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Review Article

MONITORING OF ANAESTHESIZED VETERINARY PATIENT WITH INSTRUMENT AND INTERPRETATION OF DATA

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Summary
This paper deals with the concept of monitoring veterinary patient during anaesthesia. The parameters monitored are central nervous system, cardiovascular system, respiratory system, body temperature etc which to provide continuous information about the patient that can be used to maximize the safety of anaesthesia and minimize the decrement of organ functions, thereby improving the likelihood of an uneventful recovery.
Keywords: Anaesthesia, Monitoring, Veterinary.

INTRODUCTION

The purpose of monitoring is to provide continuous information that can be used to maximize the safety of anaesthesia and minimize the decrement of organ functions, thereby improving the likelihood of an uneventful recovery. The term "monitor" comes from the Latin "to warn", and means to check systematically or keep watch over. The role of an anaesthetist is to assess the anaesthetic depth, monitor vital organ function and obtain information that can be used to maximize patient safety and minimize risk. The veterinarian in practice may serve as both anaesthesiologist and surgeon. Monitoring of the anesthetized patient is a continual process throughout the anaesthetic event from pre-medication to full recovery. Vital signs and other monitoring parameters are recorded to the surgery record every 5 minutes throughout the procedure. The anesthetist should be aware of subtle changes in parameters and prepared to address any issues immediately as they arise.

Monitoring of parameters includes

I. Monitoring the central nervous system

Administration of general anaesthetics leads to a dose dependent depression of central nervous system. This anaesthetic depression of CNS can be broadly categorized into three

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phases a) Pre-surgical anaesthesia b) Surgical anaesthesia c) Anaesthetic overdose. Surgical anaesthesia can be subdivided into 3 planes namely light, adequate and deep planes.

A. Depth of Anaesthesia

Depth of anaesthesia can be determined by evaluating various reflexes such as pedal, palpebral, corneal, ear pinch and laryngeal reflexes. It may be used to know the depth of anaesthesia. Tone of jaw muscles or relaxation of abdominal muscles may also provide an idea about the depth of anaesthesia. Reflex responses vary between species, individual animals and the drugs administered during pre-medication, induction and maintenance.

B. Common reflexes used to judge depth of anaesthesia

1. Eye position- In light plane of anaesthesia, eyeballs rotate rostroventrally (turned downward), as the anaesthesia deepens eyeball move/rotates back to be placed centrally. Reliable indicator in case of dog (plane III) and cow (plane II).

2. Eye reflexes

a) **Palpebral (blink) reflex** is tested by gently tapping on the lateral or medial canthus of the eye or gently stroking the eyelashes and observing a partial or complete closure of the eyelids (blink). Generally present throughout stage I and II, diminished in stage III and lost in stage IV. The palpebral reflex is weak to absent at a plane of anaesthesia satisfactory for surgical stimulus and can become desensitized if tested too frequently.

b) **Corneal reflex** is tested by touching the cornea with a sterile object (a drop of water or artificial tear solution) and noting whether the animal blinks and withdraws the eye into the orbit. This reflex is not commonly tested unless it is necessary to determine if the patient is too deeply anaesthetized. Usually present until stage III, plane 3 anaesthesia.

c) **Nystagmus** is an involuntary rapid movement of the eyeball usually from side to side (medial to lateral). Presence of nystagmus in horses indicates a light plane of anaesthesia. Commonly seen in horses at induction and recovery.

3. Pupil constriction/dilation and pupillary photomotor reflex- Pupil is dilated in light plane and becomes constricted during adequate plane or plane 2 but again it may be dilated during anaesthetic overdose. Pupillary photomotor reflex is intact during light anaesthesia but during adequate surgical anaesthesia it is lost. During adequate surgical anaesthesia with ketamine eyes remain wide open with dilated pupil.

4. Lacrimation- Tears are present in an awake animal to keep the eye moist. Once the patient is anaesthetized to an adequate surgical plane, lacrimation decreases. It is very

important to keep the eyes lubricated during anaesthesia. Lacrimation during anaesthesia can be viewed as a sign of light stage anaesthesia. Commonly seen in horses.

5. Swallowing reflex- Occurs spontaneously in awake animals. It is monitored by observing movement in ventral neck region and usually stimulated by the presence of saliva or food in the pharynx. The reflex is lost at medium depth of anaesthesia and regained just before patient recovers consciousness. The return of the swallowing reflex during recovery indicated that it is safe to remove the endotracheal tube.

6. Laryngeal reflex- It is stimulated when the larynx is touched by an object and response is immediate to closure of the epiglottis and vocal cords. If patient is light anaesthesia at induction, the laryngeal reflex may be seen making it difficult for intubation. A sustained laryngeal reflex response is the cause of laryngospasm commonly seen in cats. Laryngeal reflex remains intact during ketamine anaesthesia

7. Pedal reflex-It is tested by squeezing or pinching a digit or pad and observing if the patient withdraws the limb. This indicates inadequate depth for surgical stimulus. This is seen with commonly used injectable anaesthetics whereas with inhalants, pedal reflex is normally lost during induction.

8. Ear flick reflex or Whisker reflex- It is tested by gently touching the hairs on the inner surface of the pinna and observing a twitch of the ear or whiskers in a cat. It may become desensitized if reflex is tested too frequently. Head shaking in response to ear pinch in cats, rabbits and guinea pigs is indicator of light anaesthesia and this response should be lost during adequate depth of surgical anaesthesia.

9. Jaw muscle Tone- With increasing anaesthetic depth, skeletal muscles become more relaxed and offer little resistance to movement. It can be assessed by testing jaw tone and anal tone. Jaw tone is one of the easiest ways to evaluate muscle tone. Jaw tone is assessed by attempting to open the jaws wide and estimating the amount of passive resistance. During anaesthesia, it should be decreased but always present to some extent. Muscle tone is present in light to medium planes of anaesthesia and becomes more flaccid as depth increases. Extreme laxity of the jaw suggests excessive anaesthetic depth. The degree of muscle relaxation is dependent not only on the depth but also on the particular drugs administered to the animal. Yawning in response to passive opening of jaw is an indicator of light anaesthesia. Some drugs promote muscle relaxation (diazepam, xylazine) and some increase muscle tone (ketamine, tiletamine).

10. Response to Surgical Stimulus- Movement in response to surgical stimulus indicates inadequate depth. Manipulation of viscera can stimulate the patient if adequate depth is not present. Patient may pant as a response to surgical stimulus if adequate depth is not present. This reflex should not be used alone to judge depth because pain can also elicit these responses. Minor changes in heart rate during surgery are considered normal. Animals perceiving surgical stimulation may show an increase in heart rate. This does not necessarily indicate that the anaesthetic depth is inadequate unless the increase in heart rate is considerable and/or other changes in other parameters are noticable. During surgery, an increase in heart or respiratory rate, in response to stimulation, indicates light plane of anaesthesia. Shivering, body movements and coughing may also suggest inadequate depth of anaesthesia. Absence of jaw tone, bradycardia, no response to surgical stimulation, dilated pupil, hypotension and hypoventilation are, however, some of the indicators of excessive deep level of anaesthesia. Therefore, the administration of anaesthetics is to be regulated in such a way that the depth of anaesthesia is maintained at a level at which animal is unaware and unresponsive to stimulation but still able to maintain cardiopulmonary function in an acceptable range to avoid hypoxia.

- Clinical signs of depth of anaesthesia

S No.	Parameter	Light anaesthesia	Adequate anaesthesia	Deep anaesthesia
1.	Eye position	Central	Rotated (Central*)	Central
2.	Palpebral reflex	+	– (+*)	– (±*)
3.	Jaw tonicity	+	– (+*)	– (±*)
4.	Movement	Possible	Absent (Possible*)	Absent (Possible/Absent*)
5.	Cornea	Moist	Moist	Dry
6.	Heart rate	Usually increased		Usually decreased
7.	Respiratory rate	Usually increased		Usually decreased
8.	Haemodynamic and/or respiratory variations following surgical stimulation	Yes	Usually no	No
*Clinical signs of depth of anaesthesia with a dissociative anaesthetic agent				

II. MONITORING OF THE CARDIOVASCULAR SYSTEM

A. Heart Rate and rhythm- Heart rate is a major determinant of cardiac output. Cardiac Output equals heart rate times stroke volume (CO = HR x SV). Always obtain a resting heart

rate from the patient prior to administering any anaesthetic drugs. Note the rate and rhythm. Heart rate should be higher in small breeds of dogs and much higher in pediatric patients under 3 months of age. Most anaesthetic drugs have a depressant effect on heart rate and myocardial function. Bradycardia may indicate excessive anaesthetic depth, a response to vagal stimulation or other causes. Heart rate will decrease from the resting rate in most anaesthetized animals. Tachycardia may be a response to surgical stimulation and in combination with other factors that may indicate an inadequate anaesthetic level. Drugs such as atropine, glycopyrrolate, ketamine and tiletamine will increase heart rate. If heart is too high then attempts should be made to correct the underlying cause. Atropine may be used to correct bradycardia whereas lignocaine may be used to prevent myocardial dysarrhythmias.

Hear Rate	Dog	Cat	Horse	Cow
Awake animals	70-100 bpm	145-200 bpm	30-45 bpm	60-80 bpm
Anaesthetized animals	50-180 bpm	100-220 bpm	28-50 bpm	48-80 bpm
Too low	40-50 bpm	50-60 bpm	30 bpm	35 bpm
Too high	250 bpm	300 bpm	75 bpm	85 bpm

Heart Rate and Rhythm can be assessed by

1. Palpation of peripheral artery-Note rate and pulse quality

2. Auscultation of chest wall-Listening with a stethoscope in conjunction with palpating a pulse will give an indication to any pulse deficits that may be present

3. Oesophageal Stethoscope- It consists of a tube with a balloon on the end that is passed down the oesophagus of an anaesthetized animal. The open end is connected to an ordinary stethoscope headpiece. The tube should be advanced down the oesophagus until the tip is level with the heart or a heart rate can be heard. It provides information about heart rate and rhythm. It can also obtain respiration rate.

4. Electrocardiography (ECG)

ECG is an evaluation of the heart's electrical activity. ECG gives information about cardiac arrhythmias and about myocardial environment (hypoxia, hyperkalemia, acidosis, hypercalcemia). The **ECG does not** give any information about the mechanical function of the heart and should not be relied on for the sole method of monitoring cardiovascular function. The white lead is placed on the right front armpit, the black lead is placed on the left front armpit and the red lead is placed on the left hind flank in small animals and along the jugular grove in large animals. Normal heart rhythm (sinus rhythm) originates in the

sinoatrial (SA) node of the right atrium. Each waveform generated gives regional information on depolarization or repolarization and conduction in the heart.

The detail of ECG wave is

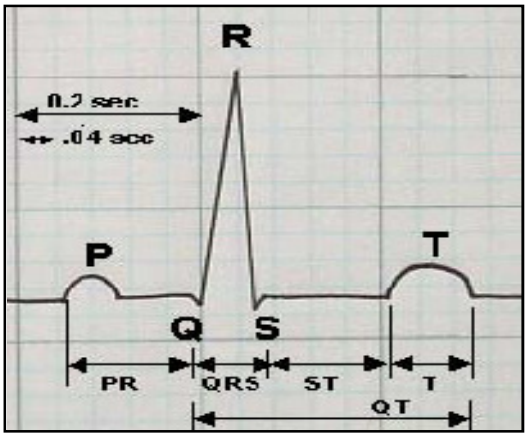
P wave = atrial depolarization (firing of SA node).

PR (PQ) interval reflects time taken for the impulse to conduct from the SA node, through the AV node and to the ventricles.

QRS complex = ventricular depolarization or contraction.

T wave = ventricular repolarization or relaxation.

QT interval indicates the duration of ventricular systole.



Common arrhythmias that can occur during anaesthesia include sinus bradycardia, second degree heart block, escape beats, ventricular premature complexes, ventricular tachycardia and third degree heart block.

Interpretation of Arrhythmias by systematically following the five-step method given below and has proven to be both simple and effective.

Step 1. Calculate the heart rate

- Decide whether the heart rate is rapid, slow, or normal.

Step 2. Assess the rhythm

- Scan the strip from left to right, noting if the R-R intervals are regular or irregular.
- A caliper is a handy tool for plotting P-P and R-R intervals.

Step 3. Identify the P waves

- **Normal P wave (positive and rounded on Lead II)** -indicates that the impulse is originating in the SA node.
- P wave that differs from normal in shape and is upright—may represent an ectopic pacemaker in the atrium.

- **P waves that are inverted**—on lead II, indicate that the impulse was formed in or near the atrioventricular junction.
- **Absence of P waves**—signifies atrial fibrillation, atrial standstill, or buried P waves in QRS complexes of AV junctional rhythms.
- **P waves can be superimposed**—on a portion of the QRS complex, S-T segment, or T wave of the preceding cardiac cycle in various supraventricular tachycardias

Step 4. Assess QRS shape and duration

- **Normal duration QRS complexes**—identical to those recorded before an arrhythmia, indicates normal activation of the ventricles. These complexes are either formed in the SA node or from an abnormal site anywhere above the bundle of His.
- **Wide QRS complexes**—with various configurations indicate an ectopic pacemaker below the bundle of His (ventricular) or a lesion in the intraventricular conduction system (bundle branch block).

Step 5. Relationship between P waves & QRS complexes

- Normally, there should be one P wave for every QRS complex, with a constant P-R interval.
- P waves may precede normal QRS complexes by different time spans.
- **Long P-R intervals**—indicate an AV conduction delay (1° AV block).
- **Short P-R intervals**—are seen with accessory conduction around the AV node, or in AV junctional rhythms in which the P wave is positioned close to the QRS complex.
- **P wave not followed by a QRS complex**—an AV block (2° AV block) has occurred. If the P-R interval lengthens gradually until a P wave occurs without a succeeding QRS complex, another form of 2° AV block has occurred.
- **P-R intervals vary**—in 3° AV block the relationship of the atria and ventricles is interrupted. One impulse forming ‘site is the SA node; the other is an independent ventricular escape rhythm.

Finally, last step: Name that arrhythmia

- Place the arrhythmia within the classification.
- The best name for an arrhythmia always identifies exactly which part of the heart is not working properly

Commonly used Anti-arrhythmic drugs

- **Atropine:** 0.02-0.04 mg/kg for treating sinus bradycardia
- **Glycopyrrolate:** 0.01-0.02 mg/kg treating for sinus bradycardia

- **Lidocaine**: 1-2 mg/kg over 3-5 min for treating VPCs, maximum 8 mg/kg (use lower dose in the cat with maximum not exceeding 4 mg/kg)
- **Procaine amide**: 2-4 mg/kg over 3-5 minutes for treating VPCs, usually given when VPC treatment is nonresponsive to lidocaine, maximum 20 mg/kg

B. **Ventricular performance-**Ventricular performance (the contractile force of the heart) can be roughly gauged by auscultation of the loudness of each heartbeat. The routine use of oesophageal stethoscope and heart sound amplifiers may be useful in this regard. Ventricular performance can be estimated from systolic time intervals, which are indices calculated from simultaneous recordings of central arterial blood pressure, ECG and phonocardiogram.

C. **Cardiac output-** Cardiac output is the product of stroke volume (SV) and heart rate (HR). CO = HR x SV. Stroke volume is the product of end diastolic ventricular filling volume and contractility. Stroke volume is the volume of blood ejected by the heart during systole. Cardiac output can be estimated by indicator or thermodilution techniques that involves the injection of an indicator of a known concentration into the right atrium and the measurement of the change in the concentration of the indicator at pulmonary artery. The most commonly used indicator is Indocyanine Green dye. The other techniques in which room temperature or ice saline is used. CO is the main determinant of oxygen delivery when the PaO_2 is above 60 mmHg.

D. Tissue Perfusion

1. **Mucous membrane color-**The easiest way to assess the mucous membrane colour is at the gingival region. Normal mucous membrane should be pink and moist to touch. Pale mucous membranes are as a result of poor perfusion and may indicate blood loss or anaemia. Purple or blue mucous membranes indicate cyanosis, a shortage of oxygen in the tissue. Cyanosis during anaesthesia is usually the result of respiratory failure or upper airway obstruction and must be corrected immediately. Dry, clamy, or sticky mucous membranes can indicate that the animal (particularly the horse) may be dehydrated.

2. **Capillary Refill Time (CRT)-** It is the time taken for capillary bed to refill with blood following digital pressure on the gums. It normally takes less than 2 seconds for color to return normal. Pressure on the mucous membrane compressed the small capillaries and blocks blood flow to that area. When the pressure is released, the capillaries rapidly refill with blood and the color returns, provided the heart is able to generate sufficient blood pressure. Prolonged CRT (> 2 sec) is an indication of vasoconstriction which can indicate

poor perfusion resulting from excessive anaesthetic depth or circulatory shock. CRT is usually prolonged in patients in whom the systolic blood pressure is less than 80 mm Hg. Animals suffering from this degree of hypotension will usually feel cold and have pale mucous membranes. Other factors that may cause prolonged CRT or poor perfusion include hypothermia, vasodilation and cardiac failure.

E. Blood Pressure (B.P.)- It is the product of cardiac output and vascular resistance. It can be defined as the lateral force exerted on per unit area of vessel wall. BP=CO X Peripheral vascular resistance. CO = Heart rate X Stroke volume. Blood pressure assessment is an integral part of anaesthesia monitoring to assess tissue perfusion. B.P. during anaesthesia may be decreased due to deeper plane of anaesthesia or haemorrhagic or neurogenic shock. In light plane of anaesthesia, surgical stimulation may lead to sudden increase in blood pressure. Arterial blood pressure can be described using the following terms:

1) **Systolic Pressure (SAP)** is produced by the contraction of the ventricles and propels blood through the aorta and major arteries. In awake healthy animals the SAP is 140-160mmHg

2) **Diastolic Pressure (DAP)** is the pressure that remains when the heart is in its resting phase, between contractions. It is the lowest pressure that is exerted throughout the cardiac cycle. In awake healthy animals the DAP is 85-95mmHg

3) **Mean Pressure (MAP)** maybe calculated by MAP = Diastolic BP + 1⁄3 (Systolic BP – Diastolic BP). MAP establishes an adequate perfusion pressure for the major organs. A MAP of 60mmHg in small animals and 70mmHg in large animals is required to ensure adequate minimal blood flow to the kidneys, brain and liver. During anaesthesia, hypotension is defined as below 60mmHg in small animals and 70mmHg in large animals. Neonates or paediatric patients (less than 3 months) have an immature sympathetic nervous system. They are more dependent on heart rate for cardiac output than adults. A lower ABP is tolerated because they have less contractile tissue than adults do. Changes in cardiac output are mediated by changes in the rate rather than contractility

- Normal values for the anaesthetized patient include:

Parameters	Dog	Cat	Horse	Cow
Systolic Pressure	80-120mmHg	80-150mmHg	100-120mmHg	120-150mmHg
Diastolic Pressure	40-80mmHg	40-80mmHg	50-80mmHg	75-100mmHg
Mean Preassure	60-100mmHg	60-120mmHg	70-100mmHg	90-120mmHg

Ways to evaluate blood pressure of the patient

1. INDIRECT BP MONITORING (NON-INVASIVE METHODS)

It can be monitored by using Doppler ultrasound probe coupled with a pressure cuff and sphygmomanometer or an automated oscillometric device (e.g., Dinamap®). The advantage of automated oscillometric detector device over Doppler ultrasonic detector is that the oscillometric is automated and requires neither experience nor labor of the operator.

Most of the indirect methods of blood pressure monitoring are based on Riva-Roci technique, where a superficial artery is occluded by an inflatable cuff. The detection of blood flow is done either by auscultation of "korotkoff" sound by stethoscope or by other methods like ultrasound. Use of conventional cuff and stethoscope is not common in veterinary practice due to the unavailability of superficial artery of sufficient size.

a. Oscillometric technique (blood pressure cuff)

- It has been used to measure the mean, systolic and diastolic pressures. This technique calculates diastolic and systolic parameters by sensing peripheral pulse. Non-invasive measure of peripheral blood pressure by mechanically inflating a cuff placed around the extremities in small animals or the tail in large animals.
- Oscillometric BP monitors consist of an appropriately sized cuff, transducer, microprocessor, and display unit. These automatic devices work by detecting oscillations (periodic fluctuations) within the cuff produced by arterial wall motion. As the cuff is deflated, oscillations rapidly increase at the systolic pressure, reach a maximum at the MAP, and then rapidly decrease at the diastolic pressure. The attached electronic monitor displays SAP, MAP and DAP as well as pulse rate. For most devices, MAP is most closely measured, whereas SAP and DAP are calculated via programmed algorithms.
- In this technique a pneumatic cuff is coupled with a pressure sensing bladder. A microprocessor controlled device inflates the cuff to suprasystolic pressure and then deflate cuff while simultaneously noting the pulse wave oscillation in the cuff.
- Proper size of cuff is determined by measuring the width of the cuff to the circumference of the limb. The width of the cuff should be approximately 40% the circumference of the limb. An artery should be palpated and the arrow on the cuff should be placed over the artery.
- ❖ If the cuff is too tight or too wide the readings will be erroneously low because the cuff itself will partially occlude the underlying artery
- ❖ If the cuff is too loose or too narrow the readings will be erroneously high because excessive cuff pressure will be required to occlude the underlying artery.

Advantages

1. Process is more automated, requiring less technical skill; the operator simply chooses the appropriate cuff size, places it on the patient, and hits the start button. Monitors can be programmed to measure blood pressure at timed intervals.
2. This method is automated, portable, has alarm capabilities and provides SAP, DAP, and MAP as well as pulse rate.
3. Modification of the algorithms used by the processor might make oscillometric techniques more accurate and efficient for animals less than 11 lb (5 kg).

Disadvantages

1. Oscillometric techniques are most appropriate for use in animals weighing more than 11 lb (5 kg).
2. These methods are less efficient than Doppler techniques because they may not be able to obtain readings as easily, especially in patients with a fast or rapidly changing heart rate, in low-flow conditions, and in cats and small dogs.
3. Inconsistency between different devices, decreased efficiency in the presence of shivering or muscle movement and limited use in small patients

b. Doppler technique

- A Doppler ultrasound probe coupled with a pressure cuff and sphygmomanometer or an automated oscillometric device (e.g., Dinamap®, Criticon, Tampa, FL).
- Doppler shift principle was developed in 1960 for measuring blood flow in the vessels. Doppler technology uses 10 MHz ultrasound waves to detect blood flow in a peripheral artery. The Doppler effect refers to detection of a shift in frequency of waves relative to an observer.
- Doppler BP devices consist of a probe/ transducer having two piezoelectric crystals for producing and receiving ultrasonic waves. The probe is placed over an artery distal to an inflatable cuff with an attached aneroid manometer. The blood flow is occluded by inflatable cuff placed proximal to the ultrasound probe and then released slowly. The moving red blood cells produce a shift in the frequency of ultrasound wave as a result of the Doppler effects within the artery which is converted into the audible range and amplified. An audible sound of the pulsating artery should be heard.
- A pressure gauge (sphygmomanometer) is attached to the cuff. The cuff is inflated until the pulse sound stops. Slowly deflate the cuff until the pulse is heard. Only measures systolic blood pressure is measured. Doppler's attached to cats have been shown to read 10-

15mmHg lower than actual value. Locations for placement of the doppler crystal include proximal to the metacarpal or metatarsal pad, ventral aspect of tongue, medial aspect of humerus, lateral aspect of hock, medial aspect of thigh, lateral aspect of tibia or ventral aspect of tail.

Disadvantages of the Doppler method include

1. Inability to reliably determine diastolic arterial pressure (DAP) and therefore MAP.
2. In addition, Doppler methodology is operator-driven (i.e., it is not automatic) and requires some practice and patience to locate the vessel with the probe.

Advantages of the Doppler method include

1. Relatively low cost and technical ease (compared with direct measurements)
2. Non-invasiveness, and portability

c. Photoplethysmography

- The most recent method of indirect blood pressure monitoring is photoplethysmography. This technique is based on the transmission of infrared light to detect arterial volume.
- A constant arterial blood volume is maintained by an inflatable cuff so that the measured cuff pressure equals the intraarterial pressure.
- A microprocessor controlled cuff maintains arterial volume at a constant value such that the cuff pressure corresponds to arterial blood pressure fluctuations.
- The cuff is placed around the metatarsal region just distal to the hock. There have been few veterinary studies, but this technique has been shown to have accuracy similar to that of the Doppler method compared with direct measurements in anesthetized cats.
- The major disadvantage of this technology is that its use is restricted to animals weighing less than 22 lb (10 kg) because it was developed for use on human fingers.

2. DIRECT B.P. MONITORING (INVASIVE METHODS)

a) A catheter is placed into a peripheral or superficial artery and then directly connected to a pressure transducer and monitor/recorder. This is the most accurate measurement of arterial blood pressure and the 'gold standard' against which all other methods are compared.

b) An electronic pressure transducer is attached to the catheter by extension tubing. A cord from the pressure transducer transmits the signal to a monitor and displays SAP, DAP, MAP and a constant waveform. If equipment is not available, an aneroid manometer can be attached to the arterial catheter. The only reading obtained is the MAP.

c) Advantages-

1. Provides a continuous, beat to beat assessment of the patient's blood pressure,
2. It is more accurate in hypotensive situations
3. It provides good access to an arterial blood sampling site for blood gas analysis

d) Disadvantages

1. Invasive technique that is best placed in anaesthetized patients because flushing the arterial catheter with heparinized saline is painful to the awake animal.
2. It must be placed at the same level as the apex of the heart and zeroed. A transducer that is lower than the heart will give a false high reading and a transducer that is higher than the heart will give a false low.
3. Thrombosis and occlusion of flow to the extremity can occur if taped too tightly.
4. If transducer becomes disconnected from the arterial catheter without notice, the patient can essentially bleed out.
5. Equipment needed for set up can be expensive.

Species	**Name of Arteries that are commonly catheterized**		
Dog / Cat	Palmar common digital arteries	Dorsal pedal artery	Femoral artery or carotid artery
Horse	Facial artery, Transverse facial artery	Lateral nasal artery Common digital artery	Metatarsal arteries
Ruminants	Facial artery	Median Auricular artery	Metatarsal arteries
Sheep/Goat /Pig	Median Auricular artery	-	-

F. Central venous pressure (CVP) measurement

- Central venous pressure (CVP) is the measure of the ability of the heart to pump the quantity of fluid being returned to it. CVP indicates a balance between the cardiac output and the venous return. It is an estimate of relationship between the blood volume and blood volume capacity. It is invasive method and requires catheterization of jugular vein so that the tip of the catheter lies ideally in the right atrium. CVP is the luminal pressure of the intra-thoracic anterior vena-cava or right atrial pressure when the tip of the catheter is passed upto the right atrium. It monitors the adequacy of venous return, intravascular blood volume and right ventricular function. It gives information about cardiovascular status and cardiac compliance as well as venous blood volume and filling of right ventricle.
- CVP is measured by manometer or electronic pressure transducer. The catheter of the manometer passed through the jugular vein upto the anterior vena-cava or right atrium. It can be recorded in animals restrained in lateral recumbency or in standing position. The point to

keep in mind is that the zero point of manometer should be placed at the level of sterna manubrium. The horizontal difference between the zero level and the meniscus of the fluid in the deep chamber represents CVP.

- The measurement of CVP should be taken before inspiration and at the end of expiration. The normal CVP in small animals is 0-10 cm H_2O (awake or anaesthetized), 5-15 cm H_2O in awakes horse, 25-35 cm H_2O in anaesthetized horse. Measurements in the range of 15 to 20 cm H_2O are too high and efforts should be made to determine and treat the cause of the deviation. CVP will increase if the pumps begin to fail with vasoconstrictor and with hypervolaemia. CVP will decrease with vasodilatation, with hypovolemia and with obstruction to venous return. Verification of a well-placed, unobstructed catheter can be ascertained by observing distinctive pressure wave characteristics on the monitor

G. Pulmonary artery pressure wedge pressure (PAWP)

- It is determined by insertion of a catheter, via a peripheral vein, through the right side of the heart and into a branch of the pulmonary artery. It is passed to the point where its circumference exceeds the lumen of the branch and it becomes wedged. It thus measures the back pressure from the left ventricle (left ventricular end-diastolic pressure). This value indicates left ventricular function. The importance of monitoring PAWP is based on the requirement for adequate left heart output to perfuse the heart, brain, kidney and splanchnic circulation and the lack of correlation between the left and right heart preloaded values in many disease states.
- PVR= PAWP/CO X 80
- SVR= MAP- CVP/CO X80

Where SVR- Systemic vascular resistance, PVR- Pulmonary vascular resistance, MAP- Mean arterial pressure, and units- dynes per second per cm to 5 power.

The pulmonary capillary wedge pressure is 3-8 mm Hg.

III. MONITORING THE RESPIRATORY SYSTEM

A. Breathing rate and rhythm

- The overall goal of the respiratory system is to move oxygen into the lungs and remove carbon dioxide from the lungs. It gives little information about the adequacy of ventilation.
- Respiration rate is depressed to some degree by the anaesthetic drugs used in pre-medication, induction and maintenance. Normal inspiration lasts 1-1.5 seconds and expiration lasts 2-3 seconds.

- Normal values

Respiratory Rate	Dog	Cat	Horse	Cow
Awake animals	10-20 bpm	15-25 bpm	8-16 bpm	10-16 bpm
Anaesthetized animals	8-14 bpm	10-14 bpm	6-10 bpm	6-10 bpm

- Basic respiratory monitoring is based on clinical observations. The rate and depth can be assessed by observing movement of the chest or reservoir bag. Chest excursions of the anaesthetized patient should be assessed with both spontaneous respiration and assisted ventilation. Respiratory rate and character can be evaluated via oesophageal stethoscope.
- An elevated respiratory rate may indicate a progression from moderate to light anaesthesia and is often one of the first signs of arousal from anaesthesia. Breathing should be smooth and regular, with thoracic and diaphragmatic components. Difficult or labored breathing may indicate the presence of an airway obstruction.
- Animals anesthetized with ketamine may exhibit an apneustic respiratory pattern, in which inspiration is followed by a prolonged pause before expiration.
- Normal respiratory sounds are almost inaudible. Harsh noises, whistles or squeaks may indicate narrow or obstructed airways or the presence of fluid in the airways
- Abnormally slow breathing rate (bradypnea) are associated with organic (cerebral edema, neoplasm or haematoma) or metabolic (depression, severe hypoxia, hypo or hypercapnea or visceral organ failure) or dysfunction of medullary respiratory center.
- Rapid rate of breathing (tachypnea) is caused by hypercapnea, hypoxemia, hypotension and hyperthermia. Too light level of anaesthesia may be associated with tachypnea similarly too deep level of anaesthesia may also be associated with tachypnea.

B. Ventilometry

- Ventilometry measures the amount of air moving in out of lungs. It is used to estimates ventilation volume (Tidal volume and minute volume). Tidal volume is defined as the volume of air inhaled or exhaled in one inspiration or expiration. It can be recorded with the help of respirometer/ ventilometer. Respirometry assesses tidal volume and minute volume in the anaesthetized patient.
- A respirometer (or Wright or Boehringer respirometer) is an instrument that measures the amount of volume of expired gases. The device is usually placed between the expiratory limb of an anaesthetic machine to record tidal volume and the anaesthetic breathing hose. Alternatively, a respirometer connected to a face mask may be used to assess ventilation

efficiency in a non-intubated anaesthetized patient, although the accuracy is reduced due to air leaks around the mask.

- The normal tidal volume ranges between 10 to 20 ml/kg. In small animals tidal volume should be about 14 ml/kg and about 11 ml/kg in large animals. A smaller than normal tidal volume is acceptable if breathing rate is faster.
- Tidal volume can be used to calculate minute volume. Minute volume /ventilation = breathing rate X tidal volume. It is also called as minute respiratory volume. The minute ventilation ranges between 150 to 250 ml/kg/min. Minutes ventilation below 100 ml/kg/min needs positive pressure ventilation.

C. Ways to monitor oxygen and carbon dioxide

1. DIRECT METHOD

Arterial blood gas analysis

- The partial pressure of the oxygen can be measured with a blood sample. It gives an indication of ventilation, oxygenation and acid-base status (arterial blood pH) of the animal. It is most accurate method to determine tissue oxygenation and carbon dioxide content (removal of carbon dioxide) for an anaesthetized patient. Blood gas analysis is the 'gold standard' method for evaluation of gas exchange.

Sample collection for blood gas analysis

- Arterial or venous blood is collected from patients is used for blood gas analysis. Venous blood may be used to get reliable values for base deficit but doesnot provide any information about the ability of lung to oxygenate. Most important gaseous component of arterial blood is oxygen, which is measured as PaO_2. Arterial carbon dioxide ($PaCO_2$) is direct and immediate reflection of adequacy of alveolar ventilation in relation to metabolic rate. Increased level of $PaCO_2$ during anaesthesia is primarily due to hypoventilation.
- Arterial blood in dogs can be collected from dorsal paedal artery, femoral artery or lingual artery whereas venous blood from jugular, saphenous or cephalic vein. Blood samples are drawn from the femoral, carotid or lingual arteries in the small animal and from the coccygeal, mandibular, radial, saphenous, brachial, caudal auricular, digital, carotid arteries or aorta in large animal.
- Blood should be collected aseptically by arterial or venous puncture and should be analyzed immediately since delay in time taken can alter the results obtained. If it is to be analyzed later the most suitable anticoagulant is heparin and should be stored at 0°C to 4°C

and the determination should be made within 1 hour. Arterial puncture is difficult than venipuncture but skill can be developed on practice.

- Samples are collected in syringes from which the air has been expelled and in which dead space is filled with heparin solution. Glass syringes are advantageous owing to less friction and to greater ease in expelling air bubbles. In plastic syringes, PaO_2 values in excess of 400 mmHg drop more rapidly than in glass syringes. The syringe tip must be closed or bend after sampling. Usually 3 ml of blood from an artery by a 22-25 gauge needle taking precaution that negative pressure should be minimized so as to avoid reduction in oxygen, haemolysis and introduction of air bubbles in the syringe. Blood collected is analyzed by using **blood gas analyzer** and continuous monitoring of blood gases and acid-bases status can be done.

Blood Gas Analyzer

- A variety of blood gas analyzers are available and selection of the particular equipment may be dictated by work load, frequency of analysis and budget of laboratory. Blood gas analyzer should be installed in a room close to the operation theatre.
- The parameters analyzed on blood gas analyzer vary with the make of the machine. Irrespective of the machine, collected arterial blood sample is analyzed by using Blood Gas Analyzer machine and the following information can be obtained- **pH**: indicates whether acidemia or alkalemia is present. **$PaCO_2$**: Partial pressure of CO_2 in arterial blood. **PaO_2**: Partial pressure of O_2 in arterial blood. **HCO^{3-}:** Bicarbonate. **Total CO_2**: Total carbon dioxide present in the body. **BE**: Base excess. **SaO_2**: Oxygen saturation in the arterial blood. From these values anion gap and acid base balance of the blood can be estimated which provides idea about the condition of animal.
- Normal blood pH in most animals is 7.36-7.44, which also serves as an indicator of acid-base balance of the blood. A pH below 7.35 represents acidaemia and above 7.45 represents alkalaemia.
- Normal values for arterial blood in awake animals

Arterial blood	Dog	Cat	Horse
$PaCO_2$	34-40 mmHg	28-34 mmHg	36-46 mmHg
PaO_2	85-100 mmHg	90-110 mmHg	90-100 Hg

- Ventilation level of the animal can also be assessed by noting hyperventilation indicated by decreased partial pressure of carbon dioxide in arterial blood (PaCO2) and

hypoventilation characterized by increased PaCO2, the normal level being 35-45mmHg. CO2 should be the same for awake and anaesthetized animals

- All healthy patients on 100% oxygen during anaesthesia should have a PaO_2 between 400-500 mmHg. The predicated PaO_2 is approximately 4-5 times the percentage of inspired oxygen.
- Bicarbonate values in dogs is approximately 24 mEq/L at pH of 7.4
- Total CO_2 represents the sum of CO_2 dissolved in plasma as carbonic acid and bicarbonate. The ratio of bicarbonate / carbonic acid is equal to 20/1. It is good index of bicarbonate activity.
- Base excess refers to the number of mEq of acid or base required to titrate 1 litre of blood at 37°C to a pH of 7.4 with $PaCO_2$ of 40 mmHg. Base excess value range from -4 to +4 mEq/L. True base deficit value (-) indicates metabolic acidosis, whereas true base excess value (+) indicates metabolic alkalosis.
- Anion gap can be estimated by subtracting the level of major anions from the major cations $((Na^+ + K^+) – (HCO_3^- + Cl^-))$. The value range from 10 to 20 mEq/litre. In dog value is 13 to 27 mEq/litre. This helps to determine the electrolyte disturbances and evince body's response to underlying disease process. Elevation of anion gap indicates metabolic acidosis whereas decreased anion gap indicates metabolic alkalosis.
- Saturation with oxygen (SaO_2) determines the ability of blood to carry oxygen to the tissues

2. INDIRECT

a. Capnograph

- Capnography can be used to evaluate a patient's perfusion, ventilation and metabolism as well as anaesthetic and ventilator equipment. It is non-invasive measurement of carbon dioxide and provides graphic representation of changing carbon dioxide concentration during respiratory cycle called capnogram or capnograph. It provides breath to breath numerical values of end tidal carbon dioxide (ET CO_2). It is measured through a gas sampling line and reflects the amount of carbon dioxide exhaled by the patient. The normal value ranges from 35-40 mmHg.
- A capnometer is a CO_2 monitor that displays a number (ie,end-tidal CO_2 [ET CO_2]).
- A capnograph is a CO_2 monitor that displays a number and a waveform. The wave form represents- Upward slope = expiration. Downward slope = inspiration, baseline should read zero.

➢ The CO_2 waveform or capnogram displays changes in the CO_2 concentration during the respiratory cycle. Carbon dioxide measured at the airway can be displayed as a function of time (CO_2 concentration over time) or exhaled tidal volume (CO_2concentration over volume).

➢ Under ideal conditions $ETCO_2$ reflects the alveolar concentration of carbon dioxide. It is usually presumed that alveolar and capillary carbon dioxide are equilibrated, therefore ET CO_2 can be used to estimate $PaCO_2$. $ETCO_2$ under estimates $PaCO_2$ by 10-15 mmHg.

mm Hg	kPa	Interpretation
<35	<4.6	Hypocapnia
35-45	4.6-6.4	Normocapnia
> 45	>6.4	Hypercapnia

Principle of capnograph

➢ The two primary methods used for measuring CO_2 in expired air are mass spectroscopy and infrared light absorption spectroscopy. The mass spectrograph separates gases and vapors of different molecular weights. These units are expensive and bulky and thus impractical for most veterinary practices. Infrared light absorption spectroscopy is the most common method for measuring CO_2 in respiratory gases.

➢ Polyatomic gases (i.e., nonelementary gases such as nitrous oxide and CO_2) and water vapor absorb infrared rays. CO_2 selectively absorbs infrared light at 4.3 μm. The amount of light absorbed by the CO_2 is directly proportional to the concentration of the absorbing molecules.

Types of capnograph

➢ Capnometers and capnographs can be categorized based on the sensing device location. The two options for placement of the measuring device are mainstream or sidestream. Sidestream analysers are most commonly used in veterinary practice.

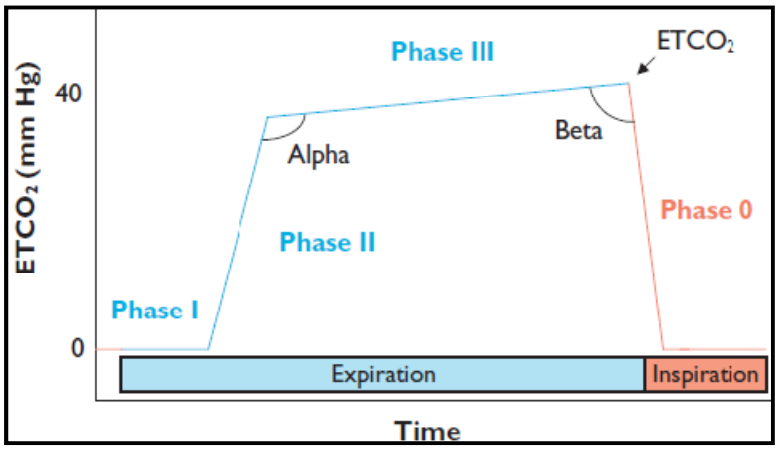
NORMAL CAPNOGRAM

➢ The capnogram is the graphic representation of the amount of CO_2 in the respiratory gases versus time. There are two different types of time capnograms: a slow speed to show CO_2 trends, and a fast speed that shows changes in each breath.

➢ The fast speed capnogram waveform is useful in determining causes of changes in ET CO_2. Terminology representing various phases of the time capnogram based on logic, convention, and tradition was introduced by Bhavani-Shankar *et al.* in 1992.

➢ The capnograph/capnogram waveform has three phases of expiration and one of inspiration:

- **Phase I (expiratory baseline)** is the beginning of exhalation and corresponds to exhalation of CO_2 -free dead space gas from the larger conducting airways. The CO_2 value during this phase should be zero.
- **Phase II (expiratory upstroke)** involves exhalation of mixed alveolar and decreasing dead space gas, which rapidly increases the CO_2 concentration.
- **Phase III (expiratory plateau)** occurs when all the dead space gas has been exhaled, resulting in exhalation of complete alveolar air. The highest point of phase III corresponds with the actual ET CO_2 value. The plateau has a slight positive slope because of the continuous diffusion of CO_2 from the capillaries into the alveolar space.
- **Phase 0 (inspiratory downstroke)—**Because of inhalation of CO_2 –free gas, the CO_2 concentration rapidly declines to zero.



➢ The alpha angle is between phases II and III. In humans, the average angle is 100° to 110°. The alpha angle increases as the slope of phase III increases. Thus the alpha angle is an indirect indication of the VA/Q status of the lungs. The beta angle is between phases III and 0 and is usually 90°. The beta angle is used to assess the degree of rebreathing. During rebreathing, the beta angle increases as well as the response time of the capnometer compared with the respiratory cycle time of the patient. Normal values for these angles have not been published for dogs or cats.

➢ **Analysis of capnogram-** Capnography is a useful diagnostic monitoring tool for airway, breathing, and circulation assessment. Thorough examination and interpretation of

the capnogram yields information about a patient's ventilation, perfusion, and metabolism. Any deviations from the above normal shape of capnogram should be investigated.

- **Interpretation of abnormal traces**

Trace abnormaility	**Symptoms**	**Reason**
Elevated base line	Rebreathing	Gas flow too low, Exhausted soda lime
Oscillations on trace	Cardiac trace	Cardiac movement moves, Gas in airways
Extra peak at the end	Additional ventilation	Reversal of neuromuscular blockade Fighting ventilator
Sloped plateau	Delayed expiration	Obstructed endotracheal tube, Obstructive air way disease
High ET CO_2	Hypercapnia	Hypoventilation
Low ET CO_2	Not full expiration (no plateau)	Hyperventilation, High ventilation rate (Non-rebreathing system)
	Dilution with air (no plateau)	Leak in the endotracheal tube cuff
	Decreased cardiac out put	Fresh gas contamination
Sudden decrease in $ETCO_2$	Decreased pulmonary perfusion	Cardiopulomonary crisis, Pulmonary thromboembolism
No trace	No gas to analyse	Apnoea, Airway obstruction, Disconnection of ET, Ventilator failure

b. Pulse Oximetry

- It is noninvasive technique that measures the arterial oxygen saturation of haemoglobin, symbol is SpO_2. It. They do not directly measure tissue oxygen delivery, as this is also dependent upon cardiac output and haematocrit (available haemoglobin). Now it has gained widespread popularity in veterinary practice.
- Pulse oximetry is based on two principles

1. Spectrophotometric oximetry- The degree of oxygenation of haemoglobin depends upon the absorption of red and infrared light. Haemoglobin absorbs red and infrared light at different wavelengths, depending on whether the haemoglobin is bound to oxygen (infrared) or deoxygenated (red). Oxyhaemoglobin looks red because it reflects red light and absorbs blue light and deoxyhaemoglobin looks blue because it reflects blue light and absorbs red. The amount of light absorbed at each wavelength is measured by sensitive photodetectors. The pulse oximeter uses two light-emitting diodes that pulse red and infrared light through perfused tissue several hundred times per second. The absorption data is expressed as a percentage of oxygenated haemoglobin to total haemoglobin.

2. Pulse photoplethysmography- There is change in volume of tissue bed due to arterial pulsation and can be measured by change in light absorption.The light signal following transmission through the tissues has a pulsatile component, resulting from the

changes in volume of arterial blood with each pulse. This is distinguished by the microprocessor from the non-pulsatile component resulting from tissue, venous and capillary light absorption. Thus, the percentage of arterial oxygen saturation of haemoglobin is calculated. The signal is obtained from the animal by placing a probe containing the light sources across any well perfused area of tissue.

- Pulse oximeters have either transmittance or reflectance probes. The probe clipped into the tongue is transmittance probe and placed into the oesophagus or rectum is reflectance probe.
- Both types of probes contain light emitting diodes (LEDs) which shine light of red and infrared wavelengths alternately (at an alternating frequency of 770-1000 Hz) through or into the chosen tissue bed (tongue, toe, ear, rectum, oesophagus). The most commonly used sites include tongue, pinna, prepuce, toe web and vulva.
- Pulse oximeters display a digital record of pulse rate, with an audible beep and some monitors display the oxygen saturation waveform. The pulse oximeter displays a continuous waveform or signal together with a numerical oxygen saturation value written as SpO_2. Most pulse oximeters also display pulse rate.
- Normal pulse oximeter readings in anaesthetized animals should be 99-100%. Haemoglobin oxygen saturation (SpO_2) of 90% corresponds to PaO_2 of 60 mmHg which provides definition of hypoxemia if lower than this value. The percent of saturation gives an indication of the adequacy both of ventilation and of circulation.
- Oxygen-haemoglobin dissociation curve is a graphic representation of the relationship between the percentage of oxygen saturation of haemoglobin (SaO_2 or SpO_2) and the partial pressure of oxygen in the arterial blood (PaO_2). $SpO_2$is related to PaO_2 by a sigmoid relationship (the oxyhaemoglobin dissociation curve). This means that the SpO_2will remain high as the PaO_2 falls and the SpO_2will only fall when the PaO_2 has reached low levels. In this respect, the pulse oximeter has been described as a 'cliff - edge monitor' because by the time SpO_2falls (below about 90%) the actual PaO_2 has already fallen markedly.
- A pulse oximeter gives no information on any of these other variables such as oxygen content of the blood; amount of oxygen dissolved in the blood; Respiratory rate or tidal volume, i.e. ventilation and cardiac output or blood pressure.

Interpretation of pulse oximeter data

SpO_2	PaO_2	Action required
100%	-100 mmHg or more	Normal monitoring and actions appropriate
90%	-60 mm Hg	Inform Veterinary surgeon Ensure adequate ventilation (airway, RR, V_t, O_2 supply and CO_2 clearance) Increase F_iO_2 to 100% (turn off nitrous oxide and flush breathing system) Assess cardiac function
75%	-40 mmHg	Consider patient positioning, surgical effects (e.g. pneumothorax), medical disorders (e.g. pulmonary interstitial fibrosis)
50%	-27 mmHg	Equivalent to a normal PvO_2 value

IV. MONITORING OF BODY TEMPERATURE

➢ The continuous measurement of patient body temperature should also be monitored during general anaesthesia to avoid accidental hypothermia or detect malignant hyperthermia. Hypothermia leads to reduced cellular metabolism, decreased anaesthetic requirements (danger of overdosage), delayed recovery, bradycardia and increased morbidity. General anaesthesia inhibits thermoregulation, vasoconstriction and shivering, thereby decreasing the threshold for cold responses. The greatest loss in body heat occurs within the first 20 minutes of anaesthesia. Cold surfaces and excessive use of cold scrub solutions should be avoided. Body temperature should always be monitored during prolonged surgery of the body cavities. Electronic thermistor probe is commonly placed either in rectum or esophagus for continuous temperature monitoring. The temperature should be checked at the end of anesthesia to see whether external heating is required. The animal in low body temperature will increase muscle contraction to raise body temperature at the time of recovery. Majority of heat loss in an anaesthetized patient occurs through evaporation. The various ways to prevent hypothermia during anaesthesia are following-

1. **Heat lamps**: Care must be taken to avoid thermal injury if lamps are placed too close to the patient. Infra-red lamps should be at least 100 cm from the surface of the patient.

2. **Electric heat pads**: These warm up very quickly but are one of the main causes of burns in veterinary patients. Therefore, heating pads should always be set at the low setting and sufficient bedding should be placed between the patient and the pad. The patient should not be placed directly on to the pad.

3. **Circulating warm air blankets (BAIR huggers):** These blankets circulate warm air through fenestrated, disposable, sterile blankets. They minimize the risk of localised thermal

necrosis of the skin because there is no direct heat contact with the skin. They come in various shapes and sizes and can be used underneath, over or can envelope the patient. Fluid warming coils can be placed into the tubing which connects the blanket to the machine. These have a thermal marker indicating the temperature reached.

4. **Recirculating water** - filled thermostatically controlled pads: These are mostly used on operating tables and are very effective in warming patients. However, there is a risk of piercing the pad with claws, needles etc. making them less suitable for the recovery period.

5. **Simple hot water bottles, heated intravenous fluid bags and water - filled gloves**: It is important that the patient is protected from direct contact with the bottle, bag or glove, which should be wrapped in either bubble wrap or fabric. Heated fluid bags should be mixed well before using, as there may be hot spots within the bag if they have been warmed in the microwave. These forms of warming need to be changed regularly as they lose heat quite quickly.

6. **Drip line warmers or heated intravenous fluids**: Drip line warmers can be used to warm the fluid line closer to the patient as opposed to fluid bag warmers where the fluid has to travel down the fluid line.

7. **Reusable wheat or cherry - stone filled bags**: These can be heated in a microwave and retain their heat for several hours. Remember to protect the patient from direct contact with bag.

8. **Incubators**: These are an effective way to warm the patient but are only really suitable for small dogs and cats. Oxygen can be administered through a port into the incubator and the patients are easily observed. A number of small doors/hatches enables contact with the patient without losing too much heat by opening of the main door.

9. **Reflective aluminium space blankets (Mediwrap ®) and plastic bubble wrap**: These are good insulators for small patients, and can be disposed of if they become soiled. They do not provide a heat source as such but do reduce further radiant heat loss in the recovery period. Bubble wrap can be used during anaesthesia to cover the head, feet, limbs and body where access is not required.

- **Hyperthermia-** Hyperthermia developing in dogs and cats is most often caused by either excessive application of heat in an attempt to prevent hypothermia or by a pyrogenic reaction to a bacterial infection, a contaminant in IV fluids or drugs. Other causes of intra-operative hyperthermia are loss of central nervous system temperature regulation, thyrotoxicosis or phaeochromcytoma. Hyperthermia is sometimes manifested by malignant

hyperthermia syndrome, which is a life threatening hypermetabolic condition triggered by stress and certain anesthetic agents. Hyperthermia can develop in cats during recovery from anaesthesia that were induced with tiletamine-zolazepam or ketamine. Increased temperature is associated with increased muscle activity such as paddling, uncoordinated movements or purposeful movements directed at restraints or bandages.

V. MISCELLANEOUS

A. Monitoring Urine Volume/ Urine ouput

➢ The primary purpose of monitoring includes avoiding excessive distension of the bladder, as an indicator of renal perfusion, adequacy of blood and fluid therapy. Urine output depends on the renal blood flow which in turn depends on cardiac output and circulating blood volume, thus it is relatively sensitive indicator of the circulatory state during anaesthesia. Horses with full bladders will most likely have a rough recovery from anaesthesia; it is always a good idea to catheterize them for procedures that require anaesthesia for longer than one hour. Urine output should be maintained at 1-2 ml/kg/hour. Urine output of less than 0.5-1ml/kg/hour is inadequate. Oliguria may be treated with one, or in combination of the following agents-

- Fluids (e.g. Ringer lactate solution) at 15-40 ml/kg/hr
- Furosemide at 2-5 mg/kg IV or 1 mg/kg/hr
- Mannitol or dextrose at 0.25-0.5 g/kg IV over 5-15 minutes
- Dopamine at 1-5 mcg/kg/min IV

B. Monitoring Blood Glucose

➢ Should always be monitored in pediatric patients, diabetics, patients with hepatic disease, portal systemic shunts, insuloma, septicemia or endotoxemia. Consequences of hypoglycemia are coma, hypotension, or prolonged recovery from anesthesia with depression weakness or even seizures. Patients at risk should be given dextrose in some form during fluid therapy.

C. Monitoring Post-operative Pain

➢ Pain assessment should be continued throughout the entire anaesthetic period. Parameters that should be evaluated to assess pain includes respiratory rate and pattern, heart rate, anxiety, vocalization, body position and response to manipulation and palpation. Evaluate what analgesic drugs were given peri-operatively and the time they were administered. Opioid agonists can induce dysphoria in some animals, which can be mistaken as vocalization due to pain.

D. Anaesthetic Record Keeping

➢ In order to achieve the best out of monitoring equipment it is advisable to maintain a written record of every anaesthetic procedure. Minimal data to be entered into an anaesthesia record are patient identification, operative procedure, significant preoperative findings in patient's record, amount and route of anaesthetic agents and other drugs, monitoring of heart rate and breathing rate, and complications. Monitored variables such as heart rate and breathing rate are recorded at regular intervals with minimum of 10 minutes apart, although 5 minute interval recording is a common practice during anaesthesia in Veterinary practice. Anaesthetic records are useful for four main reasons- 1) Trends in patient variables to be noticed, at an early stage. 2) An archive of anaesthetic records will be useful to compare similar cases and establish statistical analysis 3) Record keeping will aid the inexperienced personnel concentrate and improve their standard of patient monitoring. 4) In cases where the anaesthetic management of a case needs to be defended, an anaesthetic record is of enormous worth both as a reminder of the details of the individual cases and as evidence of the general standard of care given by the veterinary practice. To be admissible anaesthetic record must be contemporaneous i.e. it must have been made at the same time that the anaesthetic was given.

References

[1] Bhavani-Shankar, K., Moseley, H. and Kumar, A.Y. (1992): Capnometry and anaesthesia. *Can J Anaesth* 39(6):617–632.

[2] Brodbelt, D., Brearley, J., Young, L., Wood, J. and Pfeiffer, D. (2005). Anaesthetic-related mortality risks in small animals in the UK. *AVA Spring Meeting, Rimini, Italy 20–23 April 2005.*

[3] Lee, L (1995). The American College of Veterinary Anesthesiologists guidelines of anaesthetic monitoring JAVMA 206 (7): 936-937

[4] Muir, W.W. (2007) Considerations for general anesthesia. In: Tranquilli, W.J., Thurmon, J.C., Grimm, K.G., eds. Lumb and Jones' veterinary anesthesia and analgesia. 4th ed. Ames: Blackwell; 17–30.

[5] Palmer, D. and Branham, T. Anaesthesia monitoring. From Internet *wsvma.site- ym.com/associations /2620/ files/022%20**Branham**.pdf*

[6] Seymour, C. and Gleed, R. (1999). (eds) BSAVA Manual of Small Animal Anaesthesia and Analgesia 1999.

[7] Thurmon, J., Benson, J. and Tranquilli, W. (1996). Veterinary Anesthesia, Williams and Wilkinson.