be dark pigment. If the number of samples is less than the required 200 or if less than 2 of dark pigment successfully complete the test, subjects will be added to include 2 of dark pigment and at least 200 data points.

## 3. Desaturation

Each subject will have an arterial catheter inserted in the left or right wrist.

For each subject, a series of desaturation runs are performed. Run 1 starts with a stabilized period at room air and is followed by stabilized plateaus at various lower saturation levels. Run 2 starts with a stabilized period at 100% and is followed by stabilized plateaus at various lower saturation levels. The following are value targets:

Run 1	Room Air, 97, 87,77
Run 2	92, 82, 72

The objective of these targets is to spread the data points evenly over the desired range. Achieving them exactly is not important, though every effort will be made to be within 2%. Saturation level at each plateau and the number of plateaus can vary depending on the subject's condition.

The SpO<sub>2</sub> value is reduced by delivering a mixture of medical air and nitrogen, controlled by 2 manually controlled needle valve flowmeters. The operator controls the SpO<sub>2</sub> by observing the breath-by-breath arterial saturation, which is in turn computed from end tidal PO<sub>2</sub> and PCO<sub>2</sub>. FiO<sub>2</sub> is reduced suddenly at first then adjusted to achieve a stable plateau value at the desired target. A plateau is defined as stable when the readings of the sponsor Control instrument have not changed more than 1 % for 20 seconds (they do not have to agree with each other). Each desaturation plateaus should not exceed 10 minutes. When the sponsor confirms that stability is achieved, a blood draw is taken to flush the tubing, then the first sample is taken using a 2.5 cc syringe. At the time when the gas operator thinks the SpO<sub>2</sub> is stable, the sponsor can ask that the blood sample be delayed for up to 90 seconds. If the stability of a plateau cannot be confirmed in the data analysis, the Sponsor may discuss with the PI the validity of the data collected at such plateau. The second, third and fourth sample are taken by intervals of 30 seconds. The number of blood samples can vary depending on the subject's condition. Extra samples may be required at the discretion of the PI, in which case the total number of blood samples should not exceed 32. The gas mixture is then changed for the next value. This is then repeated for each plateau value.

For each subject, this allows 25 samples to be taken when Room air sat is considered. So, with for example 12 subjects in the study, this produces 300 samples. This ensures that even if one or two subjects and some data points are thrown out, the results will meet the FDA norm of 10 subjects and 200 data points.

During this procedure, the subject is coached on breathing. If he/she appears to fall asleep, he/she is woken up. At any signs of distress, he/she is given 100% oxygen.

Each run should take Between 15 and 25 minutes. It is normal to schedule as many as 10 subjects per day.

Trained Nihon Kohden personnel will be present at the procedure. The role of the Nihon Kohden person is to give technical support relative to the use of the pulse oximeter OLV-4202 including applying the sensors to the subjects, recording the time of blood draw on OLV-4202, and to perform study monitoring. All these actions will be done under the careful direction of the investigators.

Data of the test devices will be automatically recorded simultaneously with measurement in an SD card inserted into the pulse oximeter OLV-4202. The screen of OLV-4202 measuring SpO<sub>2</sub>, PR, and pulse wave will be videotaped, and the video recordings will be stored on an SD card. Subject's demographic data, time of blood draw, and Co-oximeter values will be collected using specific data collection forms.

#### 4. Reference Data

The reference blood samples will be analyzed using two Radiometer ABL90 co-oximeters (ABL-A and ABL-B). Readings of two ABLs will be used to determine the validity of the readings of each other. When two ABLs are determined to be valid, the SaO<sub>2</sub> reference value is the average of the SaO<sub>2</sub> measurements of the two ABLs. The validity of ABL measurements is determined by the following procedure:

- Check if the difference between two ABL readings is within 2%
- If the difference between two ABL readings is within 2%, the readings of two ABLs are valid.
- Readings of two ABL differed by more than 2% saturation will be excluded from the analysis.
- If only one ABL returns the value, the value will be assumed to be correct.

The co-oximeters should be quality control checked and calibrated at the study site to be functioning properly before use.

The heart rate will be measured using a Nihon Kohden PVM-4763 as an ECG monitor. The monitor should be quality control checked using a Fluke Prosim8 at the study site to be functioning properly before use.

## 5. Sensor Placements

A 3-lead ECG will be taken on each subject with the sponsor Control instrument. The electrodes for the sponsor Control instrument will be the L-150X disposable ECG electrodes.

The probes for the primary test instruments will be the TL-052S SpO<sub>2</sub> probe for adults and neonates, and TL-260T multi-site Y probe for adults, children, neonates and low birth weight infants. Probes will be attached to the study subjects by Nihon Kohden engineers who are well trained to use the test devices under the supervision of PI or co-investigator. These probes will be arranged as follows:

On the right-hand side

	Subject 1 + 4 + 7 + 10	Subject 2 + 5 + 8 + 11	Subject 3 + 6 + 9 + 12
TL-052S	Index	Middle	Ring
TL-260T	Pinky	Pinky	Pinky

In addition, the following probes will be applied as non-primary probes:

On the left-hand side

	Subject 1 + 4 + 7 + 10	Subject 2 + 5 + 8 + 11	Subject 3 + 6 + 9 + 12
TL-273T3-BLK1	Index	Middle	Ring
TL-201T-BLK2	Middle	Ring	Pinky
TL-201T-BLK4	Ring	Pinky	Index
TL-201T-BLK5	Pinky	Index	Middle

On the right-hand side

	Subject 1 + 4 + 7 + 10	Subject 2 + 5 + 8 + 11	Subject 3 + 6 + 9 + 12
TL-273T3-BLK2	Middle	Ring	Index
TL-273T3-BLK3	Ring	Index	Middle

On the ears

	Subject 1 + 3 + 5 + 7 + 9 + 11	Subject 2 + 4 + 6 + 8 + 10 + 12
TL-260T	Left Ear	Right Ear
TL-Ear9	Right Ear	Left Ear

On the forehead

	All Subjects
TL-571T-P3	Forehead

## 6. Subject Safety

1. The sensors will be isolated as follows 500V between the sensor and earth ground
2. 4 KV between AC mains power and the low voltage power supply and 1.5 KV between the low voltage power supply and the sensor, OR 5 KV between AC mains and the sensor.

Non-invasive blood pressure will be measured at a screening. EtCO<sub>2</sub>, respiratory rate, and FiO<sub>2</sub> of the subjects will be monitored. In addition, the laboratory maintains criteria for subject selection that have been proven to minimize the risk of any problems during the study.

Adverse event and serious adverse event will be assessed throughout the study by the PI and co-Investigator, or research nurse designated by the PI. If any adverse event occurs during the study, an appropriate medical treatment will be provided to the subject by a medical staff at the laboratory. Nihon Kohden may suspend or prematurely terminate the study when there are serious violations and deviations from the GCP which could adversely affect subject's safety and correct data recording.

The test will be discontinued when a subject requests to withdraw from the study, or the PI or co-investigator will terminate the desaturation procedure and/or a subject's participation in the study because of the reasons including: 1) the subject experiences unexpected oxygen desaturation or 2) the subject loses consciousness.

Risks and anticipated adverse device effects associated with participation in the study that are to be assessed include the following:

- a. Risks of arterial cannulation include bleeding, infection, nerve injury and bruising at the site of catheter insertion. There are also remote risks of an allergic reaction from the lidocaine used for local anesthesia, or the development of arterial spasm, dissection, or thrombosis.
- b. The risks of the brief exposures to hypoxia are include feeling short of breath, headache, and dizziness. Brief loss of consciousness may occur but is not expected at the levels of oxygen targeted for these tests.
- c. The risks of hyperventilating include feeling light-headed or dizzy. The risks of breathing air with increased amounts of carbon dioxide include feeling short of breath and developing a headache.
- d. The risks of burns and skin problems from poor blood circulation. Poor circulation can be avoided by not putting SpO<sub>2</sub> probes too tightly.

Nihon Kohden has determined that there is no residual risk associated with the test devices. Nihon Kohden will be responsible for maintaining the test devices.

Monitoring will be performed by Nihon Kohden. Any adverse events (serious and non-serious) and adverse device effects will be documented in case report forms and reported to Nihon Kohden by PI in a timely manner.

## 7. Data Analysis

Collected data used for data analysis will be reviewed by PI and Nihon Kohden. Data will be retained by the laboratory and Nihon Kohden per their SOPs and policies. Nihon Kohden has no access to subject's personally identifiable information.

The following case report forms (CRFs) will be used to record data and information:

- Subject demographics CRF: Subject information will be recorded.
- Adverse event CRF: An adverse event related or not related to the test devices will be recorded.
- Subject withdrawal CRF: Any subject withdrawal after the subject signs informed consent will be recorded.
- Device deficiency CRF: A deficiency occurred to the test devices will be recorded.
- Protocol departure CRF: Any departure from the defined procedures as outlined in the protocol including mistake in recording of blood draw time will be recorded.

Data from subjects who did not complete the protocol will be thrown out. Also, if subject's carboxyhemoglobin level is confirmed to be over 3% during or after the study, data from the subject will be thrown out. Missing data will not be supplemented.

Data that meets the following conditions will be also thrown out:

- The CO-oximeter experienced error conditions
- Two CO-oximeter readings differed by more than 2% saturation
- The first data points at a plateau where a co-oximeter output differs over 2% saturation from the second points at the same plateau
- Data points at a plateau where a co-oximeter output changes over 2% saturation from the previous points at the same plateau
- Data points which are the only ones at a plateau
- Data points from unstable pulse wave signal where the motion artifact red p-p amplitude is over the PPG p-p amplitude of the subject
- Data points from unstable pulse wave signal where the respiratory artifact red p-p amplitude is over the PPG p-p amplitude of the subject
- PR readings where heart rate changes over 4bpm for 10 seconds
- PR readings at a plateau where heart rate changes over 19bpm for 10 seconds

SpO<sub>2</sub> data will be reduced using the ARMS method and accuracy will be reported as the ARMS deviation between the co-oximeter (SpO<sub>2i</sub>) and the test instrument reference value (S<sub>Ri</sub>) for all points gathered from each sensor. Arms is the root-mean-square (rms) difference between measured values (SpO<sub>2i</sub>) and reference values (S<sub>Ri</sub>), as given below. S<sub>Ri</sub> is the SoO<sub>2</sub> co-oximeter.

$$A_{rms} = \sqrt{\frac{\sum_{i=1}^n (SpO_{2i} - S_{Ri})^2}{n}}$$

PR data will be reduced using the ARMS method and accuracy will be reported as the ARMS deviation between the ECG monitor and the test instruments for all plateaus gathered from each sensor. Accuracy will be determined by comparing the noninvasive pulse rate measurement of the pulse oximeter (PRi) to the heart rate obtained from an electrocardiography reference device (HRRi) and calculating the arithmetic root mean square (Arms) error value as follows:

$$A_{rms} = \sqrt{\frac{\sum_{i=1}^n (PRi - HRRi)^2}{n}}$$

All records of this study related to TL-052S and TL-260T will be retained by Nihon Kohden for at least 3 years after the date of release for commercial distribution of the test devices.

Data will be statistically analyzed by the laboratory per UCSF SOP. The laboratory will provide a summarized report for TL-052S and TL-260T, using the data recorded by the sponsor suitable for FDA 510K submission. Any deviation from the protocol will be reported promptly using case report forms and reported in the report.

## Appendix A Description of the investigational device

## A.1. Test devices: \*recorded oximeters

Device name	Model name	Quantity	Intended populations	Materials that will be in contact with subject's skin	Approved for market in Japan	Appearance
Pulse oximeter	OLV-4000 series, OLV-4202 (SW version: 01-15)	6	Adult/Child/Neonate	-	Yes	
SpO <sub>2</sub> Connection Cord	JL-400T	11	-	-	Yes	
*SpO <sub>2</sub> Probe	TL-052S	1	Adult/Neonate	Polyurethane	Yes	
Attachment tape	- (option for TL-052S)	12	Adult/Neonate	Polyvinyl chloride	Yes	
*Multi-site Y probe	TL-260T	1	Adult/Child/Neonate/Low birth weight infant	-	Yes	
Attachment tape	Type L/ Type S (option for TL-260T)	12	Child/Neonate/Low birth weight infant	Polyurethane	Yes	

## A.2. Test devices: \*\*unrecorded oximeters

Device name	Model name	Quantity	Intended populations	Materials that will be in contact with subject's skin	Approved for market in Japan	Appearance
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**Finger probe	TL-201T-BLK2	1	Adult/Child	Silicone rubber, Polyetherimide, Polyacetal, PPO, PPE	No	
**Finger probe	TL-201T-BLK4	1	Adult/Child	Silicone rubber, Polyetherimide, Polyacetal, PPO, PPE	No	
**Finger probe	TL-201T-BLK5	1	Adult/Child	Silicone rubber, Polyetherimide, Polyacetal, PPO, PPE	No	
**SpO <sub>2</sub> probe	TL-273T3-BLK1	12	Adult/Neonate	Polyurethane, polyester, acrylic adhesive	No	
**SpO <sub>2</sub> probe	TL-273T3-BLK2	12	Adult/Neonate	Polyurethane, polyester, acrylic adhesive	No	
**SpO <sub>2</sub> probe	TL-273T3-BLK3	12	Adult/Neonate	Polyurethane, polyester, acrylic adhesive	No	
**Multi-site Y probe	TL-260T	1	Adult/Child/Neonate/Lo w birth weight infant	-	Yes	
TL-260T clip adapter	- (option for TL-260T)	1	Adult	Silicone	Yes	

**Ear probe	TL-Ear9	1	Adult	Silicone, Polyurethane, ABS	No	
**Forehead sensor	TL-571T-P3	12	Adult	Polyurethane, Acrylic adhesive, Acrylonitrile butadiene styrene, Silicone	No	

The safety assessment per section 201.11 of ISO 80601-2-61:2011 has been conducted for all the test devices and confirmed that the test devices can be used on human subjects.

All test devices can be identified by serial number or lot number. Nihon Kohden will be responsible of keeping records documenting the delivery, use, return, and disposal of the test devices.