Review of Packed Cell Volume and Total Protein for Use in Equine Practice

C. Langdon Fielding, DVM, Diplomate ACVECC*; and K. Gary Magdesian, DVM, Diplomate ACVIM, ACVECC, ACVCP

Packed cell volume (PCV) and total protein (TP) typically increase together during dehydration and decrease together during the acute stages of blood loss. However, divergence of PCV and TP may indicate severe disease and warrants further investigation. Authors’ addresses: Loomis Basin Equine Medical Center, Emergency/Critical Care, 3901 Sierra College Blvd., CA 95650 (Fielding); and Medicine and Epidemiology, 2108 Tupper Hall, School of Veterinary Medicine, University of California, Davis, CA 95616 (Magdesian); e-mail: langdonfielding@yahoo.com. *Corresponding author. © 2011 AAEP.

1. Introduction

Packed cell volume (PCV) and total plasma protein concentration (TP) are among the most common laboratory tests used by equine practitioners. They are simple and inexpensive to determine, and they are readily measured. Although most veterinarians are familiar with causes for increases and decreases in these tests, the relationship between these two parameters offers another level of insight into the physiologic changes taking place in the patient.

The relationship between PCV and TP is made both interesting and complicated by the fact that protein moves more freely from the vascular space (the blood volume) into the tissues (interstitium) than red blood cells. With disease states (particularly inflammation), there is a gradual increase in the permeability of the endothelium to proteins (the blood vessels become leaky to protein). It is not until severe disease of the vasculature, such as occurs with trauma or disseminated intravascular coagulation, that extravasation of red blood cells is observed. These important physiologic differences allow these simple measurements, both PCV and TP, to be practical means of assessing vascular integrity. The purpose of this article is to review the common causes for changes in PCV and TP and then focus on situations where PCV and TP can move in unison or opposite directions.

Increases in PCV are commonly caused by dehydration and splenic contraction and less commonly by chronic hypoxia resulting in additional red cell production. Loss of water from the blood volume (which occurs with dehydration or hypovolemia) will cause a higher percentage of whole blood to be made up by red cells (with a subsequent increase in the PCV). Unlike in most species, the equine spleen has a large red cell reserve and can more than double the PCV under conditions of intense vasoconstriction (occurs with activation of the sympathetic nervous system). Chronically low oxygen delivery to the tissues (particularly to the kidney) will cause

NOTES
an increase in erythropoietin secretion, with a resultant increase in red cell production and PCV. This condition can occur in conditions of pulmonary (caused by hypoxemia) or circulatory (caused by reduced oxygen delivery) compromise.

Decreases in PCV have three general causes: (1) loss of erythrocytes, which is primarily seen with internal or external hemorrhage, (2) erythrocyte destruction (immune-mediated hemolytic anemia is an example), and (3) decreased production. Chronic disease, such as occurs with chronic antigenic stimulation, or diseases affecting the bone marrow specifically, such as leukemia, will both result in decreases in PCV.3

Increases in TP are commonly seen both with dehydration and chronic disease. Similar to PCV, TP increases as the amount of water relative to protein in whole blood gradually drops. Chronic inflammatory diseases (e.g., infection or cancer) will cause a gradual increase in globulin concentration, resulting in an increase in TP.3,4 Although chronic disease can also suppress albumin production, the net effect is to create an increase in TP concentration.

Causes for decreases in TP are more complicated but usually result from one of two main categories. (1) Protein loss as a result of bleeding (internal or external) or inflammation, resulting in protein leak- age out of the bloodstream. This loss is commonly seen in colitis, peritoneal infections, and pleural infections.5 Less common causes of protein loss in horses include kidney disease (especially glomerular diseases) and cutaneous burns. (2) Decreased TP production in horses with severe liver failure, where protein production is decreased.

2. Relationship Between PCV and TP

The relationship of PCV and TP can be split into four general categories: (1) concurrent increase in PCV and TP, (2) concurrent decrease in PCV and TP, (3) divergence of PCV (increasing) and TP (decreasing), and (4) divergence of PCV (decreasing) and TP (increasing). Although all four scenarios indicate an abnormal physiologic state, the two categories involving the divergence of PCV and TP are not as well understood.

3. Concurrent Increase in PCV and TP

The most common reason for an increase in both PCV and TP is dehydration—a decrease in the amount of water in the vascular compartment relative to the number of circulating red cells or grams of protein. Dehydration is corrected with the administration of either oral or IV fluids, usually containing balanced electrolytes. Severe dehydration may require large volumes of isotonic IV crystalloids (as much as 80–120 ml/kg) or initial resuscitation with a hypertonic solution (e.g., 7.2% hypertonic saline at 4 ml/kg).

Response to fluid administration can also be evaluated using changes in PCV and TP. Estimations using TP may be more reliable than PCV but are still only approximate. As a general guideline, a decrease in TP concentration of 25% would represent a 25% expansion of plasma volume. It is important to remember, however, that much of the isotonic IV fluid volume administered (75% or more) will not remain in the vascular space; it will eventually disperse throughout the rest of the extracellular fluid volume, including the interstitial and transcellular spaces.6

4. Concurrent Decrease in PCV and TP

The most common reason for a decrease in both PCV and TP is blood loss. When blood is initially lost, such as with acute hemorrhage, there is no change in either parameter, because the red cells, protein, and water (plasma) are lost in equal proportions. As the body slowly replaces the lost water through fluid shifts and increased drinking, the remaining red blood cells and TP are diluted. The final values may not be reached for 24 h or more depending on the rate at which water is replaced within the blood volume.

Treatment of blood loss is simple in principle—water, cells, and proteins (among other plasma constituents) require replacement. Deciding how and when to replace the loss is a more challenging clinical judgment. Mild cases of blood loss may require no treatment. The animal will replace lost water volume by drinking, and red cells and protein will be gradually produced over time.

Moderate blood loss can be replaced with IV crystalloids (isotonic or hypertonic).4 This replacement will address the emergency loss of blood volume and cardiac output, but the patient can likely replace the red cells and protein by increased production over time. Some practitioners may have unwarranted concerns about administering IV fluids to horses with a moderately low PCV and causing further dilution. Although the PCV may decrease, the total number of red cells will not change with IV fluid administration. From an oxygen delivery standpoint, it is more important to replace blood volume and therefore, restore cardiac output than maintain a specific PCV value in this scenario. If the PCV is below a critical mass or the signs of shock do not abate with fluid administration, then blood transfusions are warranted.

Severe blood loss requires blood transfusion; affected horses often require replacement of red cells and proteins as well a fluid volume.6,7 Techniques and complications of blood transfusions are beyond the scope of this review, but care should be taken to minimize the chances for a transfusion reaction.8,9

Deciding whether blood loss is mild, moderate, or severe is often difficult when performing a clinical examination on the horse. In general, single measurements of PCV and TP are not guides in this regard, because they may be normal or change slowly after acute blood loss. Serial measurements are more useful. Clinical perfusion parameters
transfusions.

Clinical judgment as to the necessity of blood transfusion should incorporate many of these parameters into making a clinical judgment as to the necessity of blood transfusions.

5. **Divergence of PCV/TP Ratio**

**Increase in PCV and Decrease in TP**

This form of PCV/TP divergence is one of the most important laboratory indicators that equine practitioners can use to recognize critically or severely ill horses. One important setting associated with this divergence is the presence of concurrent inflammation and dehydration; systemic inflammatory states can result in decreases in total protein (it leaks out of the blood volume because of capillary leak syndrome), whereas the PCV increases in such cases because of inadequate circulating fluid volume. An example of such fluid volume and total protein loss is acute enterocolitis.

Early recognition of this PCV/TP pattern (in addition to clinical signs) is important for appropriate diagnosis and treatment. Affected animals often require aggressive fluid volume resuscitation and rehydration as well as restoration of lost plasma proteins; this treatment of concurrent hypovolemia and hypoproteinemia can be accomplished with administration of synthetic colloids such as hetastarch. 

Consideration should be given to conditions that can cause significant protein loss and concomitant dehydration, including colitis, cutaneous burns, and pleural or peritoneal infections with third space loss of protein-rich body fluids. In addition to replacing lost fluids, the primary disease needs to be addressed to mitigate the associated inflammation and abnormal capillary permeability.

More important than any one specific measurement of PCV and TP ratio is the serial trend in the relationship of the two variables. Patients that have a rapidly increasing PCV and decreasing TP over time should be monitored closely and often require intensive care. These patients are at risk for worsening hypovolemia, with subsequent complications such as acute kidney injury.

Treatment of patients with diverging PCV and TP is controversial. Although nearly all of these patients require immediate vascular volume replacement, the optimal rate of administration and type of fluid used is equivocal and likely varies with the underlying etiology and individual case circumstances. Isotonic crystalloids (e.g., lactated Ringer’s solution and commercially available acetated fluid) can be used to replace vascular volume, but the low plasma protein in these patients means that much of the administered fluid may leak out of the vascular space. Additional dilution of plasma proteins can result. This dilution can result in tissue edema, but it also means that the administered fluid may not be as effective at restoring blood volume.

Colloids are another option for treatment of this group of patients. Depending on the type of colloid (synthetic such as hetastarch versus plasma) administered, more of the fluid volume will potentially remain in the vascular volume and expand the plasma volume more effectively. The concern with these products is that the protein or polysaccharides in these fluids (plasma or hetastarch, respectively) may also leak out of the blood vessels because of significant increases in capillary permeability associated with the underlying inflammation. This leakage would also exacerbate edema formation in the tissues. Numerous clinical trials in human patients have been unable to identify the ideal fluid choice between crystalloids and colloids. It has been the authors’ experience that hetastarch in combination is more likely to decrease the PCV in affected horses compared with crystalloids alone, but the effects are often short-lived. Use of colloids should be cautious in animals with suspected marked increases in local or systemic capillary permeability, such as with acute respiratory distress syndromes (ARDS), because of theoretical concerns about leakage of the colloid particles into the alveolar space.

**Decrease in PCV and Increase in TP**

This pattern of changes is most commonly seen with chronic infections. There is an increase in total protein as a result of chronic antigenic stimulation with an increase in plasma immunoglobulin concentrations. It is not uncommon for a concurrent decrease in plasma albumin concentration (negative acute-phase response) to present in horses with chronic infections or tumors; however, the total protein concentration is usually increased. The PCV is often decreased because of bone marrow suppression from the chronic disease. These changes can be subtle depending on the stage or severity of disease. As with other PCV and TP patterns, monitoring changes over time can be particularly helpful, especially in response to therapy.

Before considering treatment, diagnosis is important. A source of infection should be investigated and may often be abdominal or thoracic in origin, such as with abscesses. Less common locations of chronic infection may be bone, reproductive organ, or guttural pouch infections among others. After the location of infection has been identified, appropriate samples should be collected for culture and susceptibility testing and/or histopathology. PCV and TP will gradually return to normal with appropriate antimicrobial treatment for abscesses or chronic infections, but it may take weeks to months.
Normalization of the PCV and total protein concentration can be used as one guide, along with clinical and hematologic improvement, to determine duration of therapy.

6. Conclusion
In conclusion, PCV and TP are often interpreted separately in equine practice, but their serial, relative relationship to each other is also clinically important. The specific changes outlined in this article can help identify patients at risk for underlying serious disease and those patients that require immediate treatment. These two simple tests can be very diagnostic and may provide immediate answers to guide further diagnostic testing and treatment.

References