## Monitoring of Inspired Oxygen Concentration

### *Principles of Operation*

Oxygen is a highly reactive chemical species, providing many chemical and physical opportunities to detect its presence. Three main types of oxygen analyzer are seen in clinical practice: paramagnetic oxygen analyzers, galvanic cell analyzers, and polarographic oxygen analyzers.

Paramagnetic gases are attracted to magnetic energy because of unpaired electrons in their outer shell orbits. Oxygen is a highly paramagnetic gas. Differential paramagnetic oximetry has been incorporated into a variety of operating room monitors. These instruments detect the change in sample line pressure resulting from the attraction of oxygen by switched magnetic fields. Signal changes during electromagnetic switching correlate with the oxygen concentration in the sample line.[2]

Galvanic cell analyzers meet the performance criteria necessary for operative monitoring. These analyzers measure the current produced when oxygen diffuses across a membrane and is reduced to molecular oxygen at the anode of an electrical circuit.[3] The electron flow (current) is proportional to the partial pressure of oxygen in the fuel cell. Galvanic cell analyzers require regular replacement of the galvanic sensor capsule. In the sensor, the electric potential for the reduction of oxygen results from a chemical reaction. Over time, the reactants require replenishment.[4]

Polarographic oxygen analyzers are commonly used in anesthesia monitoring. In this electrochemical system, oxygen diffuses through an oxygen-permeable polymeric membrane and participates in the following reaction: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$. The current change is proportional to the number of oxygen molecules surrounding the electrode. Polarographic oxygen sensors are versatile and are important components of gas machine oxygen analyzers, blood gas analyzers, and transcutaneous oxygen analyzers.[5]

### *Proper Use and Interpretation*

The concentration of oxygen in the anesthetic circuit must be measured. Anesthesia machine manufacturers place oxygen sensors on the inspired limb of the anesthesia circuit to detect and alarm in the event that hypoxic gas mixtures are delivered to the patient. Carbon dioxide may reduce the usable lifetime of a galvanic oxygen sensor, so it is preferable to place the oxygen sensor on the inspired limb. Oxygen monitors require a fast response time (2 to 10 seconds), accuracy (±2% of the actual level), and stability when exposed to humidity and inhalation agents.

The removable external oxygen sensors seen commonly on anesthesia machines, such as the Dräger Narkomed and Dräger Fabius (Dräger, Inc., Telford, PA) are of the galvanic type. These devices should be calibrated against room air (21% $FiO_2$) daily, and also after 8 hours of use. These devices may also infrequently require calibration against 100% $FiO_2$. As part of the preoperative checkout of the anesthesia machine, the clinician must confirm that the alarm limits of the inspired oxygen analyzer are set appropriately to alert to the presence of hypoxic mixtures. Inspired oxygen alarms cannot be relied upon to detect disconnection of the circuit.

### *Indications*

According to the ASA Standards for Basic Anesthesia Monitoring,[1] Standard 2.2.1 states, “During every administration of general anesthesia using an anesthesia machine, the

concentration of oxygen in the patient breathing system shall be measured by an oxygen analyzer with a low oxygen concentration limit alarm in use."

The careful monitoring of the inspired oxygen concentration is of particular significance during low-flow anesthesia, in which the anesthesiologist attempts to minimize the fresh gas flow to the amount of oxygen necessary to replace the patient's metabolic utilization. The gas mixture within the breathing circuit may become hypoxic if insufficient fresh gas flow is supplied, even if the fresh gas flow itself comprises pure oxygen.

## *Contraindications*

The requirement to monitor inspired oxygen concentration may be waived by the responsible anesthesiologist under extenuating circumstances. There are no clinical contraindications to monitoring inspired oxygen concentration.

## *Common Problems and Limitations*

Adequate inspiratory oxygen concentration does not guarantee adequate arterial oxygen concentration.[6] Consequently, ASA[1] Standard 2.2.2 mandates additional monitoring for blood oxygenation, including the provision of adequate lighting and exposure to assess the patient's color by direct observation. The practice of pediatric anesthesia merits additional vigilance to monitoring inspired oxygen concentration. Indications for altering inspired oxygen concentrations to facilitate anesthetics in children are common; for example, using a nitrous oxide-oxygen blend to facilitate inhalation inductions of anesthesia. Increased awareness of fire hazards in the operating room environment further reinforces the need for careful monitoring of $FiO_2$ in pediatric anesthesia. Tonsillectomy and adenoidectomy, among the most common of surgical procedures in the pediatric anesthesia population, carry an increased risk of airway fire. In addition to using of cuffed endotracheal tubes, careful monitoring and maintenance of a decreased inspired oxygen concentration whenever electrosurgical equipment is in use may decrease airway fire risk in these patients.[7],[8]