PEER REVIEWED

ANESTHETIC MONITORING

Your Questions Answered

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This article is the first one in a series that will discuss the goals of anesthetic monitoring as well as associated procedures and equipment. In this first article, the authors provide an overview of modern anesthetic monitoring and answer questions about why and how to provide cutting-edge anesthesia for your patients.

LINKS TO ANESTHESIA GUIDELINES

To read the American College of Veterinary Anesthesiologists and American Animal Hospital Association anesthesia guidelines, go to **acva.org/docs/Small_Animal_Monitoring_2009.doc** and **aahanet.org/PublicDocuments/Anesthesia_Guidelines_for_Dogs_and_Cats.pdf**, respectively.

Noninvasive monitoring techniques in the anesthetized dog and cat have been described since the 1990s.[1] More recently, major advances in technology have improved the efficiency and affordability of equipment. These advancements, in turn, have improved veterinarians' and anesthetists 'abilities to detect abnormalities in the anesthetized patient.

Advances in anesthetic monitoring have led to a "gold standard" approach that emphasizes:

- Appropriate clinical evaluation
- Training of personnel
- Preanesthetic evaluation
- Advanced monitoring techniques.

All of the above help minimize adverse side effects of anesthesia and surgery.

Why Monitor Anesthetized Patients?

Anesthetic agents coupled with invasive procedures can cause drastic hemodynamic changes in the patient's cardiorespiratory system (**Table 1**, page 24). In addition, each patient exhibits different physiologic and pharmacologic responses to anesthetic agents. Because these responses are not always predictable, it is vital to monitor each patient closely.

Prompt detection of respiratory or hemodynamic instability allows the anesthetist time to properly diagnose what is happening and intervene. This, in turn, prevents morbidity, such as cardiorespiratory collapse, which, if otherwise untreated, can lead to mortality. Furthermore, despite successful sophisticated surgery or diagnostic procedures, lack of a rapid and smooth recovery may defeat the purpose of performing them.

Saved by Monitoring (Case 1, page 25, **and Case 2,** page 27) describes how anesthetic monitoring made a difference in the surgical experience of two patients.

Table 1. Adverse Effects of Anesthetic & Analgesic Drugs

Anesthetic/ Analgesic Drug	Common Adverse Effects
Alpha-2 Adrenergic Agonists • Dexmedetomidine • Medetomidine • Xylazine	• Bradycardia • Cardiac output reduction • Hypertension/hypotension • Vasoconstriction
Anti-inflammatory Drugs • NSAIDs • Steroids	• Bleeding disorder • Diarrhea and vomiting • Gastrointestinal ulceration • Lethargy • Renal and liver failure
Benzodiazepines • Diazepam • Midazolam	• Minimal cardiorespiratory effects • Paradoxical excitement in some patients
Inhalant Anesthetic Agents • Halothane • Isoflurane • Sevoflurane	• Decreased cardiac output* • Decreased myocardial contractility* • Hypothermia/hyperthermia • May result in hypotension • Vasodilation*
Intravenous Induction Agents • Diazepam/ ketamine • Propofol • Tiletamine/ zolazepam	• Cyanosis • Occasional muscle fasciculations and seizures • Profuse salivation/airway secretions • Respiratory depression (hypoventilation, apnea) • Transient tachycardia • Vasodilation
Local Anesthetics • Bupivacaine • Lidocaine • Mepivacaine	• Bradycardia • Hyperthermia in some animals; hypothermia more likely • Cardiac arrest • Hypotension • Seizure
Opioids • Buprenorphine • Butorphanol • Fentanyl • Hydromorphone • Morphine	• Bradycardia • Mydriasis/miosis • Respiratory depression (hypoventilation, apnea) • Vomiting
Other Sedatives • Acepromazine • Other phenothiazine-derivatives	• Heat loss due to peripheral vasodilation† • Vasodilation and hypotension†

NSAID = nonsteroidal anti-inflammatory drug
** Dose dependent*
† Specific for acepromazine

What Information Is Obtained During Anesthetic Monitoring?

By monitoring the anesthetized patient, the anesthetist obtains information in the following areas:

1. **Physiologic condition of the patient** (eg, cardiovascular, respiratory, and metabolic systems)
2. **Patient's response to anesthesia**, including anesthetic depth and level of analgesia.

In addition, assessing the status of anesthetic equipment ensures its proper function, helping the anesthetist prevent iatrogenic crises that can jeopardize the patient's health.

The information obtained via patient monitoring is used to achieve three goals:

1. **Ensure adequate tissue perfusion** with well-oxygenated blood
2. **Prevent pain** before, during, and after a surgical procedure
3. **Provide a smooth and rapid recovery** from anesthesia/surgery.

ANESTHESIA SPECIALTY FOR VETERINARY TECHNICIANS

The **Academy of Veterinary Technician Anesthetists (AVTA)** is a recognized specialty of the National Association of Veterinary Technicians in America (NAVTA). The AVTA was officially recognized by NAVTA in January 1999, and became its second recognized specialty; the first being the Academy of Veterinary Emergency and Critical Care Technicians (1996).

The AVTA focuses on:

- **Certifying technicians** interested in specializing in veterinary anesthesia
- **Enhancing members' knowledge** in the care and management of anesthesia cases
- **Providing extensive information** on sources of continuing education
- **Promoting patient safety**, consumer protection, professionalism, and excellence in anesthesia care.

Applications for the AVTA certification examination are accepted each year. This year's examination will take place September 8–12, 2012, at the 18th International Veterinary Emergency & Critical Care Symposium, San Antonio, Texas. Applications for this examination are due in January 2012.

To find out more about the AVTA, including how to become certified, go to **avta-vts.org**. A list of AVTA members, noted by the credentials **VTS (Anesthesia)**, can be found on the homepage of the website.

Saved by Monitoring
Case 1: Canine Abdominal Surgery

EVALUATION

History: A 7-year-old, 25-kg mixed-breed dog presented with a 3-month history of chronic vomiting.

Physical Examination: The dog was bright and alert with strong femoral pulses; heart and lung sounds were within normal limits.

Blood Analysis: Packed cell volume, 44%; total protein, 5 g/dL; glucose, 125 mg/dL; some mild electrolyte imbalances were noted.

Imaging: Radiographic assessment, including a barium series, revealed dilation of the proximal small intestines.

Diagnosis & Treatment: Intestinal foreign body was suspected and exploratory abdominal surgery was scheduled. Pre-operative fluids were administered intravenously to correct the electrolyte imbalance.

ANESTHETIC MONITORING

Anesthetic Protocol:

- Premedication with acepromazine (0.02 mg/kg IM) and hydromorphone (0.01 mg/kg IM)
- Induction with propofol (3 mg/kg IV)
- Maintainance with isoflurane to effect

Blood Pressure Monitoring during Anesthesia: Oscillometric blood pressure monitoring was performed; blood pressure values were validated with simultaneous direct blood pressure measurement via pressure transducer and an arterial catheter placed in the dorsal pedal artery.

Monitor Warning: While the dog was undergoing pre-operative surgical prepping, its blood pressure began to decrease (20 minutes after induction).

Vital Signs of Anesthetized Patient (20 Minutes After Induction)

Systolic blood pressure (mm Hg)	81
Diastolic blood pressure (mm Hg)	32
Mean blood pressure (mm Hg)	**49**
Heart rate (beats/min)	110
Respiratory rate (breaths/min)	9
Oxygen level in blood (SpO_2) (%)	100
End tidal CO_2 (mm Hg)	48
Temperature (°F)	100.5

Diagnosis: **Acepromazine/isoflurane-induced hypotension**

Correction: Balanced electrolyte fluids (Plasma-Lyte A, baxter.com) were increased to 20 mL/kg/H and isoflurane reduced from 1.75% to 1.25%.

Pertinent Vital Signs After Fluid Administration & Isoflurane Reduction

Systolic blood pressure (mm Hg)	108
Diastolic blood pressure (mm Hg)	50
Mean blood pressure (mm Hg)	**70**

The new vital signs indicated **improved blood pressure**. Intra-operatively, the dog received two additional doses of hydromorphone (for its isoflurane-sparing effect and to provide additional analgesia) to maintain isoflurane between 1.25% and 1.75%.

Outcome: Foreign body material consistent with pieces of a stuffed animal was removed from the jejunum; a 4-inch section of the jejunum was resected and an anastomosis was performed. The dog recovered smoothly and uneventfully.

Take-Home Message: Without blood pressure monitoring to guide isoflurane adjustment, analgesia management, and fluid therapy, the dog's blood pressure would have remained low for an extensive period of time, resulting in poor tissue perfusion and potential morbidity and mortality.

DON'T MISS TOP 10 TIPS ABOUT ANESTHESIA

In the November/December 2011 issue of *Today's Veterinary Practice*, our Top Ten column featured the article **Ten Tips to Improve Anesthesia in Your Practice** (page 47). Dr. Lysa Posner provided information on medication combinations, local nerve blocks, decreasing induction drugs, and more. To read this article, go to our website, **todaysveterinarypractice.com**, and select Back Issues from the top navigation bar.

Table 2. Cardiorespiratory & Physiologic Parameters in the Anesthetized Dog & Cat

	Variable	Dog	Cat
Circulation	Heart rate (beats per min)	60–120	120–160
	Systolic blood pressure (mm Hg)	90–140	90–140
	Diastolic blood pressure (mm Hg)	60–90	60–90
	Mean arterial blood pressure	70–90	70–90
Ventilation	Respiratory rate (breaths per min)	8–16	12–24
	Tidal volume (mL/kg)	10–15	10–15
	Arterial blood pH	7.35–7.45	7.35–7.45
	$PaCO_2$ (mm Hg)	35–45	35–45
	Bicarbonate (mmol/L)	22–26	22–26
	End-tidal CO_2	35–45	35–45
Oxygenation	SpO_2 (%)	≥ 95	≥ 95
	PaO_2 (mm Hg)	≥ 100	≥ 100
Other	Body temperature (°F)	98–101	98–101
	Hematocrit (%)	34–59	28–47
	Total protein (mg/dL)	5–8.3	5.9–8.4
	Blood glucose (mg/dL)	90–150	90–150
	Blood lactate (mmol/L)	< 2	< 2
	Urine output (mL/kg/H)	1–2	1–2

CO_2 = carbon dioxide; $PaCO_2$ = partial pressure of carbon dioxide in the arterial blood; PaO_2 = partial pressure of oxygen in the arterial blood; SpO_2 = saturation level of oxygen in hemoglobin

What are the Target Physiologic Values for the Anesthetized Dog & Cat?

Physiologic and cardiorespiratory variables in anesthetized dogs and cats are listed in **Table 2**.

What are Important Components of Anesthetic Monitoring?

- **Pre-anesthetic Evaluation**: The monitoring process starts prior to premedication. It begins by obtaining a complete history of the patient, followed by a thorough physical examination, including blood analysis and indicated diagnostics. The patient is given an ASA (American Society of Anesthesiologists) classification based on assessment of its anesthetic risks (**Table 3**).

  Deficits in homeostasis, such as dehydration, anemia, or any other significant abnormality (eg, low total protein, electrolyte imbalance, endocrine dysfunction, bleeding disorders) should be stabilized prior to any anesthetic procedure. A recent study has shown that mortality rates are higher in small animals with higher ASA status (ASA III–V) regardless of anesthetic agents used.[2]
- **Monitoring All Anesthetic Phases**: Once pre-anesthetic evaluation has been completed and the patient is approved for anesthesia, monitoring continues through:
  - » Premedication
  - » Induction
  - » Maintenance
  - » Recovery.

  Monitoring also applies to patients that have been prescribed take-home pain medication; this is accomplished through follow-up phone calls with the owner.
- **Sedated Patients**: Sedated patients should also be monitored. Both the American College of Veterinary Anesthesiologists[3] (ACVA) and the American Animal Hospital Association[4] (AAHA) have monitoring guidelines, which emphasize that a sedated patient should receive the same quality of monitoring care as a patient under general anesthesia. To review these guidelines, see **Links to Anesthesia Guidelines**, page 23.

Table 3. American Society of Anesthesiologists Physical Status Classification System

ASA Classification	Animal Health Description
ASA I	• Normal, healthy
ASA II	• Mild to moderate systemic disease
ASA III	• Severe systemic disease, but still active
ASA IV	• Severe systemic disease and incapacitated
ASA V	• Moribund, terminally ill
ASA-E	• Emergency

Saved by Monitoring
Case 2: Feline Cystolithiasis

EVALUATION

History: A 12-year-old, 3.8-kg domestic shorthair cat presented with bladder stones.

Physical Examination: The cat was alert with strong femoral pulses; heart and lung sounds were within normal limits.

Blood Analysis: Packed cell volume, 38%; total protein, 7.6 g/dL; glucose, 125 mg/dL.

Imaging & Diagnosis: Radiographic assessment revealed multiple uroliths within the bladder.

Treatment: Cystotomy was scheduled for bladder stone removal.

ANESTHETIC MONITORING

Anesthetic Protocol:

- Premedication with midazolam (0.4 mg/kg IM) and hydromorphone (0.1 mg/kg IM)
- Induction with propofol (3 mg/kg IV)
- Maintenance with isoflurane to effect

Blood Pressure Monitoring during Anesthesia: Oscillometric blood pressure monitoring was performed.

Monitor Warning: While the cat underwent surgical preparation, its blood pressure and heart rate decreased (10 minutes after induction).

Vital Signs of Anesthetized Patient (Ten Minutes After Induction)

Systolic blood pressure (mm Hg)	69
Diastolic blood pressure (mm Hg)	51
Mean blood pressure (mm Hg)	**57**
Heart rate (beats/min)	**95**
Respiratory rate (breaths/min)	16
Oxygen level in blood (SpO_2) (%)	100
End tidal CO_2 (mm Hg)	38
Temperature (°F)	100.3

Diagnosis: **Isoflurane-induced hypotension and hydromorphone-induced bradycardia**
Correction:

- Balanced electrolyte fluids (Plasma-Lyte A, baxter.com) were maintained at 10 mL/kg/H.
- The isoflurance percentage was already low (1.25%); lowering it any further may have allowed the cat to awake prematurely.
- An anticholinergic, glycopyrrolate (0.005 mg/kg, IV titration), was administered until the targeted heart rate was reached (normal parameter, 120–160 beats/min) and blood pressure improved (mean blood pressure, 70–90 mm Hg).

Pertinent Vital Signs (Three Minutes after Glycopyrrolate Administration)

Systolic blood pressure (mm Hg)	96
Diastolic blood pressure (mm Hg)	67
Mean blood pressure (mm Hg)	**77**
Heart rate (beats/min)	**120**

Take-Home Message: Monitoring both heart rate and blood pressure simultaneously provided a useful tool to pharmacologically manipulate the heart rate in order to maintain proper blood pressure in this cat.

Table 4. Assessing Vital Signs of Sedated/Anesthetized Patients

	Clinical Evaluation	Specific Variables
Circulation	• Palpation of peripheral pulses • Auscultation of heart beats using a regular stethoscope, Doppler, or esophageal stethoscope	Presence, absence, strength; frequency of heart beats with simultaneous peripheral pulses
	• Assessment of capillary refill time (CRT)	Prolonged CRT (> 2–3 seconds) suggests poor tissue perfusion or dehydration
Ventilation	• Observation of chest wall movements • Excursion of rebreathing–reservoir bag • Auscultation of lung sounds • Fogging of endotracheal tube or face mask	Presence, absence, regularity, frequency, characteristics, pattern, and depth of respiration
Oxygenation	• Assessment of mucous membrane and tongue color	Pink (adequate oxygenation) versus pale and/or cyanotic blue color (inadequate oxygenation)
Depth of Anesthesia	Assessment of: • Palpebral, corneal, and swallowing reflexes • Eyeball position • Jaw tone • Muscle and anal tone • Response to noxious or surgical stimulation • Purposeful movements	**Light anesthesia:** • Strong palpebral and corneal reflex • Central eye position • Swallowing, muscle twitching, and purposeful movements • Increase in heart and respiratory rate with/without vocalization **Moderate anesthesia:** • Ventral rotation of the eyeball • Loss of palpebral reflex with sluggish corneal reflex **Deep anesthesia:** • Muscle relaxation and loss of jaw tone • Central eye position • No corneal reflex • No response to surgical stimulation • Slow heart and respiratory rate, weak pulses
Postoperative Pain	• Observation of animal's behavior and cardiorespiratory variables during early recovery (first hour after extubation) • Use of pain scales to provide consistent pain assessments over time • Assessment of the degree of pain and differentiation of it from residual sedation or silent pain • Differentiation between delirium,* dysphoria,† and pain	• Vocalizing, thrashing, salivation, vomiting • Frequent changes in body position • Self-mutilation • Aggression toward personnel (ie, when palpating surgical site) • Increases in heart rate and/or blood pressure • Changes in respiratory rate, pattern, or effort

CRT = capillary refill time;
**Delirium: sudden, severe confusion and rapid changes in brain function;*
†Dysphoria: an emotional state marked by anxiety, depression, and restlessness

LINK TO PAIN MANAGEMENT GUIDELINES
View the AAHA/AAFP Pain Management Guidelines for Dogs & Cats at **aahanet.org/publicdocuments/painmanagementguidelines.pdf.**

- **Personnel**: *There is no single piece of monitoring equipment that can replace the role of a capable and vigilant anesthetist monitoring an anesthetized patient*. The ACVA monitoring guidelines recommend trained personnel be present for continuous evaluation of a sedated/anesthetized patient. See **Anesthesia Specialty for Veterinary Technicians** (page 24) for information on technician certification in veterinary anesthesia.
- **Documentation**: *When a patient is under general anesthesia, all vital signs must be evaluated and recorded on an anesthetic record at least once every 3 to 5 minutes*. The anesthetic record becomes part of the patient's medical record and legal documentation.

Table 5. Anesthetic Monitoring Equipment

Circulation
Electrocardiography (ECG): • Monitors heart rate and rhythm • Definitively diagnoses arrhythmias • Monitors progress of cardiac arrhythmia treatment
Ultrasonographic Doppler blood flow detector: • Measures blood flow, pulse rate, and systolic blood pressure (BP) when used with sphygmomanometer
Oscillometric BP measurement: • Uses a BP cuff on the limb to obtain systolic, diastolic, and mean arterial BP at a set time interval but not continuously
Invasive BP measurement: • Uses arterial catheter, BP transducer, and monitor to obtain continuous beat-to-beat pulse waves • Gold standard for measuring systolic, diastolic, and mean BP
Ventilation
Respirometer: • Measures respiratory rate and tidal volume (minute volume)
Arterial or venous blood gas: • Measures partial pressure of CO_2 ($PaCO_2$ or $PvCO_2$)
Capnography: • Noninvasively measures end-tidal CO_2 concentration
Oxygenation
Pulse oximetry: • Noninvasively measures saturation of oxygen in hemoglobin (SpO_2)
Arterial blood gas: • Measures partial pressure of oxygen (PaO_2) in arterial blood samples
Body Temperature
Rectal thermometer **Esophageal temperature probe** **Infrared thermometer:** • Measures tympanic membrane temperature
Depth of Anesthesia
Gas analyzer: • Measures expiratory inhalant concentration (allows anesthetist to estimate depth of anesthesia together with other vital variables mentioned in this table) **Bispectral index (BIS) monitor:** • Algorithmic analysis of a patient's electroencephalogram during general anesthesia

BIS = bispectral index; BP = blood pressure; CO_2 = carbon dioxide; ECG = electrocardiography; $PaCO_2$ = partial pressure of carbon dioxide in arterial blood; PaO_2 = partial pressure of oxygen in arterial blood; $PvCO_2$ = partial pressure of carbon dioxide in venous blood; SpO_2 = saturation level of oxygen in hemoglobin

What Methods & Equipment are Used for Anesthetic Monitoring?

Priorities for monitoring an anesthetized patient include:

- A physical assessment (**Table 4**) of the anesthetized patient by qualified personnel
- Appropriate vital sign monitoring (**Table 5**).

Adverse side effects of anesthesia are minimized when the anesthetist systematically and regularly evaluates circulation, ventilation, oxygenation, and analgesia. ■

In the next article in this series, anesthetic monitoring equipment and the physiologic components it measures will be discussed in-depth.

References

1. Ko JC. Noninvasive techniques in monitoring anesthetized patients. *Vet Tech* 1996; 17(5):301-307.
2. Bille C, Auvigne V, Libermann S, et al. Risk of anesthetic mortality in dogs and cats: An observational cohort study of 3546 cases. *Vet Anesth Analg* 2012; 39:59-68.
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