

## Treating Intraoperative Hypotension

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**Hypotension**, or low blood pressure, (mean arterial blood pressure [MAP] <60 mmHg in small animals or <70 mmHg in horses) is the second most commonly reported anesthetic complication (hypoventilation is the most common anesthetic complication). Hypotension often occurs secondary to excessive anesthetic depth. Hypotension leads to decreased blood flow (and therefore decreased oxygen delivery) to organs and tissues and the consequence of hypotension depends on which organ or tissue is affected. Organs with high oxygen consumption are most vulnerable to damage and this includes the kidneys, brain and myocardium.

Unfortunately, many of the anesthetic drugs that we use (primarily the inhalant anesthetics) contribute to hypotension. Also, our patient profile has changed over the last several decades and we are more likely to be anesthetizing patients that are not in the 'young, healthy' category and these patients (neonates, geriatrics, patients with advanced disease, etc...) are much more likely to develop hypotension under anesthesia.

### Causes of hypotension

- The cardiovascular system is just like any other system with fluid that needs to be circulated. The system requires a pump (the heart), some fluid (blood) and pipes (blood vessels). Adverse changes in any of these components can be caused either by the patient or by the anesthetist, and can cause a decrease in pressure. Changes include:
  - Inadequate pump function (heart rate too slow or too fast; heart muscle (myocardium) not contracting normally. Causes:
    - Patient disease (cardiovascular disease or disease that causes cardiovascular changes)
    - Anesthetic drugs: Contractility primarily inhalants; rate primarily opioids; propofol can affect rate & contractility
  - Inadequate circulating blood volume. Causes:
    - Patient disease (dehydrated, blood loss, protein loss)
    - Vasodilation causes the blood not to circulate. The blood is still there but because the vessels are large, there is no driving force to make the blood move around the body. So there is inadequate volume that is circulating. Causes: anesthetic drugs, inhalants; acepromazine might contribute if the dose is high or if the patient is already vasodilated (like a patient that has been hemorrhaging or is in shock)
    - Evaporation from airways & body cavities (this is normal and is treated by administering IV fluids)
  - Blood vessels excessively dilated. The blood vessels will always dilate a little when inhalant anesthetics are used but excessive dilation is uncommon. Causes:
    - Patient disease (eg, shock)
    - Anesthetic drugs: Primarily inhalants; acepromazine might contribute if the dose is high or if the patient is already vasodilated (like a patient that has been hemorrhaging or is in shock).

### Identifying hypotension

- **Direct measurement of arterial blood pressure** using a catheter placed in a peripheral artery is the most accurate way to determine blood pressure but is not necessarily the most practical way. In a few practices with a high volume of critical patients, direct arterial blood pressure measurement might be appropriate. However, for most practices, the technique is too time-consuming and cumbersome and is not necessary in most patients. The exception is surgical equine practice. All horses anesthetized with inhalant anesthesia should be monitored using direct arterial blood pressure.
- **Doppler** - provides audible indication of blood flow (comforting!), can be used for monitoring heart rate and for determining blood pressure (systolic - so maintain above 90 mmHg). This is my absolute favorite monitor for the price (relatively inexpensive) and utility (extremely useful). However, the monitor does take a bit of work to set up (shave the skin, appropriately place the probe, tape on the probe, manually measure blood

pressure) and some experience to use the unit well. TIP: We are underutilizing this tool! Use for measuring blood pressure in anesthetized patients, in patients with hypertensive disease (eg, renal disease, hyperthyroidism, etc...) and in patients with likelihood of hypotension (eg, hypothyroidism or shock from trauma, etc...). Use for heart rate in exotic species - works great in pocket pets, birds, snakes, etc.... All you have to do is find an artery!

- **Oscillometric blood pressure monitors** - these units are easier to use than Dopplers (just put the cuff on and press start) and generally provide consistent readings in medium to large patients. However, readings may not be consistent in small patients (eg, cats), patients with arrhythmias, patients that are moving (or shivering) and extremely hypotensive patients. Thus, having a Doppler AND an oscillometric unit is often a wise choice.
- **Recommendation:** Every clinic should be monitoring blood pressure in as many patients as possible. Blood pressure is one of the most important, and most frequently changed, parameters in the anesthetized patient. If you don't have a blood pressure monitor, get one. If you have one and aren't using it, start using it as often as possible.
- **TIP:** The width (but not the length) of the blood pressure cuff is crucial to getting appropriate blood pressure measurements. The cuff width should be approximately 40% of the circumference of the limb that the cuff will be placed on. Cuffs that are too wide cause falsely low readings while cuffs that are too narrow cause falsely high readings.
- **TIP:** The height of the cuff in comparison to the heart is also crucial and the cuff should be placed level with right atrium. A cuff that is above the level of the right atrium will cause falsely low blood pressure readings while one that is below the level of the right atrium will cause falsely high blood pressure readings.
- **From the literature:** In cats, the 'systolic' blood pressure measured oscillometrically or by Doppler is probably not actually systolic pressure but is a pressure that is somewhere between systolic and mean. Thus, we should strive to get a value >60 mmHg but perhaps it doesn't have to be as high as 90 mmHg.

#### **Step by Step Treatment of Hypotension** (*See the flow chart at the end of the notes*)

- **STEP 1: Stabilize the patient.** Treatment of hypotension should start BEFORE the patient is anesthetized. Factors that are known to contribute to hypotension include increasing American Society of Anesthesiologists (ASA) score, low preoperative blood pressure and high dosages of induction drugs. We can compensate for this by:
  - Stabilizing the patient and (hopefully) decreasing the ASA score.
  - Improving preoperative blood pressure by administering IV fluids.
  - Premedicating the patient with a sedative or analgesic drug so that high dosages of induction drugs are not necessary.
- **STEP 2: Decrease the dose of inhalant.** The anesthetic gases contribute more to hypotension than any other drug that we use in anesthesia. Decreasing the inhalant dose (ie, turning down the vaporizer) generally improves the blood pressure. In order to decrease the inhalant dose, extra analgesia may be required. Analgesia is best supplied by:
  - Boluses of opioids
  - Local or regional anesthetic blockade
  - Constant rate infusion of analgesic drugs
- **STEP 3: Give a fluid bolus:** Fluids 1) replace fluid deficits that were already present (eg, dehydration, blood loss); 2) replace fluids that will be lost during surgery (eg, urine production, evaporation from the airway, evaporation from open body cavities, blood loss); and 3) counteract some of the effects of inhalant-induced vasodilation by filling the vessels, which decreases 'pooling' of the blood in the vessels and causes the blood to circulate better.
  - Normally we start with crystalloid fluids because crystalloids have an electrolyte composition that is similar to body fluids (ie, high in sodium). Thus we are replacing lost fluid with a fluid that has a similar composition to that of the lost fluid. That is why we call crystalloids **replacement fluids**.
  - Fluids should be administered at an appropriate rate (anywhere between 3-20 mls/kg/hour depending on the patient) and boluses should be used to increase blood pressure.

- The volume of the bolus will depend on the patient. Here are some guidelines:
  - Large bolus (5-20 mls/kg) if the patient is severely hypovolemic, dehydrated or is losing a lot of fluid intraoperatively (losing blood, evaporation from a large open body cavity, etc...). Can be repeated as needed to rehydrate the patient and replace losses. If the blood pressure does not increase with fluid boluses or if the pressure is REALLY low (MAP<40 mmHg), add Step 4 (colloids).
  - Medium bolus (5 ml/kg) if the patient is already hydrated and not losing a lot of fluids (most of our patients fit in this category). Can be repeated 2-3 times but if the patient is well-hydrated and the losses are being replaced, continuing to give crystalloids probably won't help the pressure so move on to Step 4 (colloids).
  - Small bolus (2-5 ml/kg) if the patient has cardiovascular disease (the heart can't pump a lot of extra fluid) or low protein (we don't want to cause further dilution of the patient's protein – remember that crystalloids do not contain protein). Boluses usually not repeated. Move on to Step 4 or even Step 5 depending on the patient.
- **STEP 3: Check the heart rate (HR) and fix if necessary. Yes, this is also Step 3!!** As the fluids are being administered, check the heart rate and decide if it is too slow or too fast and fix it.
  - A low heart rate can contribute to hypotension because heart rate is a component of blood pressure (Blood Pressure = Cardiac output [HR x contractility of the heart muscle x amount of blood in the heart] x Systemic vascular resistance [which is the tone of degree of constriction of the blood vessels])
    - Both atropine and glycopyrrolate are appropriate. If possible, administer the anticholinergic IM. The heart rate increases by a greater magnitude when the anticholinergic is administered IV. Increased heart rate = increased cardiac work.
    - Atropine dose: 0.04 mg/kg; Glycopyrrolate dose: 0.01 mg/kg
    - REMEMBER: Don't increase the HR just because it is low – ONLY increase it if blood pressure is also low. Alpha-2 agonists (eg, dexmedetomidine or Dexdomitor) cause low heart rates but HIGH pressures.
  - A really high heart rate can also contribute to hypotension because the heart does not have time to fill up with blood if it is beating too fast. If it can't fill up with blood, it doesn't have any blood to push into the circulation, so blood pressure goes down.
    - Treat a really high heart rate by treating the condition that is causing it. Causes: pain, hypoxemia (low oxygen), hypercarbia (high carbon dioxide), inadequate circulating volume (eg, blood loss), etc...

**Now let's look at our patient!** In many patients, these steps will return the blood pressure to normal. We wait about 5-10 minutes after making the changes above and, if the blood pressure is increasing (the blood pressure may not be normal yet, but it should be increasing), then we can wait another 5-10 minutes before making further changes. HOWEVER, if it is not increasing in 5-10 minutes, we need to move to the next step. What is the next step? It depends on the patient (see the flow chart at the end of the notes for more information). If the patient is still dehydrated, still losing a lot of fluid or is responding to the crystalloid boluses, keep giving boluses! If not, let's move on to the next step.

- **STEP 4: Increase the circulating volume:** We can use colloids to do this. Remember that crystalloids replace lost fluids and crystalloids are distributed to all the places where fluid might be lost (circulation, tissues, etc...) and this helps blood pressure if fluid loss is the only problem. BUT, sometimes the patient really needs more volume in the vessels and colloids are big molecules which stay in the vessels and do not distribute to all of the tissues. Because this increased volume improves perfusion of the organs, we call colloids *perfusion fluids*.
  - The volume of the colloid bolus will depend on the patient. Here are some guidelines:
    - 2-5 ml/kg if the patient has a healthy heart (most of our patients fit in this category). Can be repeated for a total dose of 20 ml/kg.
    - 2 ml/kg if the patient has cardiovascular disease (the heart can't pump a lot of extra fluid whether it is crystalloids or colloids) or low protein (we don't want to cause further dilution of the patient's

protein – remember that colloids do not contain protein). Usually not repeated in these patients. Move on to Step 5.

Again, wait 5-10 minutes. If no improvement, either repeat the colloid bolus (if appropriate) or go to Step 5 (ie, improve contractility). If you know the patient has a heart that is not healthy and not contracting normally, Step 5 should be initiated within 10-20 minutes of starting anesthesia. If you think that the patient's heart is healthy but you have done all of the other steps and the blood pressure did not improve, then the patient either doesn't have a healthy heart OR the inhalant anesthetics are causing a major impact on myocardial contractility. Either way, go to Step 5.

- **STEP 5: Improve contractility:** If volume expansion and increased heart rate are ineffective or if the heart is not capable of appropriate contraction (eg, in patients with myocardial disease or diseases that affect myocardial contractility – like hypothyroidism or sepsis), a positive inotrope should be utilized. Positive inotropes increase the heart's contractility.
  - The most commonly used inotropes are *dopamine* and *dobutamine* (dosage 1-10 microg/kg/min for both drugs; Table 1) and both must be administered as constant rate infusions.
  - Dobutamine is slightly more potent at the beta receptors (greater contractility) but dopamine has a slight alpha effect (some vasoconstriction).
  - If both drugs are available and one fails to increase the blood pressure, it is appropriate to try the other drug or even to administer both simultaneously.

ALMOST ALL of our patient's will respond to these 5 steps. Rarely do we need to go to Step 6, but if the patient is excessively vasodilated (eg, patients in shock), then Step 6 will be necessary to improve blood pressure.

- **STEP 6: Decrease vasodilation.** If cardiac contractility is presumed normal or if dopamine and/or dobutamine fail to increase blood pressure, a vasopressor should be used.
  - *Norepinephrine* (0.05-0.4 microg/kg/min; generally start 0.1 microg/kg/min and increase as needed) activates beta receptors and has a very potent effect at the alpha receptors. Norepinephrine is useful in septic patients and in patients receiving beta-blocking drugs like propranolol or atenolol. The profound vasoconstriction could lead to tissue ischemia but this is unlikely to be of clinical concern in most patients when dosages within the normal range are administered.
  - *Phenylephrine* (1.0-2.0 microg/kg bolus and 1.0 microg/kg/min infusion - increase as needed) activates primarily alpha receptors. It is often used with dobutamine for potent beta effects in combination with the phenylephrine-induced alpha effects. Less likely than norepinephrine to cause increased heart rate.
  - *Epinephrine* (0.05-0.4 microg/kg/min; generally start at 0.1-1.0 microg/kg/min) provides potent effects at both beta and alpha receptors but also increases cardiac work, myocardial oxygen consumption and the potential for arrhythmias (especially in some anesthetized patients). As with norepinephrine, the profound vasoconstriction could lead to tissue ischemia. Epinephrine is generally reserved for patients that do not respond to other support.
  - *Vasopressin* is potent nonadrenergic vasoconstrictor that has no inotropic effects. Vasopressin stimulates specific V1A receptors in the smooth muscle of the vasculature, leading to vasoconstriction. Boluses (0.2-0.8 U/kg IV) or an infusion can be administered to treat catecholamine-resistant hypotension. Vasopressin is especially useful in patients with septic shock since the patients are generally profoundly vasodilated and catecholamines may be ineffective in the acidic environment of the blood and tissues. As with the other vasoconstrictive drugs, profound vasoconstriction could lead to tissue ischemia.

### Final notes on fluid therapy

Crystalloids and colloids are the main fluids used during anesthesia but don't forget to replace what is lost. So if a patient has lost a lot of protein or blood, then plasma, packed red blood cells, or whole blood should be administered. Also remember that fluid therapy is not benign. Fluids should be thought of similarly to the way we think about drugs. That is, they are a tool that can be used – and abused --- and abuse can lead to adverse effects. Excessive fluids create increased work for the heart and can cause edema. Fluids should be administered to meet, but not exceed, the patient's needs. Also, specific fluids can have specific adverse effects. For example, plasma

can cause an anaphylactic reaction, colloids can cause clotting dysfunction, etc... Monitor fluid therapy by monitoring 1) the total dose of fluids administered; 2) blood pressure changes in response to fluids; 3) packed cell and total protein; 4) presence of edema; 5) harsh lung sounds; 6) urine production (if possible); etc....

#### Summary for treating hypotension:

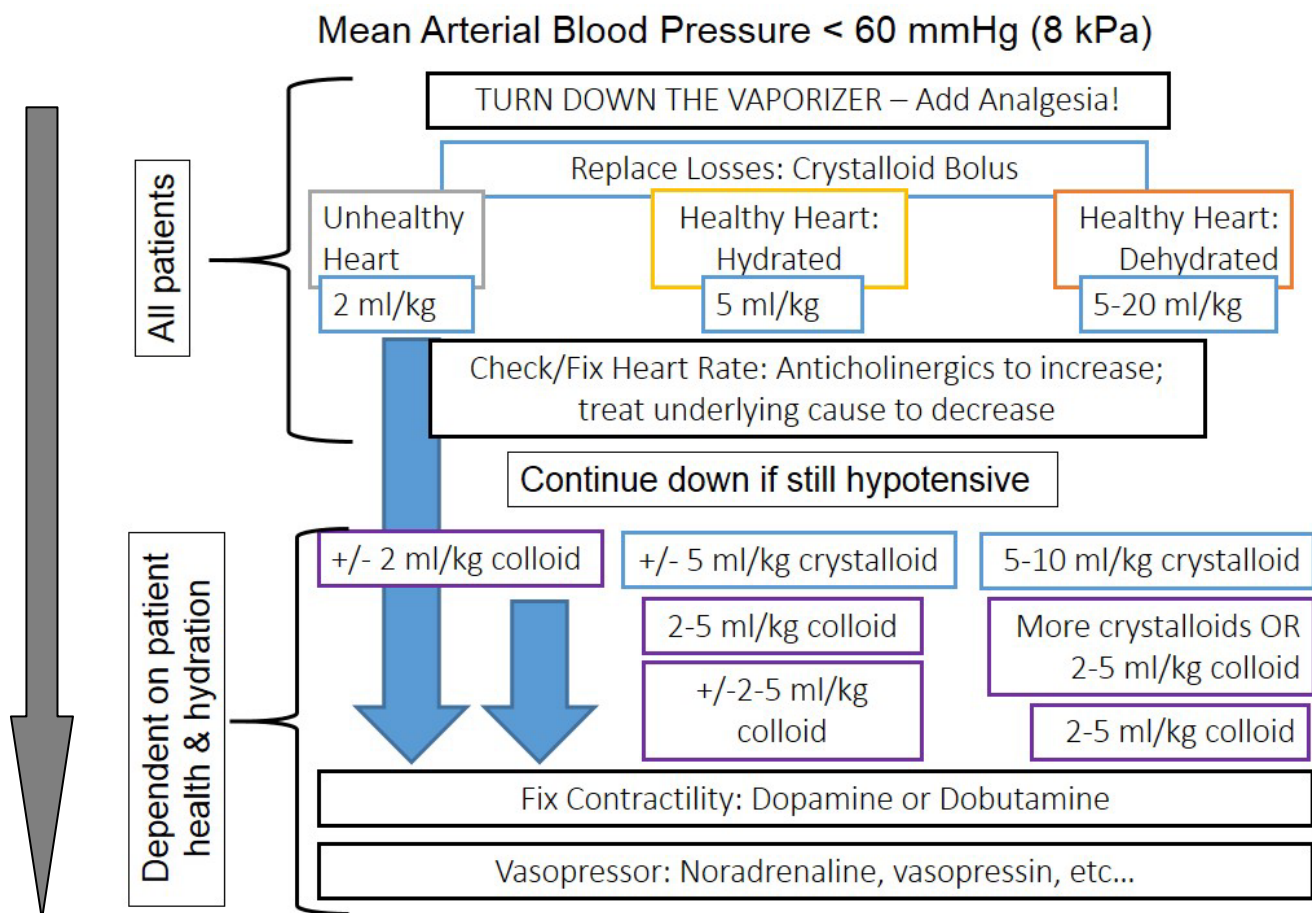
1. **Stabilize** the patient prior to anesthesia.
2. **Turn down the vaporizer** – may need to add analgesia.
3. **Replace fluid losses.** Increase the rate of fluid administration and/or administer fluid boluses of crystalloids.
3. **Check the heart rate** and fix if too high or too low.
4. If steps 1, 2 and 3 are not producing an increase in blood pressure within 5-10 minutes, increase the perfusion pressure by **increasing the circulating volume** with a bolus of colloids.
5. If steps 1-3 do not produce an increase in blood pressure or if the patient is likely to have decreased cardiac contractility (eg, patients with cardiac disease or disease that affects contractility), **increase contractility** with an infusion of a positive inotrope like dopamine or dobutamine.
6. If these steps fail or if the patient is in an extreme vasodilatory state (like septic shock) **decrease the vasodilation** with a vasopressor like norepinephrine, epinephrine or vasopressin.

#### Table 1: Dobutamine / Dopamine Infusion

**Add 4.0 mls (50.0 mg) of dobutamine (12.5 mg/ml) or 1.25 mls (50.0 mg) of dopamine (40 mg/ml) to 250 mls saline.** The concentration of either CRI will be 200 microg/ml (3.3 microg/drop with 60 drop/ml set). The standard dose of either drug is 1-10 microg/kg/min. For mild to moderate hypotension start either drug at 2 microg/kg/min and for profound hypotension start at 5 microg/kg/min. If no response in 3-5 minutes, increase the rate by 1-2 microg/kg/min every 3-5 minutes until the blood pressure starts to improve or the maximum dose is reached. If the maximum dose is reached and there is no response either the drug is not effective (expired?) or the problem is not cardiac contractility. In this case, check for other causes of hypotension (eg, bradycardia, inadequate fluid volume, vasodilation, etc...).

The following chart works for a 60 drop/ml set and the number in the column is equal to the drops/min (which also works out to be the mls/hr with a 60 drop/ml set). Appropriate dosing in patients over 40 kg needing high dosages of dopamine or dobutamine will require a 10 or 15 drop/ml set. For really small patients, the infusion can be made more dilute so that more drops/min can be administered. The easiest way to dose any sized patient is to use a syringe pump and program the dose into the pump.

Weight/kg	1	2.5	5	7.5	10	12.5	15	20	25	30	35	40
Dose in microg/kg/min	Drops/min using a 60 drop/ml set. Number of drops/min have been rounded up or down, as appropriate. Because the dose is a range and not an absolute value, rounding does not jeopardize safety. The actual drops the patient gets per minute will also have to be rounded – for example 61 drops/min is hard to count but 60 drops/min=1 drop/sec is quite easy.											
2	1	1	3	5	6	8	9	12	15	18	21	24
4	1	3	6	9	12	15	18	24	30	36	42	48
5	2	4	8	11	15	19	23	30	38	45	53	61
6	2	5	9	14	18	23	27	36	45	54	63	73
8	3	6	12	18	24	30	36	48	61	72	85	97
10	3	8	15	23	30	38	45	61	76	91	106	121



Progressively move down the flow chart until hypotension is resolved.