





RESPIRATORY MEDICINE

Practice Step by Step: Providing Supplemental Oxygen to Patients

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Supplemental oxygen is an important treatment for animals with signs of respiratory distress. Hypoxia refers to low tissue oxygen concentrations and can occur for several reasons (**TABLE 1**). Depending on the cause of hypoxia, oxygen supplementation may be very helpful (e.g., for heart failure or pulmonary fibrosis). Other causes of hypoxia are not especially oxygen-responsive, however, and require alternative treatment strategies to provide a benefit (e.g., red cell transfusion to an anemic patient).

In the short term, oxygen supplementation is always appropriate until further data have been acquired to understand the specific case more deeply. In the long term, oxygen toxicity could occur if an animal is exposed to high concentrations of oxygen for several consecutive days.¹ This article concentrates on a practical approach to providing supplemental oxygen to small animal patients.

SUPPLEMENTAL OXYGEN TECHNIQUE

For larger dogs, nasal lines can be easily placed using a catheter inserted via the ventral meatus to the level of the medial canthus.

**WOULD THIS PATIENT
BENEFIT FROM
SUPPLEMENTAL OXYGEN?**

In the triage setting, several clues may prompt the clinician to provide oxygen, including tachypnea, shortness of breath and orthopnea (**FIGURE 1**), cyanosis, and abnormal respiratory noises. With further examination, some of the causes of respiratory distress may ultimately prove to be “nonrespiratory lookalikes.”² These are patients without cardiopulmonary disease that breathe rapidly or with effort, such as animals with large-volume abdominal effusion, pain, or



FIGURE 1. Bulldog puppy that had aspiration pneumonia and demonstrated orthopnea receiving oxygen via facemask.

TABLE 1 Causes of Hypoxia

HYPOXIA CATEGORY	MECHANISM	EXAMPLES
Hypoxic hypoxia	Insufficient oxygen available to lungs	Low FiO ₂ (e.g., anesthesia machine failure) Hypoventilation (e.g., coral snake envenomation, drug overdose) Ventilation perfusion mismatch (e.g., pulmonary disease) Anatomic shunting (e.g., patent ductus arteriosus) Diffusion impairment (e.g., pulmonary fibrosis)
Anemic hypoxia	Reduced hemoglobin content	Immune-mediated hemolytic anemia Hemorrhage
Circulatory hypoxia	Cardiovascular impairment	Hypovolemic shock Anaphylaxis Septic shock Cardiac tamponade Massive pulmonary thromboembolism Systolic failure (e.g., dilated cardiomyopathy)
Histotoxic hypoxia	Cells incapable of using oxygen	Cyanide toxicity Mitochondrial dysfunction

metabolic acidosis or those that have received certain medications (e.g., opioids or corticosteroids).

Quantification of pulmonary function can provide more objective data to support the decision to supplement oxygen. Potential tools include measurement of pulse oximetry or arterial blood gas analysis. Oxygen saturation below 93% and an arterial partial pressure of oxygen below 70 mmHg should prompt oxygen supplementation.¹ These monitoring modalities may be inappropriate in animals with profound respiratory distress and rarely change the decision to provide oxygen in more severely affected patients. As mentioned above, it is often reasonable to provide oxygen to critical patients, even if other interventions are ultimately needed to stabilize them. Consequently, oxygen supplementation is often provided while other procedures are performed (e.g., obtaining vascular access, performing pericardiocentesis). Specific noncardiopulmonary disease processes (such as traumatic brain injury) may actually benefit greatly from oxygen supplementation.

HOW SHOULD OXYGEN BE SUPPLEMENTED?

Several options exist for providing supplemental oxygen. Whenever possible, the least stressful method should be considered, but this should be balanced with the ability to provide as much oxygen as needed with each method (**TABLE 2**). For

short-term oxygen supplementation, it is generally unnecessary to humidify the oxygen; however, long-term exposure of the respiratory epithelium to dry air may promote the development of respiratory infection. Humidification is easily achieved by bubbling oxygen through sterile saline or water.

Flow-by Oxygen

An easy method to provide supplemental oxygen is to hold oxygen tubing close to an animal's face (**FIGURE 2**). This modestly enriches the fraction of inspired oxygen (FiO₂), but potentially only a few

TABLE 2 Average Achieved FiO₂ Associated With Oxygen Supplementation Technique

SUPPLEMENTAL OXYGEN TECHNIQUE	AVERAGE FIO ₂ ACHIEVED (%)
Flow-by oxygen	25-40
Facemask	35-60
Oxygen hood	30-50
Oxygen cage	21-60
Unilateral nasal line	30-50
Bilateral nasal lines	30-70
Intubation (anesthesia machine)	100
Intubation (mechanical ventilator)	21-100

Adapted from Sumner and Rozanski.³

points above room air (25%) up to approximately 40% if high oxygen flow rates are used (2 to 3 L/min). Flow-by oxygen is not well tolerated by all patients, however, and could further contribute to anxiety. This approach is impractical for any protracted period and is best suited before induction of anesthesia or while procedures are being performed.

Oxygen Facemask

Oxygen administered via facemask is another simple technique but again may not be tolerated in anxious patients. The FiO_2 achieved will vary depending on how tightly fitting the facemask is and the flow rate administered. Higher oxygen flow rates (e.g., 2 to 5 L/min) are recommended to achieve an FiO_2 of 35% to 60%.³ Rebreathing of carbon dioxide can occur with more tightly fitting masks, and periodically switching out the mask is recommended.¹ Facemasks are also convenient for oxygen supplementation to dogs undergoing procedures (**FIGURE 3**).

Oxygen Hoods

Oxygen hoods can be created with the use of hard e-collars, cellophane wrap, and tape. The hood is covered in the cellophane wrap and secured in place with tape, with a small portion left open for ventilation. Pliable oxygen tubing is fed into the hood from the collar and secured in place. The hood must be saturated with higher flow rates of oxygen (e.g., 1 to 2 L/min) before the rate is reduced to 0.5 to 1 L/min. This should achieve an FiO_2 of 30% to 40% if a tight seal is created. In general, patient compliance is good. The biggest challenges with this technique involve excessive humidification and poor ventilation if too small of a gap is left in the cellophane wrap. This technique is used less commonly in hospitals that prefer alternative, more convenient techniques (e.g., oxygen cages).

Oxygen Cage

Oxygen cages are a very convenient and efficient method of supplementing oxygen to small animal patients. Several variants are commercially available, including flexible options made of polyvinyl chloride and acrylic glass boxes (**FIGURE 4**). Similar to the challenges of oxygen hoods, control of temperature, humidification, and ventilation is of paramount importance. More sophisticated and expensive models enable climate control and have soda lime systems in place to prevent rebreathing of carbon dioxide.

One advantage of oxygen cages is the physical separation of the clinical team from the patient. This can be helpful in animals for which handling could worsen anxiety and respiratory distress. A disadvantage of this approach, however, is the potential for missing alterations in audible respiratory noise in select patients (e.g., upper respiratory obstruction). Animals with respiratory embarrassment are at risk



FIGURE 2. Borzoi undergoing flow-by oxygen administration.



FIGURE 3. Mixed-breed dog sedated for bandage change receiving supplemental oxygen via facemask.



FIGURE 4. Bulldog in rigid acrylic glass oxygen cage.

Oxygen cages are a very convenient and efficient method of supplementing oxygen to small animal patients.

for potentially fatal decompensation with stressful handling. Observation from a distance can also be helpful to characterize abnormal breathing patterns that may be missed with close hands-on examination. Characteristic breathing patterns may help to localize the anatomic location of respiratory disease in the specific patient (e.g., short, shallow breaths are common with pleural space disease, and increased expiratory effort is common with lower airway disease).

More sophisticated oxygen cages frequently enable the clinician to adjust the approximate FiO_2 administered to the patient, ranging from room air (21%) to approximately 60%. The actual concentration achieved will depend on the integrity of the cage itself, with air leakage reducing the concentration. This is also true when the cage door is opened, resulting in a rapid drop of the oxygen concentration. This also limits the usefulness of this approach when frequent patient reassessment would be ideal.

Another convenience of the oxygen cage is the ability to perform nebulization without close handling. Oxygen cages are limited by their relative expense



FIGURE 5. Incubator used for neonatal and pediatric patients.

(including setup costs and requirement for oxygen cylinders); patient size also limits their utility (e.g., larger dogs are not ideal candidates for oxygen cages). For neonates and pediatric patients, incubators can be used in a similar manner, either with already piped-in oxygen or through placement of oxygen tubing into the incubator itself (**FIGURE 5**).

Nasal Oxygen

For larger dogs, oxygen cages may be too confining to be comfortable. The placement of nasal lines can be convenient in such dogs. Nasal prongs can be used but reasonably are relevant only in nonbrachycephalic breeds. The FiO_2 achieved via nasal prongs is not well established but may be similar to that seen with longer nasal catheters, provided the patient does not dislodge the prongs. In most circumstances, nasal lines can be placed easily by using 5- to 8-French red rubber catheters. Local analgesia should be instilled in the nose (e.g., proparacaine eye drops), before a lubricated red rubber catheter is inserted via the ventral meatus to the level of the medial canthus. The catheter can then be sutured to the nostrils and face to secure the tube (**FIGURES 6 AND 7**). Alternatively, the catheter can be measured to the level of the mandible for the placement of a nasopharyngeal catheter (**FIGURE 8**).

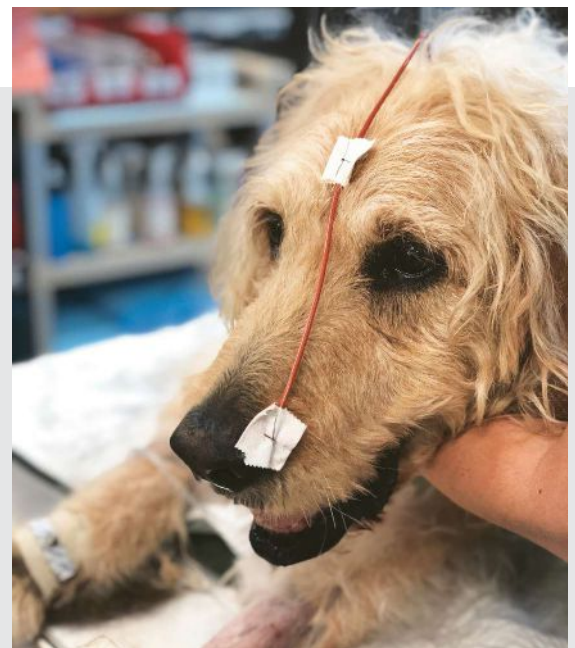


FIGURE 6. Labradoodle with spontaneous pneumothorax demonstrating correct securement of a red rubber nasopharyngeal line.

A single nasal line can provide sufficient oxygen supplementation, but dual lines may improve patient comfort by enabling lower oxygen flow rates. The flow rates used typically are in the range of 50-150 mL/kg/min. Patient discomfort may be noticed with rates exceeding 100 mL/kg per minute.¹ Nasal lines can be a very effective method of supplementing oxygen, with 1 line achieving an FiO_2 of 30% to 50% and 2 lines potentially achieving 30% to 70% depending on the rates used.³

Nasotracheal Oxygen

Nasal lines may be of limited value in brachycephalic breeds. An alternative technique for recovery from anesthesia in these breeds is the placement of nasotracheal oxygen.⁴ In these cases, a red rubber catheter can be placed extending from the external nares and directed into the trachea, before removal of their endotracheal tube. A red rubber catheter is placed from the external nares caudally, with sufficient length to enter the proximal trachea. With the dog

in sternal recumbency, the catheter is advanced until it is visible just beyond the soft palate. The catheter is then exteriorized through the mouth using long forceps before being redirected into the trachea. It is secured in a similar manner to the nasal lines as described above. When the dog is recovered from anesthesia and no longer requires further oxygen supplementation, the tube can be easily removed.

Intubation Without Positive-Pressure Ventilation

Intubation with 100% oxygen may be necessary in severe cases of upper airway obstruction (e.g., laryngeal paralysis crisis). Not every case with an upper respiratory crisis necessarily requires intubation. In cases refractory to other measures of oxygen supplementation (e.g., sedation and anxiolysis, noninvasive oxygen supplementation), timely endotracheal intubation can be a life-saving measure. Rapid induction of anesthesia is desirable to ensure efficient intubation. Propofol is an excellent induction agent but is associated with profound cardiorespiratory depression. It may therefore be sensible to premedicate the animal if time allows or to perform coinduction with another drug class (e.g., a benzodiazepine) to reduce the dose of propofol required. In cases of profound respiratory distress that are secondary to underlying cardiac disease, propofol may result in severe cardiovascular depression with risk for cardiopulmonary arrest. In such cases, depending on the patient's level of excitement and anxiety, sufficient sedation may be achieved with alternative drugs to propofol (e.g., midazolam 0.3 to 0.5 mg/kg and butorphanol 0.2 to 0.3 mg/kg) or



FIGURE 7. Cadaver image indicating the approximate termination of a red rubber catheter used as a nasal line measured to the medial canthus.

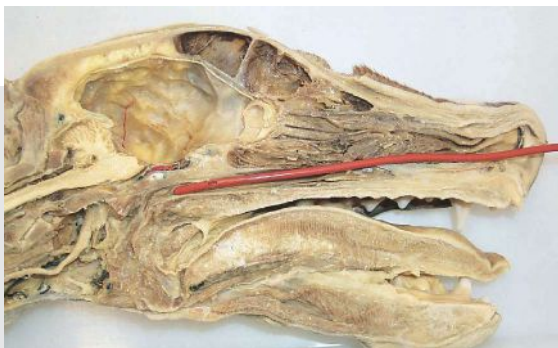


FIGURE 8. Cadaver image indicating the approximate termination of a red rubber catheter used as a nasopharyngeal catheter measured to the mandibular ramus.



FIGURE 9. Geriatric Labrador retriever mix intubated after an upper respiratory crisis associated with laryngeal paralysis.



FIGURE 10. Puppy with pulmonary contusions after being hit by a car receiving mechanical ventilation.

may dramatically reduce the dose of propofol required needed to achieve intubation. It is also sensible to examine laryngeal function in dogs with upper airway obstruction under a light plane of anesthesia.

In cases of upper respiratory obstruction associated with laryngeal paralysis, only a short period of intubation is typically necessary because the patient should retain the capacity to ventilate spontaneously (**FIGURE 9**). During this period of intubation, additional diagnostic and therapeutic measures then can be performed (e.g., chest radiography, external cooling, administration of corticosteroids). If the abnormality present is nonreversible or severe, intubation may be necessary for a prolonged period until a curative solution (e.g., surgery) has been performed.

In some situations, the upper airway may be bypassed via placement of a temporary tracheostomy tube. This

allows the pet to be recovered from anesthesia and potentially obviates the need for supplemental oxygen if the remaining respiratory tract is functioning normally.

Intubation With Positive-Pressure Ventilation

Mechanical ventilation should be considered (**FIGURE 10**) in the following circumstances:

- Hypoxemia refractory to the standard measures, typically indicating lung failure with poor oxygen saturation (e.g., partial pressure of oxygen in arterial blood <50 mmHg)
- Progressive severe hypercapnia associated with ventilatory failure
- Impending respiratory fatigue associated with severe underlying cardiopulmonary disease
- Cardiovascular instability, such as that noted in animals recovering from successful cardiopulmonary resuscitation

Long-term oxygen supplementation is associated with the risk for oxygen toxicity. One advantage of using mechanical ventilators is the ability to control the FiO_2 accurately to as low as 21%. Mechanical ventilators also offer some other options for improving pulmonary function, including the provision of positive end-expiratory pressure to facilitate airway opening and improved gas exchange.

SUMMARY

Supplementing oxygen reliably and safely is a vital and potentially life-saving intervention in small animal medicine. The specific techniques used depend on the situation at hand, as well as the equipment available. An awareness of several techniques is clinically helpful. **TVP**

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Alex Lynch is an Assistant Professor in Emergency and Critical Care at North Carolina State University, Raleigh, NC. He graduated with honors from the University of Bristol in 2009. After a period in first opinion and referral practice in the United Kingdom, he moved to Tufts University in North Grafton, Massachusetts, to undertake further clinical training in emergency and critical care. He became a diplomate of the American College of Veterinary Emergency and Critical Care in 2015. He worked as a faculty member in ECC before moving to NC State in 2017. His particular interests are coagulation, transfusion medicine, respiratory disease, and trauma.



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