MONITORING THE CRITICAL PATIENT

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Dr. Rebecca Kirby, one of the founding Diplomates of the American College of Veterinary Emergency and Critical Care, developed a list of 20 important things to monitor in any critically ill patient on a daily basis. This list helps the clinician from forgetting an organ system, and also allows, I believe, to help visualize the interaction of the different organ systems and treatment modalities in helping treat or even perhaps inhibiting treatment of a patient. The list is called Kirby's Rule of Twenty, and is listed below. We can use a case example of using the Rule of 20 in a critical patient that presents to you that requires intensive monitoring.

Kirby's Rule of Twenty

1. Fluid balance
2. Blood pressure and perfusion
3. Cardiac function (rhythm, rate and contractility)
4. Albumin
5. Oncotic pull
6. Oxygenation/ventilation
7. Glucose
8. Electrolyte and acid-base balance
9. Mentation/intracranial pressure
10. Coagulation
11. RBC/hemoglobin concentration
12. Renal function and urine output
13. Immune status, WBC, and antibiotic coverage
14. GI motility and integrity
15. Drug metabolism and drug doses
16. Nutrition
17. Analgesia
18. Nursing care, patient mobility
19. Bandage and wound care
20. Tender loving care

CASE EXAMPLE:

Signalment and History:

Birch, a 4 year old, 55 pound, neutered male Australian Shepherd, presents to you on emergency after being hit by a car. His owner witnessed the accident, and states that the car was moving at approximately 45 miles per hour. At the time of the initial accident, Birch briefly lost consciousness, and had a seizure that lasted approximately 1 minute. En route to your hospital, Birch vomited a small amount of blood-tinged fluid, and seemed very lethargic.

Physical Examination:

At the time of presentation to you, he is nonambulatory and stuporous. You notice abrasions on the forehead and anisocoria. His pupillary light reflexes (direct and consensual) are present, but sluggish. His mucous membranes are pale pink, and he has a capillary refill time of 2 seconds. His heart rate is 178 beats per minute, and you palpate weak synchronous femoral pulses. His lungs sound harsh on the right side of the chest, and breath sounds are absent on the left side of the chest. His respiratory pattern is rapid, shallow, with an abdominal push and grunt on exhalation. His abdomen is soft and nonpainful with no palpable abnormalities. There are abrasions and tire tracks on the caudo-ventral abdomen and inguinal region. The right rear leg is flaccid and swollen at the level of the mid-femur with extensive bruising and crepitus. There is blood on his prepuce, and a small amount of blood on rectal examination.

Problem List:
Vehicular Trauma
History of loss of consciousness
Seizure
Stupor
Nonambulatory
Anisocoria
Abrasions on head
Sluggish PLR
Pale mucous membranes
Prolonged capillary refill time
Tachycardia
Weak femoral pulses
Harsh lungs sounds
Muffled lung sounds
Restrictive respiratory pattern
Abdominal and inguinal abrasions
Blood on prepuce/possible hematuria
Flaccid right rear limb with crepitus, swelling and bruising
Blood on prepuce
Blood on rectal examination

Let us now group the problems according to the ABCs (Airway, Breathing, Circulation) of Triage and Emergency.

Airway and Breathing = Respiratory System
- Muffled lung sounds
- Harsh lung sounds
- Rapid, shallow restrictive respiratory pattern

Circulation = Cardiovascular System
- Stupor (lack of cerebral perfusion can contribute to stupor)
- Nonambulatory (hypotension can lead to inability to ambulate)
- Pale pink mucous membranes
- Prolonged capillary refill time

Tachycardia
Weak femoral pulses

Now that we've identified the major problems, we must also quickly assess the body for disabilities. That is, are there any other problems that can potentially be complicated or worsened by patient motion or our interventions?

Whenever there is a potential for neurologic abnormalities, you must assess whether there is the possibility of a fractured spine. In this case, Birch does not show classic signs of Schiff – Sherrington. That is, he does not show extensor rigidity of the forelimbs and flaccid paralysis of the hindlimbs that would suggest spinal trauma or fracture. He does show signs of head trauma, with abrasions on his head, anisocoria, sluggish papillary light reflexes, stupor, and history of seizure at the scene of the accident. He has signs of a femoral fracture, which should alert you to use caution when moving him to help prevent further tissue trauma or laceration of any major vessels. Both the head trauma and possibility of major damage to vascular beds of the muscles in the thigh, overzealous administration of intravenous fluids could potentially lead to cerebral edema, leakage of fluid into the cranial vault, and loosening of clots in damaged tissue, which can lead to further hemorrhage.

Let us now use Kirby's Rule of Twenty to address the patient's problems. Remember, many of these monitoring tools are done at the same time, rather than sequentially!

1. Fluid Balance: "Maintenance" fluid therapy is based on a patient's daily fluid requirements. Metabolic water requirements do not account for acute blood loss, as in the case of hemorrhage, hypovolemic shock, and hypotension. In this case, Birch has signs of hypovolemic shock, as he has a rapid heart rate, prolonged capillary refill time, and weak femoral pulses. These three parameters (heart rate, capillary refill time, and pulse quality) allow us to determine something about his perfusion, and are called "perfusion parameters". These, along with his blood pressure, tell us if he is getting enough perfusion to his tissues. Since he has signs of other underlying injuries that can become worsened if large volumes of fluids are administered, I recommend titrating his intravenous crystalloid fluids in incremental boluses as you re-assess his perfusion parameters. In a dog, a "shock" volume of fluid is 90 ml/kg. (In a cat, the recommended shock volume is ½ of this, at 45 ml/kg). When titrating crystalloid fluids to administer for treatment of hypovolemic shock, use ¼ of the recommended shock volume (take the dog's body weight in kilograms, add a zero, and that is equal to the ¼ shock volume). For example, in Birch's case, he is 55 pounds, so his ¼ shock volume is 550 ml. Infuse the 550 mls as quickly as possible, then assess what his perfusion parameters are doing. Is his heart rate coming down. Are his mucous membranes pinker, and is the capillary refill time more normal? Is the blood pressure normalizing? If so, then we can back off and not give anything more than maintenance fluids. This does not mean that we can stop assessing the patient, as blood pressure and perfusion is a very dynamic process, and can change for the worse at any time. However, if after the ¼ shock bolus of crystalloids there is little to no improvement in the blood pressure and perfusion, then we will need to either give another ¼ shock bolus of a crystalloid, or consider giving a colloid fluid like hydroxyethyl starch or pentastarch at 5 ml/kg IV bolus. In an animal with multi-

trauma that includes the potential for pulmonary contusions and hemorrhage anywhere in the body, our goal should be to raise the patient's blood pressure to normal, but not supraphysiologic levels, such that a systolic blood pressure of 100 mm Hg, a diastolic pressure of 40n mm Hg (minimum), and a mean arterial pressure of 60 mm Hg is what we need for organ (including brain and coronary artery) perfusion, without the risk of the fluid leaking out into damaged tissues or breaking clots off of things that were hemorrhaging.

2. Blood pressure and perfusion 3. Heart rate, rhythm, and contractility: We've discussed a little about blood pressure and perfusion when we discussed fluid therapy, above. Blood pressure is a function of cardiac output and systemic vascular resistance. Cardiac output is a function of heart rate and stroke volume, or the amount of blood the heart pumps with each heart beat. Stroke volume is affected by cardiac preload and wall stretch, cardiac afterload, and myocardial contractility. In a patient with hemorrhage, there is often insufficient intravascular fluid volume to allow adequate cardiac preload. By Starling's Law of the Heart, the strength of myocardial contraction, or a heartbeat, is directly proportional to the amount of wall stretch, or ventricular filling that occurs just prior to that heart beat. With insufficient circulating intravascular fluid volume, there is inadequate ventricular stretch at the end of diastole, and a decrease in the strength of contraction. Additionally, there are baroreceptors in the aortic arch and carotid body that sense tension or stretch in the blood vessels. Similarly, decreased intravascular circulating fluid volume is sensed by these baroreceptors, and normal inherent vagal input is decreased, allowing sympathetic tone to become prevalent, and result in an increased heart rate. The increased heart rate functions to compensate for decreased myocardial contraction in an attempt to maintain cardiac output and blood pressure. Pain, too, can stimulate the release of epinephrine, and contribute to an increased heart rate and vasoconstriction. Very rapid heart rates, regardless of the cause, can actually contribute to diminished cardiac output by not allowing sufficient time in between heart beats for the heart to fill. Remember that the heart fills during the diastolic phase of the cardiac cycle. With very rapid heart rates, there may be inadequate diastolic filling time, and hypotension as a result. As such, pain-induced increase in heart rate is detrimental, and should be addressed by administration of analgesic drugs, which will be discussed later. In any animal with multi-trauma, myocardial contusions can be present, and can lead to cardiac dysrhythmias. Close monitoring of Birch's ECG and blood pressure can allow you to determine if dysrthythmias are present, and if they warrant pharmacologic intervention.

4 and 5: Albumin and Colloid Oncotic Pressure: In an acute traumatized patient, albumin and colloid oncotic pressure are not likely to be decreased. However, during acute blood loss, there is also a loss of serum protein. Albumin contributes approximately ½ to the total protein content of the blood, and contributes approximately 80% to the colloid oncotic pressure, the pressure that allows fluid to be retained within blood vessels. When administering large volumes of non-colloid containing fluids, such as a crystalloid, COP and albumin can become diluted. Administration of a colloid such as hydroxyethyl starch (20 -30 ml/kg/day IV CRI) or pentastarch (20 – 30 ml/kg/day IV CRI) can be beneficial

in contributing to colloid oncotic pressure and helping retain fluid within the vascular space.

6. Oxygenation/ventilation: Any traumatized patient has the risk of pneumothorax or pulmonary contusions. In Birch's case, he has muffled lung sounds, which could be associated with a pneumothorax or a diaphragmatic hernia, and harsh lung sounds, which often are suggestive of pulmonary contusions. Definitive diagnosis of these conditions requires thoracic radiographs, however, in all cases, thoracocentesis should be considered based on the physical examination findings and your suspicions of a pneumothorax. At the time of presentation, supplemental oxygen delivered by an oxygen mask or hood should be started immediately. Thoracocentesis can be performed by clipping a large square of fur from the lateral thorax, and inserting a needle or over-the-needle catheter directly into the middle of the clipped area. Direct the bevel of the needle or catheter dorsally if you suspect air, and ventrally if you suspect fluid. Attach the hub of the needle or catheter to a length of IV extension tubing, then a 3-way stopcock, and a 60 ml syringe. Have an assistant withdraw air until you obtain negative pressure. If you cannot obtain negative pressure, or air reaccumulates rapidly, a thoracostomy tube should be placed. A patient's oxygenation can be measured non-invasively with a pulse oximeter. The goal is to maintain SpO_2 of greater than 92% or more, whenever possible. Direct arterial oxygenation can also be measured using arterial blood gas analyses. If an animal is hypoxemic, supplemental oxygen can be provided using nasal cannulas, an oxygen hood, oxygen cage, nasopharyngeal oxygen catheter, or transtracheal oxygen. Oxygen flow rates of 50 – 150 ml/kg/min of humidified oxygen should be provided until the patient can tolerate room air (21% FiO_2) without signs of respiratory distress, and maintain normal oxygenation.

7. Glucose Many traumatized patients are hyperglycemic at the time of presentation. In fact, in cases of severe trauma, blood glucose measurements of 300 mg/dL have been observed. In cases of head trauma, the degree of hyperglycemia has been shown to be directly correlated with the degree of head injury, but not associated with clinical outcome. Drugs that promote hyperglycemia should be avoided in head-injured patients. DO NOT USE STEROIDS!

8. Electrolyte and acid-base balance Many traumatized patients are at risk for metabolic or lactic acidosis. In you suspect urinary trauma, such as a ruptured urinary bladder, the patient is at risk of hyperkalemia. Acid-base and electrolyte status should be monitored at least once daily, or more frequently depending on the degree and type of injury.

9. Mentation/intracranial pressure Birch has signs of head trauma. In fact, he has abrasions, anisocoria, and is stuporous at the time of presentation. In some instances, it is very difficult to assess a patient's neurologic status until intravascular fluid volume and hypotension have been corrected. The brain needs perfusion and oxygen delivery to function! Additionally, in the multi-trauma patient, anisocoria can be associated with things other than intracranial trauma. Does the patient have an abrasion on the cornea and uveitis that is causing the pupil to constrict? What about the possibility of a brachial plexus injury, or injury to the neck that damaged the vagosympathetic trunk? Once these

types of injuries have been ruled out, and blood pressure and perfusion have been normalized, if Birch still remains stuporous, consider administering mannitol (0.5 – 1 gram/kg IV slowly over 15 minutes), followed by furosemide (1 mg/kg IV, 30 minutes after the mannitol). Be sure to not use any drugs that can increase intracranial pressure, such as alpha-2 agonists, or ketamine. Glucocorticoids should never be used in head trauma patients, as they can cause hyperglycemia and insulin resistance, and there have been no documented benefits. In fact, in a multi-center study in human patients with head trauma, the use of steroids resulted in significantly increased risk of death.

10. Coagulation Large volumes of crystalloid fluids can result in a dilutional coagulopathy. In all critical patients, monitor coagulation status and avoid therapies that can promote coagulation abnormalities.

11. RBC/hemoglobin concentration Birch is at a high risk of severe anemia both from cavity hemorrhage (abdominal, thoracic), and from the femur fracture site. There is no one number at which to transfuse. In acute hemorrhage, in many cases, restoration of intravascular fluid volume with a combination of crystalloids and artificial colloids is often sufficient improving blood flow and oxygen delivery. If an animal is still clinical for anemia despite a normal blood pressure, transfusion with blood component products may become necessary. Ideally, perform a blood type and/or crossmatch prior to administration of any red blood cell product. As a rule of thumb, 1 ml of whole blood per 1 pound of body weight will increase the packed cell volume by 1%. If a patient's PCV is still low or decreasing despite transfusion, ongoing losses may be present.

12. Renal function and urine output Any patient with multi-trauma, particularly those with fractures in the caudal part of the patient, is at risk of concurrent injury to the kidneys, urinary bladder, ureters, and urethra. Placement of a sterile urinary catheter attached to a closed collection system will not only help maintain the patient's cleanliness, but also will allow you to quantitate urine output. Normal urine output is 1 – 2 ml/kg/hour in a normovolemic patient. Additionally, the kidneys receive 25% of the circulating blood volume, and as such, are at extreme risk of injury when hypovolemic and hypotension exist. Monitoring urine output and renal values are necessary in determining renal status. If there is abdominal effusion present in a traumatized patient, measurement of creatinine, potassium, or BUN on the abdominal fluid and comparing the value to that of the patient's peripheral blood will help determine if a uroabdomen is present. If a uroabdomen is present, an abdominal drainage catheter must be placed in addition to a urinary catheter, to remove renal waste products and potassium and prevent them from being reabsorbed. The patient with a uroabdomen should be taken to surgery only after its cardiovascular and respiratory systems are more stable. With an abdominal drainage catheter, electrolyte and acid-base abnormalities can be addressed with medical management until the patient is more stable.

13. Immune status, WBC, and antibiotic coverage Any traumatized, stressed patient is at risk of immunosuppression. Antibiotic selection should be based ideally on culture and susceptibility testing. Minor abrasions often do not warrant antibiotics at all. If there are any penetrating injuries or open wounds, a first-generation cephalosporin is often

sufficient to help prevent infection. Open wounds should be covered immediately at the time the patient presents to your hospital, to help prevent nosocomial infection.

14. GI motility and integrity Hypotension and stress can both contribute to loss of GI mucosal integrity and bacterial translocation. Additionally, administration of opioid analgesic drugs can promote ileus. If a hypotensive patient has signs of bloody stools, ampicillin or metronidazole are good antibiotics choices to help prevent bacterial translocation. Monitor the patient for signs of inappetance, vomiting, or diarrhea, and treat as necessary. Enteral nutrition is preferred, and feeding tubes should be considered and placed early in the course of therapy, to help prevent GI mucosal atrophy.

15. Drug metabolism and drug doses In any patient, consider all of the medications that the animal is receiving, and consider renal function, hepatic function, drug interactions, and potential drug side-effects and how they may affect the animal's condition(s). Double-check drug doses, and avoid drugs that can be injurious, such as glucocorticoids or nonsteroidal anti-inflammatory drugs in a hypotensive patient.

16. Nutrition A friend of mine once wrote, "Food is love." I agree. Enterocytes will undergo atrophy within 24 hours of lack of enteral nutrition. An animal's normal resting energy expenditure, or daily caloric requirement, is based on the formula:

$$RER = (30 \times \text{body weight in kg}) + 70 = \text{Kcal/day}$$

We used to recommend that we arbitrarily multiply this value by an "illness, injury, infection, inflammation" factor. However, it has been found that many critically ill patients are actually hypometabolic due to down-regulation of the hypothalamic-pituitary-thyroid axis during illness. In trauma patients, daily administration of the RER can help prevent negative nitrogen balance, and aid in tissue healing.

17. Analgesia Analgesia is paramount to patient well-being and healing. Judicious use of opioid drugs, including patients with head trauma, should be implemented to treat pain and the negative consequences of pain. Opioid drugs (pure mu agonists) such as fentanyl, morphine, oxymorphone, and Hydromorphone are more potent and better at providing analgesia than partial agonists (buprenorphine) or agonist antagonists (butorphanol) are preferred. Avoid drugs that can increase intracranial pressure in head-injured patients.

18. Nursing care, patient mobility Nursing care is extremely important. When possible, getting the patient up and moving around can help prevent lung atelectasis. Movement also can help promote circulation and help prevent the formation of decubital ulceration, disuse atrophy, and limb edema.

19. Bandage and wound care Wounds should be assessed on a daily basis, at minimum. Bandages that become soiled or wet should be changed immediately, to prevent wicking of bacteria from the environment into the wound and causing a nosocomial infection.

Open wounds should be covered immediately at the time of presentation, to help prevent contamination with resistant bacterial organisms in our hospitals.

20. Tender loving care The last, but not least, aspect of Kirby's Rule of Twenty is Tender Loving Care. Allow the patient's family to visit, whenever possible. Spend time with the patient soothing them, not just during treatment times.

Keeping a check-list with these guidelines can help aid you in assessing each critical patient, focus on what might be overlooked, and hopefully improve the overall success of therapy.