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CLINICAL APPLICATION OF EXTRACORPOREAL THERAPY  
(HEMODIALYSIS AND HEMOPERFUSION)  
IN DOGS AND CATS

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Hemodialysis is an extracorporeal renal replacement therapy used to manage the biochemical and fluid  
disorders of uremia. Hemodialysis was first performed in experimental dogs in 1913 and has evolved to become  
the foundation for the management of chronic kidney disease in human patients for more than 50 years. The  
clinical use of hemodialysis has been described in dogs for nearly this same period of time, but only in the past  
15 years has it risen from clinical obscurity to the advanced standard for the management of acute uremia in  
dogs and cats. Since 1990 there has been steady advancement in clinical experience with extracorporeal  
techniques in dogs and cats. These factors have reinforced the safety and efficacy of these procedures and  
solidified a role for hemodialysis (and hemoperfusion) for blood purification in animals.

Physical Principles of Hemodialysis

Hemodialysis alters the composition of blood by exposing it to a formulated solution, the dialysate, across a  
semipermeable membrane. Solute and fluid exchange occurs by diffusion or convection, and the magnitude of  
the exchange is predicated on physical characteristics of the solute and the ultrastructure of the porous  
membrane. Water and low molecular weight solutes (< 500 D) can pass readily through the membrane pores, but  
the movement of larger solutes, plasma proteins, and the cellular components of blood is limited by pore size.  
The rate of diffusion for each solute is determined by its concentration gradient and the permeability  
characteristics of the membrane. Small solutes such as urea (60 D) diffuse faster than larger solutes such as  
creatinine (113 D), and its plasma concentration decreases faster than that of larger solutes during the course of  
dialysis. The permeability of the membrane is determined by its thickness, its effective surface area, and the  
number, size, and shape of its pores or diffusion channels.

Convective transport of solutes across dialysis membranes is associated with the process of ultrafiltration,  
in which water is driven through the membrane by hydrostatic pressure gradients. Diffusible solutes dissolved in  
the water are swept through the membrane by solvent drag. The transmembrane hydrostatic pressure gradient  
between the blood and dialysate compartments and the hydraulic permeability and the surface area of the  
membrane determine the rate of ultrafiltration and solute transfer. Convective transport can contribute to total
solute removal, especially for large solutes with limited diffusibility.

**Hemodialysis Techniques for Dogs and Cats**

Hemodialysis procedures used in animals are the same as those used in human dialysis. The delivery of hemodialysis demands in-depth understanding of dialytic procedures and nephrology and requires the following components:

- **Hemodialyzer (artificial kidney)**—The hemodialyzer has a high capacity to remove small (<500 daltons) and some middle (500 to 5,000 daltons) molecular weight solutes from the blood while selectively retaining plasma proteins and the cellular components of blood.

- **Extracorporeal circuit**—This is the route of the patient's blood during hemodialysis, and the extracorporeal path must be monitored continuously for blood leaks, disconnected or kinked tubing, clots or air in the blood path.

- **Dialysis delivery system (the hemodialysis machine)**—Collectively, the dialysis delivery system formulates and delivers the dialysate, control blood flow in the extracorporeal circuit, deliver the anticoagulant, and monitor the integrity and safety of the entire dialysis process.

- **Ultrapure water**—Water is the most abundant component of dialysate and must be free of minute traces of routine impurities, water treatment chemicals, herbicides, bacteria, viruses, or endotoxins which are formidable hazards to dialysis patients.

- **Ultrafiltration control system**—This system regulates the rate and volume of ultrafiltration during dialysis.

- **Monitoring equipment**—A variety of equipment is required to assess trends in critically ill animals undergoing hemodialysis in addition to blood pressure and coagulation monitors.

- **Hemodialysis staff**—Specifically trained and dedicated nursing and professional staff are the heart of the hemodialysis program.

**Indications and Clinical Applications of Hemodialysis**

The major application of hemodialysis in all species is the supportive management of uremia. No collection of conventional therapies can reproduce its efficacy for correction of the cumulative biochemical, acid-base, endocrine, and fluid disorders of this syndrome. Acute uremia is the most common indication for hemodialysis in dogs and cats, but it is equally indicated in animals with chronic kidney disease. Hemodialysis also can be used to clear toxins and toxic metabolites from animals after accidental poisoning or drug overdosage. Hemodialysis should be instituted for uremia when the morbidity or pending mortality cannot be alleviated by conventional medical therapies. The major benefit of dialytic therapy is the transient elimination of innumerable and unspecified solutes and fluid retained during renal failure. However, these benefits are short-term, and the concentration of urea and all toxic solutes increase immediately with cessation of the dialysis session until a new steady state is achieved or until the next dialysis session.

The diffusive removal of urea and other small molecular weight solutes is exceptionally efficient in animals because of their small size. The intensity of the dialysis treatment can be adjusted by altering extracorporeal blood flow rate, dialysate flow rate, clearance of the hemodialyzer, rate of ultrafiltration, or length of the dialysis session to accommodate therapeutic needs of the animal. After dialysis, BUN increases in proportion to urea generation from dietary nitrogen and endogenous protein catabolism and inversely with residual renal function.

**Acute kidney injury** is the most common indication for hemodialysis in dogs and cats. It alleviates most of
the clinical consequences of the uremia, and should be initiated when the clinical consequences of the azotemia, fluid, electrolyte, and acid-base disturbances cannot be managed with medical therapy.

**Chronic kidney disease** is rarely managed with hemodialysis but is equally justified. Hemodialysis is required indefinitely for these animals; however, many pet owners desire short periods of dialytic support to adjust to the inevitability of the animal’s disease. Chronic dialysis can provide prolonged periods of excellent quality of life indistinguishable from normal animals. However, as these animals are supported beyond their fated life expectancy, the spectrum and severity of clinical signs referable to renal failure increases. Collectively, chronic malnutrition, fluid overload, hyperkalemia, hyperparathyroidism, metabolic bone disease, refractory hypertension, progressive anemia, infection, and drug interactions and toxicities must be managed.

**Acute Intoxications and Fluid Overloads** Elimination of exogenous toxins and support for the metabolic consequences of the intoxication is an important but overshadowed application of hemodialysis. This use of hemodialysis is especially important if there has been delay in medical management, there is limited endogenous clearance of the toxin or its metabolites, or there is no specific antidote for the toxicant. When instituted at an early stage, hemodialysis can eliminate toxins from the body before they promote cellular damage or converted to more toxic metabolites. Toxins or drugs with low molecular weights (<1500 D), small volumes of distribution, and minimal protein binding are excellent candidates for diffusive and convective removal. Ethylene glycol has a molecular weight of 62 D, negligible protein binding, and a volume of distribution equivalent to total body water (0.5-0.8 L/kg) and consequently is readily removed by dialysis. With timely application, ethylene glycol can be eliminated before its oxidation to more toxic metabolites including, glycoaldehyde, glycolate, glyoxylate, and oxalate. Toxins that are highly bound to serum proteins including diazepam, salicylates, non-steroidal anti-inflammatory drugs (NSAIDs), and tricyclic antidepressants are dialyzed less effectively, but dialysis may still be a therapeutic option.

**Hemodialysis** is indicated for treatment of poisoning or drug overdosage with ethylene glycol, methanol, ethanol, salicylate, lithium, phenobarbital, acetaminophen, theophylline, aminoglycosides, tricyclic antidepressants, and possibly metaldehyde. Hemodialysis secondarily corrects the acid-base and electrolyte abnormalities and the azotemia that accompany some intoxications (e.g. ethylene glycol, salicylate). Hemodialysis is initiated once conventional treatments are deemed ineffective and continued until the concentration of the toxin has decreased to an acceptable level and the clinical toxicity has disappeared. Hemoperfusion is an alternative blood purification procedure in which whole blood is exposed directly to sorbent materials with the capacity to selectively or nonselectively bind endogenous or exogenous toxins. Hemoperfusion is especially effective for the elimination of high molecular weight, protein bound, or lipid soluble toxins or drugs which are cleared poorly, if at all, by hemodialysis. Typical toxins include barbiturates, salicylates, NSAIDs, antimicrobials, antidepressants, and chemotherapeutics. Specific toxic indications include mushroom poisoning (amanitin toxins and phalloidin), herbicides, and insecticides. The combination of hemodialysis for small solute removal and hemoperfusion for removal of larger, protein-bound, or lipid soluble molecules provides opportunity for a greater spectrum of blood purification in animal poisonings.
**Overhydration** associated with systemic hypertension, ascites, peripheral and pulmonary edema, plural effusion, and congestive heart failure is a common complication of aggressive fluid therapy in animals with acute or chronic kidney disease. The circulatory overload may be life-threatening and fail to resolve with conventional therapy. With the ultrafiltration capability of hemodialysis the clinical consequences of overhydration, life-threatening pulmonary edema, congestive heart failure, or large volume therapies (like TPN) can be corrected. Ultrafiltration without dialysis also can be used to treat noniatrogenic and nonrenal conditions associated with circulatory overload including cardiomyopathy and congestive heart failure.

**Conclusions** With modern technology and techniques, hemodialysis is technically feasible, safe, efficacious, and indispensable for the management of both dogs and cats with life-threatening uremia or intoxications. There is no alternative therapy as effective for animals with severe uremia, refractory oliguria, life-threatening hypervolemia, or acute poisoning.