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Review article

Practical Assessment of Volume Status in Daily Practice

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Fluid therapy is considered the cornerstone of treatment for patients suffering from various medical ailments particularly in emergency and critical care situations where hypovolemia commonly occurs. The ability to accurately assess a patient's volume status is critical to the decision making process when synthesizing and implementing a fluid therapy plan. Both extremes, over supplementation or not supplementing enough fluid can be detrimental to the patient. Precisely assessing a patient's blood volume without access to advanced often complicated equipment and monitoring devices is challenging. The aim of this paper is to review the practical means and tools available to aide in estimating a patient's volume status.

Introduction

Fluid therapy is a critical component when treating sick veterinary patients. Determining a fluid therapy plan starts with making an accurate assessment of the patient's hydration and blood volume to determine the animal's need for fluids. Having an accurate assessment is paramount to avoid extremes of fluid therapy—providing too much fluid or not enough—as both circumstances can lead to detrimental effects. To clearly discuss these cases, it is important to understand specific terminology like dehydration, hypovolemia, and hypervolemia. The terms dehydration and hypovolemia are sometimes used interchangeably yet it is important to understand that the pathophysiology of the 2 is different and they do require different treatment approaches.[1] The following are definitions for these terms.

Dehydration

A fluid deficit in the *interstitial* and *intracellular* fluid compartments and not a fluid deficit in the intravascular space.[2-5]

Hypovolemia

A condition of reduced *intravascular* volume resulting from plasma water or whole blood loss, which can occur with or without loss of fluid from the interstitial and intracellular compartments.[3,5,6] Hypovolemia has multiple causes (see Table 1 for a list of common causes of hypovolemia). Clinical signs often identified in patients that are hypovolemic are listed in Table 2.[3,7,8]

Hypervolemia

A condition characterized by excessive *intravascular* fluid volume (which can be relative or absolute), also referred to as fluid overload.[2,3,5] Common causes of volume overload including congestive heart failure (CHF) are listed in Table 3. A list of clinical signs associated with volume overload can be found in Table 4.[3]

The focus of this article is on assessing blood volume, not necessarily hydration; however, it should be kept in mind that severe dehydration $>10\%$-12% can result in cardiovascular collapse and hypovolemia.[3] Further details associated with dehydration such as assessment is discussed in the article by Hundley et al., in this issue.[9]

Assessment of Volume Status

The gold standard to assess whether a patient is hypovolemic, hypervolemic, or euvolemic would be to directly measure the amount of blood being pumped out of the heart in the blood vessels (i.e., the cardiac output [CO]). Although there are numerous advanced techniques available in veterinary patients that attempt to measure or estimate the CO directly, many of those techniques are invasive, require special equipment or training, and are not available in a practice setting.

These techniques include but are not limited to thermodilution, LiDCo (lithium dilution CO), pulse contour analysis, and transthoracic impedance, just to name a few. Many of these techniques and others are discussed in more detail in the article by Marshall et al., in this issue.[10] It is unlikely that a practicing veterinarian has access to these advanced techniques. Instead, assessment of a patient's volume status begins by collecting historical information and doing a complete physical examination.

History and Physical Examination

Human Medicine

There have been multiple studies in human medicine looking at the practical use of history and physical examination findings as tools to assess a patient's volume status. The population of patients often evaluated when considering hypovolemia are those suffering from blood loss, either intentionally induced via phlebotomy or related to clinical disease.[11] A meta-analysis conducted by McGee et al[4] looked at 2 types of studies relating to

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Table 1
Common Causes of Hypovolemia in Dogs and Cats and the Mechanism by Which the Indicated Cause Leads to Reduced Blood Volume

Causes of hypovolemia	
Disorder	Reason for reduced blood volume
Hemorrhage	Loss of whole blood from vascular space
Severe dehydration (> 10%-12%)	Loss of isotonic fluid or free water from vascular space
Third spacing (ascites, pleural effusion, and edema formation)	Hypoalbuminemia → decreased oncotic pressure → increased capillary leakage → vascular fluid moves into interstitium
	Vasculitis → increased capillary permeability → vascular fluid moves into interstitium
Changes in vascular tone	Dilation of blood vessels → blood trapped in dilated vessels → reduces circulating blood volume → relative hypovolemia

hypovolemia. The population in the first group of studies was healthy subjects that were phlebotomized and hypovolemia was induced. The physical examination findings that were assessed included heart rate and blood pressure (BP) taken in a supine and upright position, axillary hydration status, mucous membrane (MM) color, sunken eyes, capillary refill time (CRT), and mentation status. In the population that underwent phlebotomy the study concluded in this group of patients that the most reliable physical findings were change in heart rate > 30 beats/min and severe dizziness, both occurring after a change in posture.[4] There are no common historical findings for hypovolemia in humans that have been reported.

When studying hypervolemia in humans, the population often evaluated is those patients with CHF.[11] A meta-analysis of 18 studies evaluating the use of history, physical examination, and diagnostic tests including thoracic radiographs, electrocardiogram, and measurement of B-type natriuretic peptide was conducted by Wang et al[12] to identify congestive heart failure and volume overload. The conclusions were that the most common historical findings and presenting complaints in hypervolemic humans were a past medical history of CHF, myocardial disease, or coronary artery disease, and the presence of paroxysmal nocturnal dyspnea (shortness of breath and dyspnea), orthopnea (shortness of breath when lying flat), and peripheral edema.[12] The most frequently reported physical examination findings for hypervolemic human patients included presence of a third heart sound, jugular venous distention, rales (an abnormal rattling sound heard during auscultation of the thorax), heart murmur, and lower extremity edema.

Veterinary Medicine

In veterinary medicine, a complete physical examination is a vital tool when assessing a patient in a state of health, when practicing good preventative care or in states of disease or compromised health. A physical examination is immediately available, cost effective, and can provide a wealth of information that would directly influence the immediate therapeutic plan for a patient.[1] Another advantage of the physical examination is that it can be used as a serial monitoring tool allowing for identification of changes and trends in a patient's condition.

Table 2
Clinical Signs Commonly Associated With Hypovolemia in Dogs and Cats

Clinical signs associated with hypovolemia
Pale mucous membranes
Prolonged capillary refill time
Tachycardia (dog); bradycardia (cat)
Depressed mentation
Poor pulse quality
Hypothermia
Cool extremities
Hypotension
Decreased urine production

To date there have been no studies identified that specifically evaluate using historical information to assess the volume status of a dog or cat. However, common elements included in a physical examination that can provide information related to volume status or changes in volume status include mentation assessment, temperature, heart rate, pulse quality, respiratory (rate and effort), CRT, MM color, appendage temperature, BP, abdominal palpation, and urine production. When considering each individual element of a physical examination it is interesting to realize that of these variables and the currently accepted reference ranges associated with them, very few have actually been scientifically studied or validated in human medicine either. With that being said, diagnosis of volume status in veterinary patients is still most often empirically made based on the results of a physical examination and BP. Table 5 summarizes physical examination findings to aid in diagnosing and monitoring volume status and the upcoming text provides more detail.

Mentation

Changes in mental status can provide key information when assessing a patient's blood volume. Hypovolemic animals would have dull mentation as a result of decreased delivery of oxygen to the brain. If the patient is resuscitated appropriately, the mental status and responsiveness of the patient would improve. If the patient is not resuscitated and perfusion to the brain is not restored, the mental dullness could progress to stupor, obtundation, coma, and even death. Mental status in patients that are hypervolemic could be normal or abnormal. Abnormal mentation associated with abnormalities such as development of cerebral edema could occur in patients that have traumatic brain injury, vasculitis, or inflammatory disease due to leaky vasculature, all of which increase the blood volume within the cranium.

Rectal Temperature

Obtaining a rectal temperature and determining if a patient is hypothermic can provide information related to a patient's volume status in certain situations. For example, hypovolemic animals are often hypothermic. This is most likely due to decreased blood delivery to the rectum as a result of decreased CO.

However, there are situations where hypothermia does not reflect on the blood volume of an animal. One example would be hypothermia resulting from vasoconstriction (blood is shunted away from the rectal tissue). A second example is CHF where hypothermia commonly occurs; in those cases, poor CO results from decreased myocardial contractility and an inability to pump blood to extremities such as the rectum. Many of those CHF animals are actually hypervolemic despite hypothermia.