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Effect of the light conditions on the accuracy of SpO_2 measurements

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Introduction

Pulse oximetry is a commonly used non-invasive method of measuring blood oxygenation. Accurate measurement of SpO_2 is critical for patient safety, but a light artefact, considered as well-filtered, can occur. Pulse oximeters can protect against external light interferences by using a higher intensity of LEDs in the sensor, mechanical barriers or algorithms that read the light background during the pauses between the red and infrared LEDs in the sensor shining and subtract it from the desired signal.

However, a new form of light artefact is being created by frequency-controlled LEDs installed in hospitals not only as ambient ceiling lighting but also as surgical and phototherapy lamps. There are documented cases during routine hospital care where pulse oximeters have measured incorrectly because of these new LED light sources. One during a surgery with LED surgical light Dräger Polaris 600 and second with examination lamp Dräger Variolux.

Methods

Three LEDs with different and selective spectra were used, one infrared (IR) with peak on 940 nm, second red (R) on 627 nm and white with RGB spectrum. Two pulse oximeters were used, one Nellcor Bedside SpO_2 Patient Monitoring System (Medtronic, Minneapolis, USA) and second Masimo Radical 7 (Masimo Corporation, Irwine, USA). For both pulse oximeters an adhesive wrap neonatal and a finger clip sensor were used.

Measurements consisted of changing LED's frequency under the sensor of pulse oximeter and taking record of LED frequencies which caused a change of SpO_2, heart rate (HR) or created a noise on the plethysmography curve. Switching frequency of red and infrared LEDs inside of a pulse oximeter's sensor and their spectra were measured.

During measurement the sensors of pulse oximeters were put on SpO_2 simulator CONTEC MS100 (CONTEC Medical, Beijing, China) set on SpO_2 98 % and HR 70 bpm and positioned 5 cm above one of used LED. Changing LED frequencies was provided by function generator RIGOL DG1022 (RIGOL Technologies, Beijing, China) set on 10 V peak-to-peak voltage and measurement was made in range from 1 Hz to 1.2 kHz with 1 Hz step.

Results

Both tested pulse oximeters Nellcor Bedside SpO_2 Patient Monitoring System and second Masimo Radical 7 have same spectral parameters but different R and IR LED switching frequency. It can be seen in table 1.

Frequencies on which at least the noise of plethysmography curve occurred can be seen in figure 1 for pulse oximeter Masimo Radical 7. Switching frequency of R and IR LEDs of the pulse oximeter, its half and double are shown inside the figure 1 for better orientation. The pulse oximeter stopped the measurement while using the finger clip sensor only on the frequency 163 Hz with IR LED. With neonatal sensor the measurement stopped on frequencies 162–169, 320 and 335 Hz with R and white LED, with IR LED the problematic bends were wider. There was no disturbance monitored on frequencies higher than 338 Hz.

In figure 2 can be seen frequencies which created at least a noise in plethysmography curve on Nellcor Bedside SpO_2 Patient Monitoring System. In figure 2 there are also displayed a switching frequency of R and IR LED of the pulse oximeter, its half and quarter for better orientation. Between recorded problematic frequencies there are few listed below which caused a decrease in SpO_2, raise in heart rate and sometimes leading to end of measurement. With finger clip sensor these frequencies for IR and white LED are 806–810 Hz and 1208–1212 Hz, R LED didn't create false readings. On the other hand with neonatal sensor this interference was seen with white LED on frequencies 59, 135, 174, 220, 270, 347, 403, 484–486, 805–810 Hz, with R LED on frequencies 59, 242, 347, 405–408, 485, 805–810, 1217 Hz and with IR LED on frequencies 62, 110, 143, 162, 186, 219–221, 270, 330, 347, 404, 606, 794–820, 1200–1210 Hz.

Discussion

The main finding of this study is that frequency-controlled LED light sources can not only stop the pulse oximetry measurement but also change the measured parameters. The strongest interferences in the measurements occur when the LED light source uses the same or two times higher frequency than the pulse oximeter. Infrared LED apart from red or white LEDs can create not only higher plethysmography curve disturbance but also cause problems on more frequencies.

In the case of the Masimo Radical 7, if a major disturbance in the plethysmography curve was detected for at least 10 seconds, it would rather stop the measurement than display an incorrect SpO_2 or heart rate. On the other hand, the pulse oximeter Nellcor Bedside SpO_2 Patient Monitoring System uses higher switching frequency trying to avoid low frequency noise used in LED controlled lights. However, it was easier to interfere with the measured parameters such as SpO_2 and HR, not only the plethysmography curve.

From figure 1 and 2 is clear that neonatal sensors are more likely to be disturbed by surrounding light interference than clips sensors. This is due to the design of the sensors, which allows light to enter the photodetector of the pulse oximeter more easily.

Conclusion

Frequency-controlled LED light sources can interfere with pulse oximeters and give false readings of SpO_2 or heart rate. Although this experiment was performed under laboratory conditions, it replicated the phenomenon observed during hospital procedures. The danger in such situations is when the interfering signal significantly affects the accuracy of the measurement without triggering an alarm of the device. The strongest interference occurs when the external LED light uses the same frequency as the pulse oximeter's R and IR switching frequency.

Tab. 1. Parameters of used pulse oximeters, switching frequency between red and infrared LED and their wavelength

Pulse oximeter name	Frequency (Hz)	Wavelength R (nm)	Wavelength IR (nm)
Nellcor Bedside SpO_2 Patient Monitoring System	1200	660	940
Masimo Radical 7	167	660	940

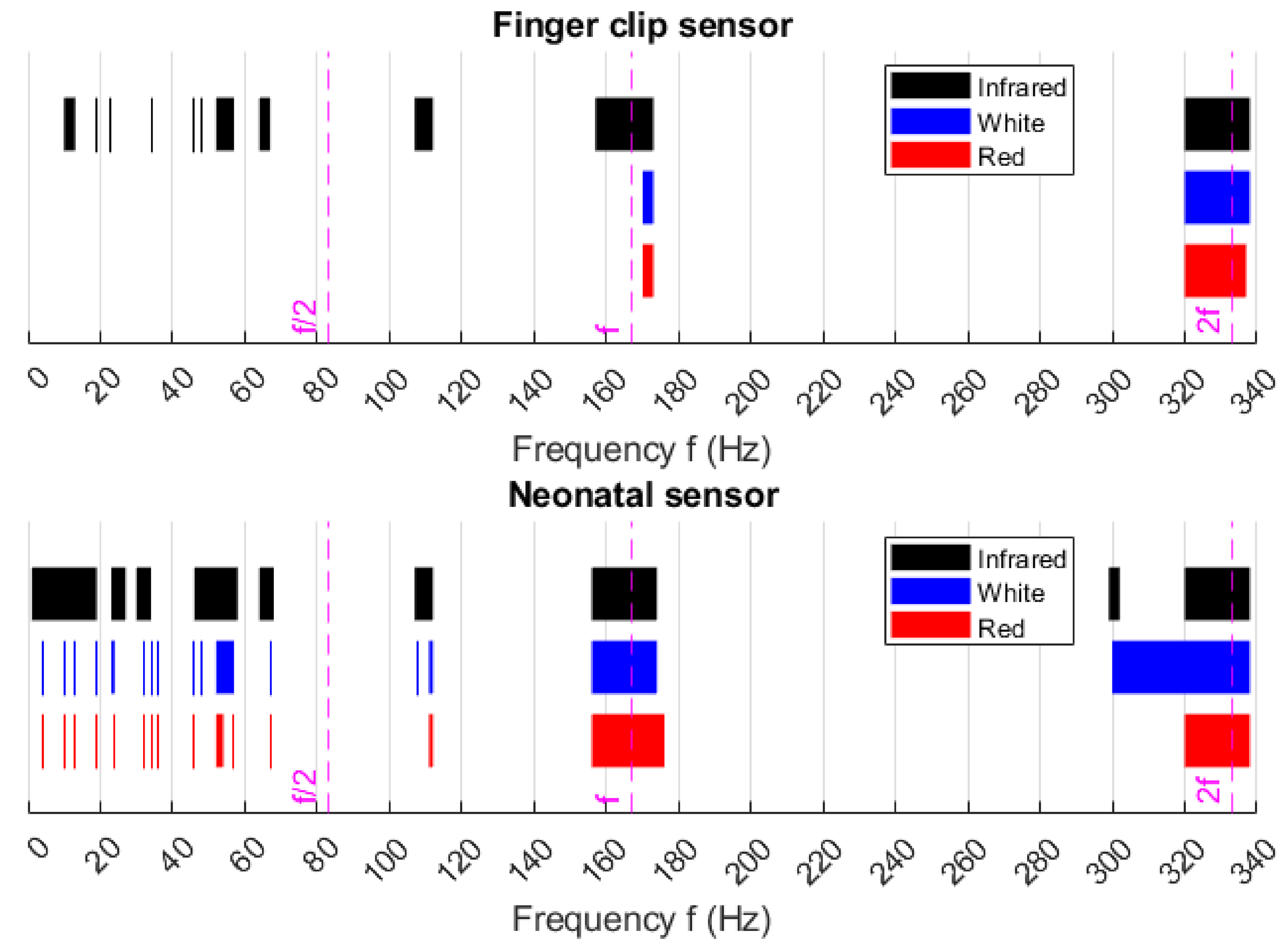

Fig. 1. Interfering frequencies of Masimo Radical 7 for clips and neonatal sensor

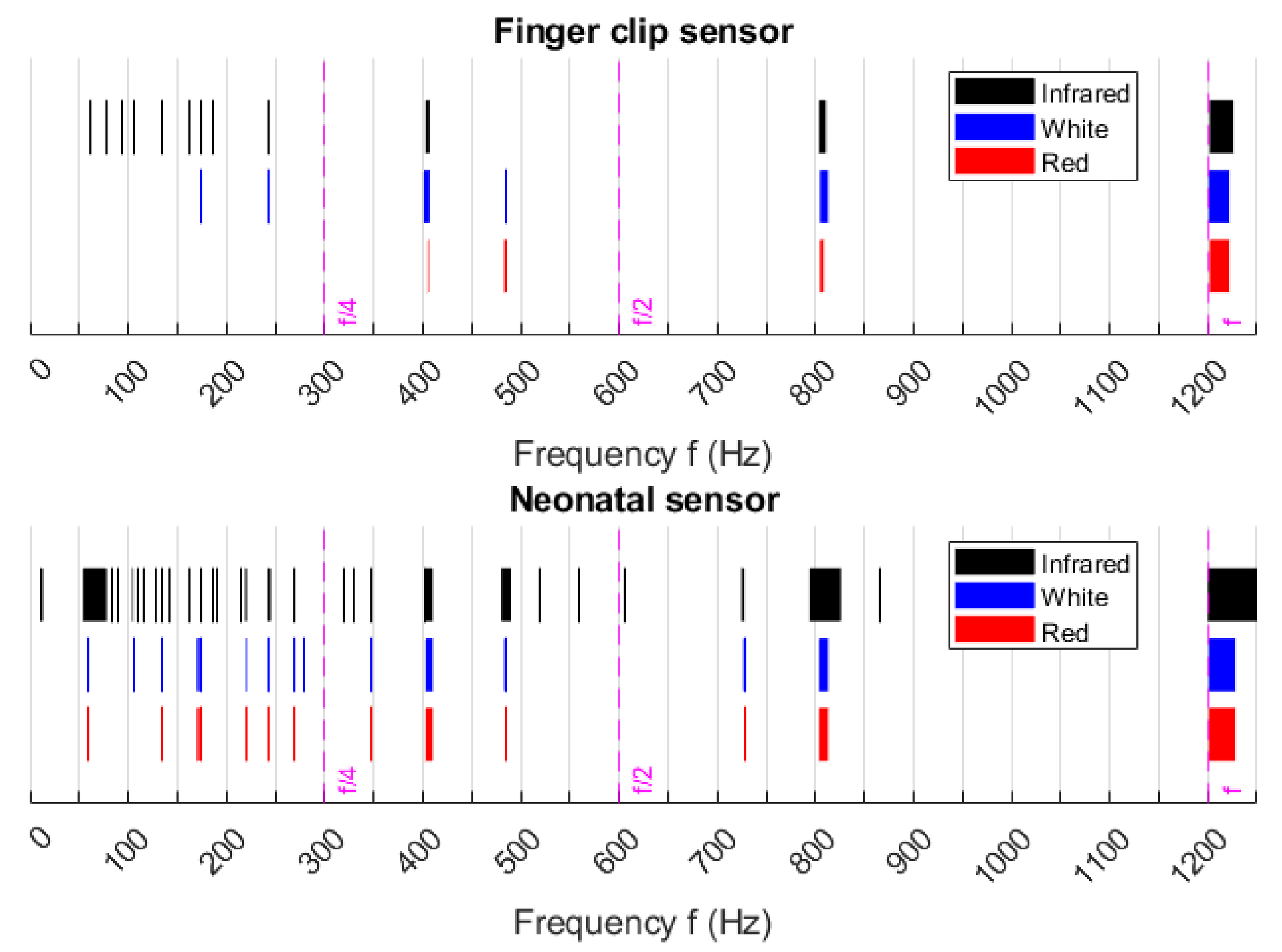

Fig. 2. Interfering frequencies of Nellcor Bedside SpO_2 Patient Monitoring System for clips and neonatal sensor

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