The Stealth Station™ Image Guidance System may interfere with pulse oximetry

[Le système de guidage par imagerie Stealth Station™ peut nuire à la sphygmo-oxymétrie]

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Purpose: Interference on pulse oximetry can come from many sources. We found an additional source of interference from the Stealth Station™. This article gives an overview of sources of pulse oximeter interference so that clinicians can better prevent them.

Technical features: This article discusses the infrared disturbances caused by the Stealth Station™. The Stealth Station™ is a frameless stereotactic positioning system that utilizes a three dimensional location system to measure the position of the patient and the surgical tools, and to relate those positions to previously recorded imaging. To understand the disturbance caused by the Stealth Station™, we discuss its operation and that of pulse oximeter monitors. Pulse oximeter interference can come from volume artifacts, electrical and light noise, and can be caused by issues related to the patient. Because the passive Stealth Station™ contains a strong infrared light source, interference caused by light is a likely reason for the interference we noted. Pulse oximeters rely on the time-variant light signal modulated by arterial volume variations in the finger. Although relatively immune to static light sources, pulse oximeters are extremely sensitive to time-varying light sources. The light emitted by the passive Stealth Station™ is time-varying at 4 Hz and this is causing the pulse oximeter to provide invalid results. Shielding can generally be used to stop the light from the Stealth Station™ from being picked up by the pulse oximeter sensor.

Conclusion: Infrared light interference can be very common, but is easily dealt with if one is aware of it.

Objectif : *L'interférence sur la sphygmo-oxymétrie peut provenir de nombreuses sources, dont une nouvelle provenant de la Stealth Station™. Nous présentons un aperçu des interférences avec le sphygmo-oxymètre, ce qui permettra aux cliniciens de la prévenir.*

Caractéristiques techniques : *La Stealth Station™ est un système de positionnement stéréotaxique sans cadre qui utilise un système de repérage en trois dimensions pour mesurer la position réelle du patient et des instruments chirurgicaux et pour relier cette position à des images virtuelles préalablement enregistrées.L'interférence avec le sphygmo-oxymètre peut provenir d'artéfacts volumique, des produits électriques et de légers bruits et elle peut être causée par des problèmes reliés au patient. Comme la Stealth Station™ passive contient une puissante source de lumière à infrarouges, c'est une raison probable de l'interférence notée. Les sphygmo-oxymètres dépendent du signal lumineux variable dans le temps qui est modulé par les variations du volume artériel dans le doigt. Bien que relativement soustraits aux sources de lumière statiques, les sphygmo-oxymètres sont extrêmement sensibles aux sources de lumière variables dans le temps. La lumière émise par la Stealth Station™ passive varie dans le temps à 4 Hz, ce qui invalide certains résultats au sphygmo-oxymètre. Une protection peut généralement être utilisée pour empêcher la lumière provenant de la Stealth Station™ d'être captée par le détecteur du sphygmo-oxymètre.*

Conclusion : *L'interférence de la lumière infrarouge peut se rencontrer souvent, mais on peut facilement la contourner pourvu qu'on en prenne conscience.*

HEMOGLOBIN oxygenation percentages as calculated by the pulse oximeter are generally trusted. However, a number of factors can cause invalid saturations to be calculated, or cause other failures of the pulse oximeter. Limitations of pulse oximeter measurements can be grouped as: volume artifacts, noise from light interference or electrical interference, and patient related interference. While the factors interfering with the saturation measurement are well understood,[1] we discovered another interference that can occur when a Stealth Station™ Image Guidance System (Medtronic Sofamor Danek, Memphis, TN,

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USA) is in use. The Stealth Station™ interfered with the pulse oximeter causing it to give invalid readings of around 80%. We investigated the cause of this problem, and are reporting it in this article.

Technical features

The Stealth Station™ Image Guidance System is a frameless stereotactic surgical positioning system, frequently used for neurological cases.[2] Magnetic resonance images (MRI) are recorded previously with fiducial markers placed on the patient's scalp. The position of the fiducial markers can be tracked in the operating room by an infrared (IR) imaging system. This system contains an IR light source and a camera, both mounted on the ceiling or on a pole. The light source illuminates the surgical field and the IR camera records the location of the markers in three dimensional space. In addition, surgical instruments outfitted with markers are also used and tracked. Because the relationship between the fiducial markers connected to the patient and the MRI is known, and the relationship between the position of the surgical instruments and the patient is known, it is possible to relate the position of the surgical instruments with the MRI. The surgical instruments' position and orientation are represented in the three-dimensional image of the patient's head and allows accurate planning of the surgical approach to the tumour.

During several cases using the Stealth Station™, oxygen saturation was monitored using a Philips CMS (Philips, Andover, MA, USA) pulse oximeter integrated monitor. The hardware revision of the pulse oximeter module was M1020A and the CMS contained software revision number 17.62. Interference on the pulse oximetry was noted (Figure 1). This interference appeared as an approximate 4 Hz disturbance, which caused the pulse oximeter to display saturations below 80%. We found that the interfering signal was coming from the Stealth Station™ Image Guidance System. There is no indication of a light source on the Stealth Station™ camera arm, because the system is IR light-based, which is not visible to the human eye.

To eliminate the interference, we attempted to shield the pulse oximeter probe from the Stealth Station™ IR light sources. We first used a blue cloth towel wrapped around the hand (Figure 2a), which reduced the amplitude of the interfering signal, but did not eliminate it. We then used the cover of an alcohol pad, which is a paper cover with an aluminium lining inside. We slid this cover over the pulse oximetry probe and the interference was eliminated (Figure 2b).

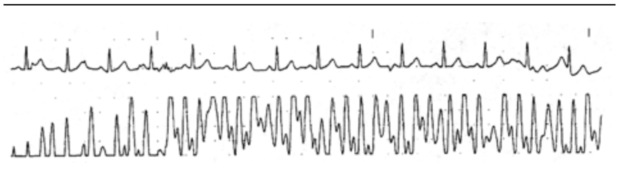

FIGURE 1 Pulse oximeter plethysmogram with interference (bottom) and electrocardiogram (top).

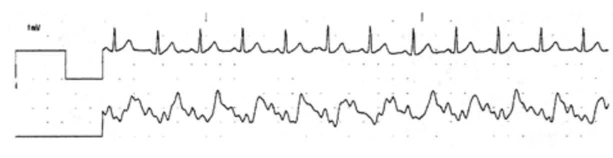

FIGURE 2a Pulse oximeter plethysmogram with interference while covered with a towel (bottom) and corresponding electrocardiogram (top).

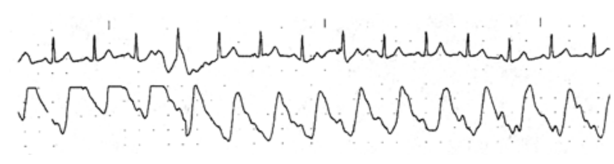

FIGURE 2b Pulse oximeter plethysmogram without interference after covering with a metallic sheath (bottom) and corresponding electrocardiogram (top).

Discussion

Interference on pulse oximeter signals can originate from a number of sources (Table). Volume artifacts are present when there are volume changes at the measurement site not caused by the arterial pulse (movement artifact for example). Noise artifacts can be light interference (like in our case) or electrical interference and will typically show up in the plethysmogram as additional waveform fluctuations. Sometimes these fluctuations cause an increased calculated heart rate or change saturation calculation. Patient related interferences, like the presence of carboxyhemoglobin, can also cause incorrectly calculated saturations.

To examine the reasons for our interference, we need to investigate the operation of the Stealth Station™ and pulse oximeters. The Stealth Station™ registers the instruments through their IR light signature. This signature is produced either actively, that is from IR light-emitting diodes (LEDs) fixed on the instruments that emit light, or passively (like in our case) from the reflection of IR light generated near the

TABLE

Volume artifacts	
Motion	Causes blood volume changes at the measurement site, resulting in difficulties calculating the saturation[3,4]
Low perfusion	Vasoconstriction, an inflated blood pressure cuff, etc., will cause the pulsatile portion of the plethysmogram to be small, causing difficulties calculating saturation[5]
Noise	
Light interference	Caused by other light sources, such as fluorescent lights, and other ambient light sources[5]
Electrical interference	Powerful radio frequency signals can cause voltage fluctuations on the detector signal from the pulse oximeter probe[6]
Patient related interference	
Presence of carboxyhemoglobin and/or methemoglobin in blood	These will cause inaccurate calculation of saturation[7]
Dyes present in blood	Depending on the dye, inaccurate saturation calculation will result[8]
Skin pigmentation	Will cause a filtering of the light emitted by the pulse oximeter probe, and cause inaccurate saturation calculations[9]

detection cameras back from circular reflectors mounted on the instruments. The detection cameras are mounted on the ceiling or on a movable pole. Because the detector can be up to ten feet away, the power of the IR system is quite strong. The IR signals are frequency modulated to facilitate pick up at the sensor. It is this modulated signal that interferes with the pulse oximeter probe. Smith *et al.* provide more details on the Stealth System™.[2]

Pulse oximeter probes contain red and IR LED on one side of the probe and a photodetector on the other side. The photodetector is used to pick up the light emitted from the LEDs that has been modulated by the pulsating volume changes in the finger. This photodetector is typically sensitive to a wide wavelength spectrum. The two plethysmograph signals (one for red, one for IR) detected by the photodetector are processed to calculate the blood oxygen saturation.

Pulse oximetry relies on the Beer Lambert law to calculate absorbency $A = -\ln(I/I_0)$ where I is the detected light intensity by the detector and I_0 is the intensity of light emitted by the photo diode. A (at a given wavelength) consists of absorbency due to oxygenated hemoglobin (A_o) and reduced hemoglobin (A_r), as well as a time-invariant absorbency due to other tissues such as bone, venous blood, etc. (A_x).[10]

$$A(\lambda) = A_o + A_r + A_x$$

To eliminate the last term a time derivative of A is taken (dA/dt), which leaves only the terms with time varying components (arterial blood). It is for this reason that pulse oximeter probes are relatively immune to fixed light signals (as long as they do not overpower the detector), but they are extremely sensitive to varying signals to facilitate detection of small vascular bed volume changes. It should also be noted that IR light sources are readily reflected by hard surfaces like walls, floors, and equipment in the operating room. As a result, the IR light sources on the Stealth Station™ do not need to be directly aimed at the pulse oximeter probe to cause significant interference.

Conclusion

Infrared interference on the pulse oximetry signal could come from many sources. Infrared communication has many applications: remote controls, synchronization (as on Palm™ devices), wireless communication between laptops and printers, etc. All of those IR light sources are modulated at some frequency, which means that they have the potential to interfere with pulse oximetry. The degree of interference will depend on the level of signal filtering present in pulse oximeters. With Stealth Station™ technology already having a rapidly growing role in orthopedic, otolaryngologic and neurosurgical procedures, this interference should be expected. Simple shielding measures will resolve this interference.

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