Recommended Use of Pulse Oximetry in Aviation

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This is an expanded version of Dr. Blue's article that appears in the FAA's "Federal Air Surgeon's Bulletin" which is sent to all Aviation Medical Examiners.

Until recently, the only objective guidance available to pilots concerning the use of supplemental oxygen in flight came from the Federal Aviation Regulations:

§ 91.211 Supplemental oxygen.

(a) General. No person may operate a civil aircraft of U.S. registry -

(1) At cabin pressure altitudes above 12,500 feet (MSL) up to and including 14,000 feet (MSL) unless the required minimum flight crew is provided with and uses supplemental oxygen for that part of the flight at those altitudes that is of more than 30 minutes duration;

(2) At cabin pressure altitudes above 14,000 feet (MSL) unless the required minimum flight crew is provided with and uses supplemental oxygen during the entire flight time at those altitudes; and

(3) At cabin pressure altitudes above 15,000 feet (MSL) unless each occupant of the aircraft is provided with supplemental oxygen.

(b) Pressurized cabin aircraft.

(1) No person may operate a civil aircraft of U.S. registry with a pressurized cabin -

(i) At flight altitudes above flight level 250 unless at least a 10-minute supply of supplemental oxygen, in addition to any oxygen required to satisfy paragraph (a) of this section, is available for each occupant of the aircraft for use in the event that a descent is necessitated by loss of cabin pressurization; and

(ii) At flight altitudes above flight level 350 unless one pilot at the controls of the airplane is wearing and using an oxygen mask that is secured and sealed and that either supplies oxygen at all times or automatically supplies oxygen whenever the cabin pressure altitude of the airplane exceeds 14,000 feet (MSL), except that the one pilot need not wear and use an oxygen mask while at or below flight level 410 if there are two pilots at the controls and each pilot has a quick-donning type of oxygen mask that can be placed on the face with one hand from the ready position within 5 seconds, supplying oxygen and properly secured and sealed.

(2) Notwithstanding paragraph (b)(1)(ii) of this section, if for any reason at any time it is necessary for one pilot to leave the controls of the aircraft when operating at flight altitudes above flight level 350, the remaining pilot at the controls shall put on and use an oxygen mask until the other pilot has returned to that crewmember's station.

The FAA requirement for the use of supplemental use by pilots at cabin pressure altitudes above 12,500 feet MSL for over 30 minutes, and at all times over 14,500 feet MSL, is based on studies done many years ago, prior to the invention of today's non-invasive technology for measuring actual blood oxygen saturation known as pulse oximetry.

A **pulse oximeter** permits crewmembers and passengers of an aircraft to evaluate their actual need for supplemental oxygen quickly and easily. However, the FAA has not yet provided any official recommendations for the use of pulse oximetry in flight. As the leading supplier of pulse oximeters to the aviation community, Aeromedix.Com has therefore prepared the following guidelines, based on our experience in medicine and aviation. As with any such recommendation, each pilot has the obligation to become familiar with the technology and its proper use, and to interpret and adapt these guidelines to the particular situation. Some pilots and passengers will need to use supplemental oxygen at oxygen saturation levels higher than other individuals, and some may need higher oxygen flow rates than others.

**Principles of Operation**

Pulse oximetry is based on the noninvasive measurement of the color changes that red blood cells undergo when they become...
oxygenated. The pulse oximeter works by transmitting a special light beam through a vascular bed of capillary blood vessels most commonly at a fingertip to evaluate the color of the red cells and calculate the degree of oxygen saturation. The units are very accurate, generally within one percent of directly measured blood oxygen levels obtained by invasive means.

The pulse oximeter requires light transmission to work. The unit is slipped over the finger so that the light source shines through the part of the finger that is covered by the fingernail. Although pulse oximeters will generally work on most fingers, they will work dramatically better if the fingernail is not covered with nail polish especially dark pigmented nail polish. Pulse oximeter readings can generally be relied upon when the instrument's perfusion indicator is "in the green" and the displayed pulse rate is accurate. To double-check that the oximeter is receiving good data, take your pulse manually and compare it with the pulse readout on the oximeter. If the two are close, you can be relatively confident that the instrument's oxygen saturation reading will be accurate.

An important limitation of pulse oximetry is that it cannot detect or measure carbon monoxide (CO) poisoning. This is because when CO binds to the hemoglobin in a red blood cell, the cell turns bright red in color, just as it does when it binds with oxygen. Consequently, you could literally be dying of CO poisoning and the pulse oximeter would show normal oxygen saturation readings. Consequently, the use of a sensitive, accurate, digital-readout CO detector is strongly recommended.

Normal And Tolerated O₂ Saturation Readings

When using a pulse oximeter, what blood oxygen saturation level is considered normal? The answer varies from one individual to another, and depends on lots of factors, including age, cardiopulmonary conditioning, and altitude acclimatization. However, as a general guideline, the following pulse oximeter readings can be considered normal:

<table>
<thead>
<tr>
<th>Altitude (MSL)</th>
<th>O₂ Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea Level</td>
<td>95-100%</td>
</tr>
<tr>
<td>10,000'</td>
<td>88-93%</td>
</tr>
<tr>
<td>13,000'</td>
<td>83-88%</td>
</tr>
<tr>
<td>16,000'</td>
<td>75-80%</td>
</tr>
<tr>
<td>20,000'</td>
<td>70-75%</td>
</tr>
</tbody>
</table>

It is important to understand, however, that normal oxygen saturation isn't the same as tolerated oxygen saturation. For instance, if you live at or near sea level, check your oxygen saturation with a pulse oximeter, and find that it reads 97%, this is normal. Now, if you travel to Jackson Hole, Wyoming, at an altitude of 6,200 feet MSL, your saturation might read 93%, which is also normal. However, when you hike or ski or perform other strenuous tasks in the rarified air at Jackson Hole, you will quickly discover that your exercise tolerance is far less than what you're accustomed to because of lower oxygen saturation.

People who live at high altitude develop an increased number of red blood cells to compensate for the decrease saturation percentage. This process is known as acclimatization and requires a period of months to occur. It explains why a person who lives at high altitude can tolerate that altitude better than a lowlander can, despite the fact that both exhibit similar pulse oximeter readings when taken at the same altitude. It also explains why our recommendations for pulse oximeter use in flight are based on deviation from each individual's normal home oxygen saturation, rather than on any absolute scale.

During flight, this distinction between normal and tolerated is all-important. For instance, flying at 12,000 feet, a pilot may have an oxygen saturation of 85% -- which is absolutely normal for that altitude -- but that may not be tolerated very well by the pilot, who could easily develop cognitive (thinking) difficulties that affects his ability to comprehend a clearance, calculate fuel consumption, or respond thoughtfully to an emergency.

Besides altitude, there are other factors which will lower oxygen saturation, such as the congestion associated with a cold, insufficiently deep breathing (which can occur with overweight people in sitting positions), underlying lung conditions such
Most people will feel better and have less fatigue if they start using supplemental oxygen when their oxygen saturation drops 5 percentage points below their normal home altitude saturation.

Note that these guidelines do not relieve the pilot from the regulatory requirement to comply with the 12,500- and 14,000-foot requirements of FAR 91.211. However, in most cases and for most individuals, adherence to the guidelines will result in using supplemental oxygen at lower altitudes than dictated by the FAR.

If you have an oxygen system that permits manual adjustment of flow rates, the pulse oximeter may be used to adjust oxygen flow to provide the desired saturation. However, it's important to understand that initiating oxygen use or adjusting oxygen flow will take 15 to 30 seconds before the effect shows up on the oximeter reading. That's how long it takes for the additional oxygen to enter the lungs, oxygenate the blood in the pulmonary blood vessels, pass through the heart, flow to the fingertip, and be measured by the oximeter. The effects of deep breathing (which also increases oxygen saturation) is also subject to this delay before it shows up on the instrument.