Supportive Therapy in the Anesthetized Horse

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As veterinarians become more familiar with use of the anesthetic drugs, longer and more involved surgical procedures may be attempted. As duration and difficulty increase, the likelihood of complications can also increase. Assessment of anesthetic depth, attention to monitoring blood pressure in anesthetized horses, and use of medication to treat hypotension can reduce the incidence of complications and improve outcome.

MONITORING

Monitoring the depth of anesthesia of equine cases makes a strong contribution to the overall success of any anesthetic protocol.[1,2] Because some of the species characteristics of the adult horse make treatment of anesthetic emergencies and post-anesthetic complications more difficult,[3] treatment can often be unrewarding. Since the consequences can be so severe, additional emphasis needs to placed on prevention along with therapy. While anesthetic emergencies often arrive seemingly without warning, good monitoring techniques often show development of trends that inform the anesthetist that the animal's condition is deteriorating far in advance of cardiac arrest or myopathy-neuropathy and allow institution of corrective measures. Precise monitoring then enables the individual to tailor administration of anesthetic drugs to fit that animal's particular need so that the insult to the cardiovascular, respiratory, central nervous, and musculoskeletal systems is minimized, thereby decreasing the risk of anesthetic complications.

In contrast to other species, horses tend to maintain heart rates in the normal range as the depth of anesthesia increases.[4] After they are no longer able to compensate, heart rate may fall precipitously and/or cardiac arrest occurs. Thus, changes in heart rate due to excessive depth or as an exaggerated response to the anesthetic drugs usually do not give sufficient lead time to the anesthetist to alter depth of anesthesia before complications occur. Thus monitoring blood pressure in addition to assessing pulse strength is highly recommended in horses under inhalation anesthesia in order to improve patient safety.

Arterial pressure provides an accurate variable for assessing depth of anesthesia. In most instances, changes in depth of anesthesia become evident quickly through increases or decreases in blood pressure before changes in other variables are noted. Additionally, it is a more definitive variable than monitoring pulse pressure alone. Monitoring pulse pressure by digital palpation determines the difference between systolic and diastolic pressure. A horse with systolic/diastolic pressure of 120/90 mm Hg will have pulse pressure similar to that of a horse with pressures of 90/60 mm Hg. However, a large difference in mean arterial pressure (MAP) or perfusion exists. The former horse will have MAP of about 100 mm Hg while the latter horse will have MAP of about 70 mm Hg. Since horses with low MAP under anesthesia are more at risk for developing myopathy, [5,6] identification of this situation is important.

Arterial pressure can be monitored either indirectly or directly. Indirect methods of determining arterial pressure require the use of various infrasonic and ultrasonic devices to detect blood flow in peripheral arteries.[7-9] Direct methods require catheterization of a peripheral artery and the use of a pressure transducer and amplifier or an aneroid manometer to determine pressure values.

The Doppler methods utilize the return-to-flow principle. A probe is placed over a superficial artery, usually the coccygeal artery, and fixed in place. A blood pressure cuff is placed around the base of the tail and connected to a manometer. The width of the cuff should be 40% of the circumference of the tail.[10,11] The cuff is inflated to a point where all blood flow to the tail is prevented and then the manometer is observed as the pressure in the cuff is slowly released. An audible signal will be heard when cuff pressure equals systolic pressure. As cuff pressure continues to decline, a change in tone or pitch of the signal will occur. This point is noted as diastolic pressure. It is important that the cuff be slowly deflated if this method is to be accurate. Since horses have relatively slow heart rates, rapid deflation of the cuff causes the anesthetist to underestimate pressure values because cuff pressure drops too rapidly between heart beats.

This technique is easily performed and gives accurate systolic pressures.[7,8] The potential for error in determining diastolic pressure is greater because of varying ability of people to detect changes in sound. Other sources of error are faulty probe placement (if the probe is not placed directly over the artery, low pressure values are often obtained), incorrect cuff size (pressure values are underestimated when the cuff is too large and overestimated when the cuff is too small), and abuse of the probe (causing it to be less sensitive and provide erroneously low pressure values). Another disadvantage is the expense of the unit, ranging from $400-$800.

The Dinamap® and other similar instruments utilize the oscillometric method to determine systolic, diastolic, and mean arterial pressures. It is used with a cuff applied to the horse's tail, similar to the Doppler method. The instrument can be programmed to automatically inflate and deflate the cuff at predetermined intervals and will display a digital value for all three pressures along with pulse rate. The only problem with older units designed for human use has been inaccuracy when the heart rate is less than 28 beats/minute or if heart block is present during anesthesia.[12] Newer models are available that are accurate with heart rates as low as 16 beats/minute. Some of the other instruments similar to the Dinamap® will display an ECG instead of providing only the heart rate along with the blood pressure values. New units cost about $3,000. However, as is the case with other pieces of equipment, used indirect BP units (either designed for human or veterinary use) are available at considerable savings.

The classical method of determining blood pressure is the direct method, involving catheterization of a superficial artery and the use of a pressure transducer and amplifier. The pressure transducer converts the pressure generated within the artery into an electrical signal, which is then conducted to an amplifier and displayed on an oscilloscope. Several precautions must be observed to eliminate errors with this method. The transducer must be calibrated prior to use. All air bubbles must be removed from the system, and thrombi cannot be allowed to form in the catheter. Thirdly, the transducer must be placed at the level of the heart, sternal midline if the horse is in lateral recumbency and the lateral tuberosity of the humerus if the horse is in dorsal recumbency, to prevent the hydrostatic effects of blood serving as a source of error.[13] With this system, it is possible to obtain systolic, diastolic and calculated mean arterial pressure values along with a visually displayed waveform on the oscilloscope. After the catheterization technique is learned, this system is easy to use and generates much accurate

information if all the precautions for use are followed. The main disadvantage to this system is its cost, in the range of $4,000 - $8,000, with the price varying depending on the number of variables measured and other features (ECG, 1-2 BP channels, pulse oximetry, recorder, battery, etc.). However, used ECG/BP units (either designed for human or veterinary use) are available at considerable savings.

An aneroid manometer can be substituted for the pressure transducer and amplifier.[9] The response time of the aneroid is slower, so only MAP and not systolic and diastolic pressure values can be obtained. When connected to the arterial catheter, the needle of the aneroid will deflect with each heartbeat. The uppermost deflection of the needle is taken as MAP. The same precautions regarding catheter patency and manometer placement must be followed with this method as with a transducer. The aneroid manometer system is accurate, simple and inexpensive (aneroid manometers from home blood pressure kits cost about $35). If the precautions are followed, an accurate value slightly less than actual MAP can be determined. The main disadvantage is the aneroid's slower response time, preventing determination of systolic and diastolic pressures. However, changes in MAP do occur rapidly in response to changes in anesthetic depth and use of the system allows the anesthetist to make appropriate responses.

Percutaneous arterial catheterization is easily performed in horses and shown to be free of complications.[14] The facial artery and dorsal metatarsal artery are most commonly catheterized. If desired, the transverse facial or palmar or plantar digital arteries can be catheterized. Over-the-needle teflon catheters are preferred due to lower incidence of hematoma and thrombus formation. Passage of this type of catheter through the unbroken skin of horses will damage the catheter, making arterial placement difficult. Thus incising the skin or piercing it with a slightly larger needle at the catheterization site is recommended. For adult horses, 3-5 cm 18-20 gauge, catheters are used with 2.5-3 cm 20-22 gauge catheters being used in foals. An extension set with a two-way stopcock is used to connect the arterial catheter to a syringe containing heparinized (2.0 units/ml) saline, and to a piece of noncompliant tubing attached to the pressure transducer or aneroid manometer. Vascular injury resulting in ischemia and necrosis can occur if irritant solutions are injected into peripheral arteries.[15,16] Every effort must be made to avoid inadvertent injection of those compounds through arterial catheters. Following removal of the arterial catheter, digital pressure is maintained at the site to prevent hematoma formation. If desired, a pressure bandage can be used.

Normal values for arterial pressures in anesthetized horses are given in Table 1. Blood pressure values should be recorded at 5 minute intervals. When using one of the direct methods for assessing blood pressure, the catheter should be flushed with heparinized saline just prior to recording the pressure values to prevent early thrombus formation from affecting the data. Manual or mechanical ventilation will influence the pressure values. The most accurate values are those obtained between the respiratory excursions.

Variable		Normal Value
Heart rate	Adults	30-50 beats/minute
	Foals	60-90 beats/minute
Systolic Pressure	Adults	90-120 mm Hg
	Foals	80-100 mm Hg
Diastolic pressure	Adults	55-90 mm Hg
	Foals	45-80 mm Hg
Mean arterial pressure (MAP)	Adults	75-100 mm Hg
	Foals	65-90 mm Hg

Table 1. Normal values for heart rate and blood pressure in anesthetized horses.

Hypotension implies excessive depth of anesthesia, shock, or an exaggerated response to the anesthetic drugs, while increasing blood pressure values imply an improvement in cardiovascular status or a decrease in depth of anesthesia. Depending upon the preanesthetic tranquilizer and induction technique, some horses will be hypotensive (MAP 55-70 mm Hg) at the beginning of anesthesia. As the induction agents dissipate and the horse equilibrates under anesthesia, blood pressure should rise rapidly and be normal within 20 minutes. Supportive therapy for these individuals is usually not necessary if certain criteria are met: pulse pressure must be strong, the vessel should not be easily collapsed during diastole by digital compression, the color of the mucous membranes must be good and capillary refill time quick, and it must be during the early postinduction period with the arterial pressure increasing with each determination. Failure to meet these criteria implies that appropriate therapy is indicated.

CARDIOVASCULAR SUPPORTIVE THERAPY

Hypotension in anesthetized horses is common and can often be corrected by adjusting anesthetic depth. Mean arterial pressure of at least 75 mm Hg or systolic pressure of 100 mm Hg and diastolic pressure of 60 mm Hg should be maintained. When movement occurs or would be expected to occur before MAP of 75 mm Hg is obtained, therapy is indicated to restore normotension and minimize the incidence of post-anesthetic myopathy.[5,6] Vasopressors can be used to correct hypotension. However, use of drugs that improve cardiac output and expansion of vascular volume with rapid fluid administration are better alternatives.[17]

Fluid administration during anesthesia will correct pre-existing dehydration if present, provide volume to offset anesthesia related vasodilatation, and provide maintenance needs. A polyionic isotonic solution with an alkalinizing effect is preferred. Lactated Ringer's or Normosol-R® are most commonly used and are administered rapidly (10-25 ml/kg/hr) during the early phases of anesthesia since horses are commonly hypotensive then. After hypotension is corrected, fluid administration may be slowed to 5-6 ml/kg/hr. To increase fluid delivery rate if needed, two administration sets can be connected to one catheter with a Y-connector, multiple catheters could be placed, or a peristaltic pump may be used. For convenience, fluids packaged in 3 or 5 liter bags can be used for large volume administration. Hypertonic saline (5-7%) may also be considered.[18] When large volumes of fluid are administered, serial determinations of hematocrit and plasma total solids should be performed to prevent excessive fluid administration and

subsequent hemodilution and pulmonary edema. Hematocrit should remain above 28% and plasma total solids above 4 gm/dl. Plasma or whole blood transfusion should be considered in hypoproteinemic or anemic individuals.

In horses that are sufficiently bradycardic to influence cardiac output (HR < 35 bpm), atropine (0.015 mg/kg IV) or glycopyrrolate (5.0 µg/kg IV) can increase heart rate and thus increase cardiac output and MAP. Rarely atropine will cause heart block before an increase in heart rate is obtained. Atropine or glycopyrrolate usually do not produce as much of a response in MAP when the heart rate exceeds 40 bpm. It is preferable not to use these drugs if the surgical procedure involves the gastrointestinal tract. When hypotension without bradycardia occurs, inotropes are preferred to increase stroke volume and cardiac output. Calcium gluconate (23% solution) increases myocardial contractility and is given as a slow intravenous infusion (1.0 ml/kg/hr) to effect. Often calcium administration can be discontinued after MAP reaches normal levels. Calcium gluconate administration can cause bradycardia, necessitating atropine administration if hypotension is still present. Ephedrine, a mixed alpha and beta compound, can be used at (0.02-0.06 mg/kg IV) to elevate MAP. It does so through an increase in cardiac contractility.[19] Typically ephedrine could be expected to increase by 10-15 mmHg with a duration of effect of 45-60 minutes. Lack of response at low doses indicates excessive depth of anesthesia.

Dobutamine, a synthetic beta catecholamine, can be used to improve cardiac output. At low doses it increases myocardial contractility and at higher doses it can affect heart rate. Overdosage causes tachycardia and arrhythmias in most species but horses often experience bradycardia and heart block with excessive doses of dobutamine. Dobutamine is recommended over dopamine because improvement in hemodynamics occurs with smaller increases in heart rate.[20] It should be administered at 1.0-2.0 µg/kg/min IV to effect.[3,17] After hypotension has been corrected, the rate of administration can be decreased to a maintenance value, usually 25-50% of the initial rate. Some horses will become sufficiently bradycardic during dobutamine administration that heart rate limits cardiac output. Those horses will also benefit from a chronotrope. There is tremendous synergism between atropine and dobutamine. Giving normal doses of atropine to a horse already receiving the loading dose of dobutamine can produce a heart rate of greater than 100 beats/minute. Conversely, beginning an infusion of dobutamine in a horse that has already received atropine can cause marked tachycardia. In the adult horse that becomes bradycardic while remaining hypotensive during dobutamine administration, one would discontinue dobutamine administration for about five minutes and then administer 1-1.5 mg atropine IV to increase heart rate. Often continuation of dobutamine infusion will be required and should be re-instituted at a reduced rate (0.2 - 0.6 µg/kg/min IV) to avoid tachycardia. Should tachycardia occur (HR > 50 beats/minute), infusion of dobutamine should be discontinued for five to ten minutes until heart rate slows and continued when needed at a lower administration rate if hypotension re-occurs.

To prepare a solution for infusion, 62.5 mg (5.0 ml) of dobutamine is added to 250 ml saline. Initially, a 454 kg horse would receive 1.0-2.0 µg/kg/min (0.5-1 mg/min) corresponding to 2-4 ml of this solution/minute. Using a standard IV set (15 drops/ml), 0.5-1 drop/second is the recommended infusion rate. It is preferable to place a separate 20 gauge venous catheter for gravity administration of dobutamine so that adjustment of the administration set and flow rate is not affected by the hydrostatic pressure of other concurrently administered intravenous fluids. Use of an infusion pump to administer the drug is recommended for both convenience and consistency. IVAC® or Travenol® type infusion pumps can be used with the above preparation.

Graseby,® Baxter,® or Medfusion® style syringe pumps with syringes containing dobutamine diluted to 1 mg/ml with saline can be used.

In conclusion, attention to detail is important during equine anesthesia. As surgical procedures become more lengthy and involved, the effects of hypotension, become more important and have the potential to influence the outcome of the case where they would have little effect on horses anesthetized for shorter periods of time. Because anesthetic emergencies and postanesthetic complications can be difficult to treat in the horse, emphasis must be placed on prevention of these complications. Monitoring blood pressure and correction of hypotension in the anesthetized horse along with assessment of the other variables used to monitor depth of anesthesia can help accomplish that goal.

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