Take a moment and consider our planet without oxygen. Imagine the earth some 2.5 billion years ago when oxygen first appeared as a waste product of early anaerobes. Oxygen, as we know it today, is essential for life. Abundant and relatively inexpensive to manufacture, oxygen has widespread use in industry and healthcare. Anesthesia providers routinely administer oxygen in concentrations exceeding that in ambient air to ensure clinical safety and to offset the predictable sequelae associated with patient, drug-related, and procedural factors. Understanding the history of this unique element is critical in evaluating the often contentious body of contemporary research that has illuminated its efficacy (as elixir) and its attendant complications (its “two-faced” nature). Of particular interest is its role in free radical formation as etiogenic in developing complications. Oxygen is a mainstay in the perioperative management of patients, but its administration should be guided by thoughtful and rational goal-directed outcomes to maximize efficacy and minimize complications associated with its use.

Key words: Complications, free radicals, hyperbaric oxygenation, oxygen, perioperative, pulmonary oxygen toxicity.

Objectives
At the completion of this course, the reader should be able to:
1. Describe the origins of oxygen as a therapeutic agent.
2. Describe the unique physiochemistry of oxygen.
3. Discuss the application of oxygen as a therapeutic and preventive agent.
4. Understand the rationale for using oxygen in a hyperbaric setting.
5. Explain the complications related to oxygen exposure with special consideration to the role of free radicals.

Oxygen: The Two-faced Elixir of Life
Oxygen is vital to our survival and is used to prevent and treat physiologic trespasses of many kinds. Inexpensive and widely available, oxygen is routinely administered in concentrations in excess of that found in the ambient air, and we rely on it to offset some of the repercussions of our pharmacologic and technical interventions that occur daily in the perioperative setting.

Detailing the history of oxygen is a good place to start the story of this gas, and examining the latest available information related to its use in the setting of patient care will complete the odyssey. This AANA Journal course will describe and acquaint readers with the nuances of this “two-faced” gas and provide a framework for its safe, effective, and rational use.

History and Discovery of Oxygen
Many attribute Priestley, in the late 1700s, to first isolating and describing oxygen, although this does a disservice to the actual course of events. As far back as 1604, Sendivogius wrote that, “Man was created of the Earth, and lives by virtue of the air; for there is in the air a secret food of life, whose invisible congealed spirit is better than the whole Earth.” Sendivogius and others observed that by heating nitre (a salt commonly referred to as saltpeter), a material termed aerial nitre (what we now know as oxygen) was released, which sustained the burning of a candle and imbued blood with its red color.

Two centuries later, Priestly (an Englishman), Scheele (a Swede), and Lavoisier (a Frenchman) independently made more scientifically compelling observations of what had become widely termed fire-air or dephlogisticated air. Lavoisier named this invisible material oxygen. Oxygen derives from the Greek oxus (meaning acid) and gennan (meaning generate); Lavoisier coined this term under the mistaken belief...
that oxygen was a component in all acids. As an aside, Lavoisier was later guillotined because of his unbridled criticism of certain powerful political leaders of the time, a great loss to the scientific community.

Priestly, writing in 1775, foreshadowed what was to become known more than 100 years later, observing,

Who can tell but that, in time, this pure air may become a fashionable article in luxury. From the greater strength and vivacity of the flame of a candle, in this pure air, it may be conjectured, that it might be very useful as a medicine, it might not be so proper for us in the usual healthy state; for, as a candle burns out much faster in dephlogisticated than in common air, so we might, as may be said, live out too fast and the animal powers be too soon exhausted in this kind of pure air.²

This passage is remarkable, given the time it was penned. Not only was the application of oxygen as a drug described, but also complications of its use, which would not be identified until more than 100 years later, were predicted.

Most of us recognize the name Humphrey Davy and credit him for many contributions to chemistry and physics, for which he was later knighted. In 1798, Davy worked at the Pneumatic Institute (Bristol, England) where inhalational gas treatments were first applied to a wide (and inappropriate) range of disorders. Although the Institute ceased operation in 1802, it represented what seems to be the first focused effort to use oxygen therapeutically.

Fast-forwarding to the early 1920s finds John Haldane³ writing his sentinel book, Respiration, in which an understanding of the physiological nuances of oxygen were taking shape. Haldane³ described the use of oxygen as highly therapeutic in selected patients. In the late 1920s, attempting to capitalize on this knowledge, Oval Cunningham designed a pneumatic steel ball, a 64-ft-high hyperbaric chamber constructed in Cleveland by the Timken Corporation that was pressurized to 2 atm. The “Timken Tank,” also known as the “Cunningham Sanatorium,” was a hospital-hotel with an eating establishment, ornamental interiors, a smoking room, and numerous private rooms (Figure 1). Funded by a man who attributed his miraculous recovery from serious illness to oxygen therapy, the pressurized hospital was viewed poorly by the American Medical Association as a bogus enterprise. The futility of the endeavor was underscored by 2 fatal flaws: (1) Virtually any illness was deemed treatable by the pressurized atmosphere. (2) By pressurizing only ambient air, the resultant PO₂ was no more than what could be delivered by a simple mask connected to an oxygen tank. The staggering cost, absence of efficacy, and endless maintenance challenges led to its early dismantling and recycling of its steel infrastructure for use in World War II.

The Physiochemistry and Production of Oxygen

Oxygen is the diatomic species and is colorless and odorless at ambient pressure and temperature, representing 20.95% of the ambient gas that we breathe on earth (Figure 2). Oxygen is the third most abundant element in the universe (hydrogen and helium are more abundant), whereas on Earth, it is the most abundant element in the oceans (86% by mass) and on Earth as a whole (28% by mass). When cooled to a liquid at –183°C, it assumes a clear but pale blue color. Elemental oxygen has an atomic number of 8 and is normally found bonded to other elements such as with hydrogen to produce water (H₂O), with silica to produce sand (SiO₂), with carbon to form carbon dioxide (CO₂), and with phosphorus to form phosphate (PO₄). Ozone (O₃) is the toxic, triatomic species of oxygen that is produced in the upper atmosphere by short wavelength ultraviolet radiation. Although estimates vary, 70% to 80% of our ambient oxygen is produced by green algae and phytoplankton (abundant in oceanic waters) as a byproduct of photo-
synthesis; the rest contributed by leafy terrestrial flora, mainly trees.

For industrial and medicinal purposes, oxygen can be produced by water electrolysis or chemical reaction. An example of the latter was the use of potassium superoxide in manned Soviet space missions. Chemical catalysts are used on commercial aircraft to produce oxygen when overhead passenger emergency masks are deployed. Faulty activation of oxygen catalysts in the cargo bay of ValuJet Flight 592 led to its deadly 1996 crash.

The different boiling points of oxygen (–183°C) and nitrogen (–196°C) and the virtually inexhaustible supply of ambient air make the fractional distillation of cooled (liquid) air the most economically feasible and reliable source of pure oxygen for clinical use. In situations in which the oxygen supply is difficult to import or produce (eg, military situations in which cylinders are difficult or dangerous to transport, impoverished or isolated locales, and some private home use), the use of oxygen concentrators has merit.

Oxygen concentrators introduce compressed air into a canister of zeolite granules in which nitrogen gas is preferentially absorbed, allowing for residual oxygen to pass on to the patient (Figure 3). After a period of about 30 seconds, compressed air is introduced into a second canister so that a continuous flow of oxygen is ensured. A valve senses the differential canister pressures resulting from this process, causing the accumulated nitrogen to be flushed and readying the zeolite for the next repeating cycle of compressed air. Modern concentrators provide about 5 L/min at a fraction of inspired oxygen (FIO₂) of approximately 0.95.

The solubility of oxygen in water varies inversely with temperature. This principle explains the ability of cold oceans (eg, polar oceans) to support a greater abundance of life forms—by a higher dissolved oxygen content. To illustrate this, at about 20°C, 1,000 mL of seawater will hold less than 5 mL of oxygen, whereas at 0°C, the same volume of seawater will dissolve about 8 mL of oxygen. At ambient pressure, oxygen is poorly soluble in plasma; for every millimeter of mercury of PaO₂, there is 0.003 mL of dissolved oxygen per 100 mL of blood. The clinical implication is that there is only 0.3 mL of dissolved oxygen in 100 mL of blood when the PaO₂ is 100 mm Hg, indicating a small margin of safety if any part of the physiologic equation is violated. Dissolved oxygen, expressed as an elevated PaO₂ level, can be markedly increased with the application of hyperbaric chamber technology (see “Hyperbaric Oxygenation”).

The Physiology of Oxygen
There was a time when there was no oxygen on Earth. In his fascinating text, Oxygen: The Molecule That Made the World, Lane describes the remarkable appearance and the ascent of planetary oxygen as the essential ingredient of life. Oxygen likely first appeared on Earth some 2.5 billion years ago as a waste product of early anaerobes; Lane describes its evolution and its incredible effect on the diversity of life forms. Readers are urged to examine Lane's book, a truly unique and scholarly examination of this remarkable element.

Vital to our physiology, oxygen nourishes cells; provides the essential substrate to metabolize carbohydrates, fats, and proteins; facilitates chemical transport of all kinds; breaks down waste products and toxins; regulates acid-base balance; and promotes the immune system. These are just a few of its myriad functions. Figure 4 illustrates the so-called oxygen cascade, revealing the PaO₂ gradient from that in inspired air down to the ultimate site of its use, the mitochondria. During oxidative phosphorylation, it acts as an electron acceptor in the mitochondria to form adenosine triphosphate more efficiently than from
anaerobic metabolism. This advantage, as Lane\(^7\) argues, proved to be the tipping point as aerobes supplanted anaerobes as the dominant planetary life forms.

Although it has been argued by some that breathing pure oxygen causes cerebral hypoxia by generating reactive species, the evidence is overwhelming that such breathing increases the \(\text{PaO}_2\) and jugular venous \(\text{PaO}_2\) and results in an increase in brain \(\text{PaO}_2\).\(^8\) In stroke victims and patients with disrupted autoregulation, supplemental oxygen is beneficial. Despite these consensus-derived views, it should be noted that a 1999 trial of nonhypoxic victims of mild or moderate strokes revealed a higher 1-year mortality in patients who received supplemental oxygen.\(^9\)

Although my own studies and those of others have revealed variable impact on systemic vascular tone and hemodynamics of breathing oxygen at various partial pressures,\(^10,11\) it is clear that even in patients with impaired ventricular function, myocardial ischemia, or frank infarction, the benefits of breathing oxygen are well recognized. Oxygen is thus used widely in such settings, even if at times unnecessarily.

The effects on the fetus of maternal administration of a high \(\text{FiO}_2\) are complex when one reviews the relevant literature. Some have proposed that the breathing of high concentrations of oxygen in parturients during active labor may result in fetal hypoxia due to reduced blood flow to the uterus. A variety of methodological issues in these studies (including, eg, cesarean section, mechanical ventilation, maternal hyperventilation, oscillating \(\text{PaCO}_2\)) make generalizations hazardous. The consensus opinion seems to be that oxygen administration in the peripartum period results in an increase in fetal oxygenation with no negative effects.\(^12,13\)

It has been argued by many, and supported in a recent randomized controlled trial,\(^14\) that oxygen is effective in reducing postoperative wound infections in patients undergoing colorectal resection for cancer or inflammatory bowel disease. In this trial, 500 patients undergoing a standardized general anesthetic were assigned to 30% or 80% oxygen intraoperatively and for the first 2 hours postoperatively.\(^14\) Valid outcome measures revealed a reduction in wound infections by 50% in the group receiving 80% oxygen. These findings differ from the findings of a subsequent trial involving 165 patients undergoing a variety of major intra-abdominal surgical procedures, in which oxygen was not found to reduce the wound infection rate.\(^15\) Although trials have differed in their outcome, it is clear that surgical and traumatic wounds negatively impact the local tissue vascular supply, causing these wounds to be hypoxic relative to normal tissue.\(^16\) Given the evidence that surgical and traumatic wounding can disrupt local vascular supply, promote tissue hypoxia, and impede oxidative bacterial killing, many argue that breathing higher oxygen concentrations during initial healing may decrease wound infection. Increasing the driving gradient of oxygen seems rational in this setting.

Figure 5 illustrates the approximate representative partial pressures (of oxygen and carbon dioxide) and pH when a fit human breathes air or 100% oxygen.\(^17,20\) Increasing the driving pressure of oxygen can have consequential downstream effects on resultant gas pressures in the body. Despite this fact, it is interesting that there is a substantial literature demonstrating that even severe degrees of hypoxemia are often well tolerated without evidence of deleterious tissue oxygenation.\(^22\) However, extrapolating this observation to an anesthetized patient with comorbidities is ill advised.

### Contemporary Use of Oxygen

The most common indication for oxygen therapy is a \(\text{PaO}_2\) of less than 60 mm Hg or a hemoglobin saturation with oxygen of less than 90%.\(^18\) Oxygen is useful in preventing and treating hypoxemia (and tissue hypoxia). Table 1 illustrates the expected \(\text{FiO}_2\) associated with...
some low-flow and high-flow devices that are commonly used in the perioperative setting.

During anesthesia care, especially care given during general anesthesia, it is routine to use a concentration of oxygen higher than found in the ambient air. The primary rationale for this practice is to provide an extra margin of safety for patients and to marginalize the well-appreciated side effects of many of anesthetic interventions. It has recently been argued that 100% oxygen should be the standard of care for general anesthesia lasting minutes to hours.24 London24 argued that oxygen, obviates the use of “toxic” nitrous oxide, does not promote absorption atelectasis, and creates an oxygen reservoir in the manner of “continued preoxygenation.” The rather aggressive arguments posed in the article seem more anecdotally driven than scientifically founded, although there is some momentum within the anesthesiology community for using high perioperative oxygen concentrations.

A 2007 randomized controlled trial argued against the routine use of nitrous oxide, instead advocating high perioperative concentrations of oxygen as a way to avoid complications associated with anesthesia and surgery.25 These complications included severe gastrointestinal distress, wound infection, pneumonia, and atelectasis. It must be stressed that the findings of research directed at determining an independent favorable effect of using higher oxygen concentrations or avoiding nitrous oxide on outcomes such as gastrointestinal distress and infections are inconsistent and sometimes contradictory.14,15,26 Absorption atelectasis can occur with the administration of very high oxygen concentrations and should not be downplayed or discounted as the authors of the aforementioned articles24,25 seem to suggest. Certainly more convincing research of a prospective and highly controlled nature must occur before we reach solid conclusions about the fate of nitrous oxide as part of our anesthetic formulary.

### Hyperbaric Oxygenation

This discussion would be incomplete without some attention to hyperbaric oxygen therapy (HOT), an approach with efficacy in a number of clinical applications (Table 2).27,28 As noted earlier, the breathing of ambient air at sea level results in about 0.3 mL of dissolved oxygen in every 100 mL of blood, whereas breathing 100% oxygen increases that amount to about 1.5 mL. Breathing oxygen at 3 atm of pressure (3 x 760 mm Hg = 2,280 mm Hg) results in a dissolved oxygen concentration of 6 mL/100 mL of blood, an amount that meets our oxygen requirement without any contribution from hemoglobin-bound oxygen.

Goals of HOT include the provision of aerobic substrate to tissues independent of hemoglobin and the reduction in the size of inert gas bubbles in blood (air embolic phenomena, decompression sickness) as a function of Boyle’s law. Furthermore, HOT increases capillary formation (neovascularization), inhibits the formation of anaerobic toxins by its bacteriostatic action on bacterial anaerobes, and may promote wound healing. Complications associated with HOT include barotrauma, pulmonary oxygen toxicity, seizure activity, and environmental claustrophobia, which argue for careful patient selection, monitoring, and titration.28

### Table 1. Oxygen Administration Devices and Expected FiO₂

<table>
<thead>
<tr>
<th>Device</th>
<th>System capacity (mL)</th>
<th>O₂ flow rate (L/min)</th>
<th>Resultant FiO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nasal cannula</td>
<td>&lt; 50</td>
<td>1-3</td>
<td>0.21-0.34</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4-6</td>
<td>0.34-0.46</td>
</tr>
<tr>
<td>O₂ face mask</td>
<td>150-250</td>
<td>5-10</td>
<td>0.40-0.60</td>
</tr>
<tr>
<td>O₂ face mask and reservoir bag</td>
<td>750-1,250</td>
<td>5-10</td>
<td>0.35-0.75</td>
</tr>
<tr>
<td>Partial rebreathing</td>
<td></td>
<td></td>
<td>0.40-1.0</td>
</tr>
<tr>
<td>Nonrebreathing</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2. Clinical Applications of Hyperbaric Oxygen

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>Venous and arterial gas embolism</td>
<td></td>
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<tr>
<td>Carbon monoxide poisoning</td>
<td></td>
</tr>
<tr>
<td>Clostridial infection</td>
<td></td>
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<tr>
<td>Compromised skin grafts and tissue flaps</td>
<td></td>
</tr>
<tr>
<td>Decompression sickness (Caisson disease/disorder)</td>
<td></td>
</tr>
<tr>
<td>Severe blood loss anemia</td>
<td></td>
</tr>
<tr>
<td>Poor wound healing (eg, diabetic ulcers, peripheral vascular disease)</td>
<td></td>
</tr>
<tr>
<td>Clostridial gas gangrene</td>
<td></td>
</tr>
<tr>
<td>Necrotizing fascitis</td>
<td></td>
</tr>
<tr>
<td>Osteoradionecrosis</td>
<td></td>
</tr>
<tr>
<td>Radiation therapy–related injury</td>
<td></td>
</tr>
<tr>
<td>Acute organ ischemia</td>
<td></td>
</tr>
<tr>
<td>Refractory osteomyelitis</td>
<td></td>
</tr>
<tr>
<td>Thermal burns</td>
<td></td>
</tr>
</tbody>
</table>

The table is based on references 27 and 28. Considered investigational or of uncertain efficacy.
The Sinister Side of Oxygen

Oxygen excels at removing electrons (i.e., it is an oxidizer) and does so with inorganic and organic materials. Walk into any health food or “organic” store, and you will find an array of antioxidants with (often exaggerated) biological potential available for purchase. Free radicals form when oxygen is metabolized by the body in the myriad reactions in which it is involved. Free radicals disrupt molecular structures and result in cellular damage. Because free radicals are continuously produced, oxygen would prove fatally toxic to our tissues if not for naturally occurring antioxidants such as superoxide dismutase, catalase, bilirubin, and glutathione. Other well-known antioxidants include vitamins A, C, and E and a host of chemicals found in plants known as polyphenols. Antioxidants react with oxygen in the body to decrease the rate of free radical production.

Free radicals are known to damage proteins (including DNA) and lipids, accelerate aging, and have a role in apoptosis (programmed cell death).29 Free radicals are unstable oxygen molecules that have a missing or unpaired electron and become damaging because they aggressively attempt to attach to materials in the body in an attempt to find another electron to become stable (Figure 6).

Although beyond the scope of this article, there is a significant literature that has accumulated arguing that newborn infants are at accelerated risk from oxidative stress posed by exposure to high concentrations of oxygen.30-32 Major concerns raised include deleterious effects on lung architecture, retinopathy, immaturity of the antioxidant system, clinical conditions that exacerbate free radical activity, and brain and renal dysfunction from high oxygen concentrations, just to name a few. A remarkable article has emerged from an international consensus committee arguing that air is as effective as 100% oxygen and may be safer for the resuscitation of most infants at birth.33

Pulmonary Oxygen Toxicity

Issues related to pulmonary toxicity in adults secondary to oxygen exposure have received a great deal of attention. It is an interesting paradox of nature that the organ exposed to the highest concentration of oxygen (the lung) is also the organ most susceptible to its toxic effects. Broadly, the concerns fall into 3 domains: (1) atelectasis due to fast absorption of alveolar oxygen beyond a non-patent airway (i.e., removal of the “nitrogen splint”), (2) proinflammatory effects of the gas on pulmonary tissues, and (3) depression of respiration in patients accustomed to a high $P_{CO_2}$ (such as patients with chronic emphysema). Nurse anesthetists are keenly aware of these issues and generally deal with them by using carefully selected gas mixtures and expansive maneuvers to offset atelectasis, using lower oxygen concentrations and reducing exposure duration to decrease the risk of inflammatory processes, and carefully monitoring a carbon dioxide–retentive patient who is administered oxygen.

Astronauts have been known to breathe pure oxygen for weeks at a time without problems, although their environment is pressurized to only one-third that of found on the Earth's surface, equating to breathing approximately 33% oxygen. In general, most authorities suggest that exposure to an $FIO_2$ of more than 0.60 for more than 48 hours is considered a “toxic” exposure. A risk in applying this rule to all patients is that it does not consider the variability (production, exhaustion, incorrect expression) of endogenous antioxidants in a particular patient. Table 3 lists the major pulmonary and central nervous system signs of oxygen-induced toxic effects.

Table 3. Manifestations of Oxygen Toxicity

<table>
<thead>
<tr>
<th>Pulmonary-related</th>
<th>Central nervous system–related</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unproductive cough</td>
<td>Nausea and vomiting</td>
</tr>
<tr>
<td>Substernal chest discomfort</td>
<td>Dizziness, tinnitus</td>
</tr>
<tr>
<td>Bronchitis</td>
<td>Pallor, sweating</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>Muscular twitching</td>
</tr>
<tr>
<td>Pulmonary fibrosis (chronic)</td>
<td>Anxiety</td>
</tr>
<tr>
<td></td>
<td>Visual changes</td>
</tr>
<tr>
<td></td>
<td>Decreased level of consciousness</td>
</tr>
<tr>
<td></td>
<td>Hallucinations, seizure activity</td>
</tr>
</tbody>
</table>

100% oxygen and may be safer for the resuscitation of most infants at birth.33

Figure 6. Free Radical Information

Reactions involving oxygen in the body often result in the formation of intermediates (free radicals) that are highly reactive, behaving like electrophiles that seek out other electrons. These molecules tend to be damaging; thus, endogenous, protective antioxidants, such as superoxide dismutase and catalase, scavenge these radicals.

Some interesting biological potential available for purchase.
increase in brainstem partial pressure secondary to a Haldane-like effect.\textsuperscript{19} It is suggested that this hyperoxic effect can be profound enough to result in hypocapnia-related vasoconstriction sufficient to cause organ damage. In their analysis, the authors concluded that the appropriate use of even high concentrations of oxygen in normal clinical practice will not adversely affect tissue oxygenation.

**Conclusions**

Describing the first ascent of Mt Everest without bottled oxygen, the German mountaineer, Reinhold Messner wrote, “I am nothing more than a single narrow, gasping lung, floating over the mists and summits.”\textsuperscript{34} His climb was all the more remarkable in the light of later measurements made at the summit (29,029 feet) of elite climbers revealing an alveolar PCO\textsubscript{2} of 7.5 mm Hg and an alveolar PO\textsubscript{2} of 35 mm Hg, tensions that would be fatal to virtually all humans.\textsuperscript{34,35} At rest, a fit human consumes about 110 to 160 mL/min/m\textsuperscript{2}, equating to about 200 to 300 mL/min in an average-sized adult.

General anesthesia and hypothermia decrease this value, whereas exercise, hyperthermia, and shivering increase this value substantially.\textsuperscript{20,36} It is not my intent to dissuade clinicians from using high concentrations of oxygen in the resuscitation and everyday care of their patients. Oxygen is vital to everyday life and, in the hospital setting, has a proven record in the care of newborns, children, and adults in treating and preventing the complications of hypoxia. Rather the intent is to reveal that a critical inquiry regarding the effects of oxygen as a drug is ongoing in a wide range of settings. Any substance, whether it is a drug (such as oxygen) or an everyday substance (such as water), can become toxic when administered in the wrong setting, in the wrong amount, or with too brief an interval between exposures.

There are many avenues of clinical oxygen-related research that remain largely uncharted. In my opinion, a few of the more important ones include the following:

1. What is the role of exogenous antioxidant therapy (eg, vitamin E, vitamin C, ceruloplasmin) in preventing and minimizing oxygen toxicity during brief (in the operating room) and long-term (in the intensive care unit) exposure?
2. How should we best measure organ concentrations (delivery and utilization) of administered oxygen to allow for its optimal titration?
3. What are optimal PaO\textsubscript{2} and oxygen saturation (as measured by pulse oximetry) in infants, children, and adults during general anesthesia? What outcome measures are most sensitive?
4. Given the current inconsistencies in research findings, what is the ideal perioperative oxygen tension to promote wound healing and reduce the rate of surgical wound infection?

5. As a cornerstone of medical and nursing practice, how might we best quantify the risks associated with hypoxia?

The administration of oxygen, like that of any drug, should be goal directed, that is, founded on outcomes that emphasize rational and evidence-based objectives, rather than simply using predetermined, “cookbook” concentrations. Although vital to life as we know it and representing a mainstay in the care of patients, oxygen can be two-faced because it has a substantial side-effect profile. I hope this course will prompt readers to be more thoughtful in its clinical application.

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