Renal Replacement Therapy - Peritoneal Dialysis

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Treatment of Renal Failure

- Conservative Strategy
  - Fluid therapy
  - Diuretics
  - Management of uremic signs
- Renal replacement therapy
  - Hemodialysis
  - Peritoneal dialysis

What is Peritoneal Dialysis (PD)?

- Dialysis: the transfer of water and solute from one compartment to another across a semipermeable membrane.
  - The blood in the peritoneal capillaries
  - The dialysis solution
  - The peritoneal membrane (dialyzer)

The peritoneal membrane as a “dialyzer”

- The capillary endothelium
- The endothelial basement membrane
- The interstitium
- The mesothelium

Physiology of PD

- Diffusion: concentration gradient,
  - Uremic solutes and potassium
  - Glucose, lactate
- Ultrafiltration: hyperosmolarity of dialysate
  - Water and associated solutes
- Absorption
  - Constant absorption of water and solute from the peritoneal cavity both directly and indirectly into the lymphatic system
Equilibrium for small solutes

Where to Start?
- Patient selection
- PD catheters
- Peritoneal dialysate

Indications for PD
- Acute renal failure
- Acute exacerbations of chronic kidney disease
- Acute poisoning or drug overdose
  - Ethylene glycol, barbiturate
- Fluid overload
  - Fulminant congestive heart failure or pulmonary edema
  - Iatrogenic fluid administration
- Peritoneal lavage

Acute Renal Failure
- Uncontrolled uremia
- Severe oliguria or anuria
- Severe azotemia
  - BUN $\geq$ 100 mg/dL
  - Creatinine $\geq$ 10 mg/dL
- Life-threatening fluid overload
  - Pulmonary edema
  - Congestive heart failure
  - Severe hypertension
- Life-threatening electrolyte disturbances
  - Hyperkalemia

Leptospirosis
- Zoonotic disease
- Oliguria/Anuria
  - Normal: 2-3 wks
  - Chronic compensated polyuric renal failure

Peritoneal Lavage
- Pancreatitis
- Uroabdomen
- Hyperthermia
- Hypothermia
Contraindications for PD

- Absolutely contraindications for human
- Peritoneal fibrosis
- Pleuroperitoneal leaks
- Major contraindications
  - Inguinal or abdominal hernia
  - Recent thoracic or abdominal surgery
  - Severe hypercatabolic state (e.g. burn patients)
  - Abdominal wall trauma and peritoneal infections or adhesions (>50% loss)

Characteristics of Ideal PD Catheters

“The catheter is both the heart and the Achilles heel of peritoneal dialysis”

- Efficient fluid inflow and outflow
- Biocompatibility
- Resistance to infection of the subcutaneous tunnel and peritoneal cavity
- Little fluid leakage at the peritoneal interface

PD Catheters

- Simple tube catheters with stylets
  - Stamey percutaneous suprapubic catheter set
  - Silicone flat drain
  - Column disc PD cath.

PD Catheters

- Toronto Western (TWH) cath.
- Coaxial design PD cath.
- Ash (T-Fluted) PD cath.
- Tenckhoff cath.
  - Straight
  - Coiled
  - Swan Neck

Catheter placement

- Blind
- Surgical
- Peritoneoscopy

Blind Catheter Placement

- Acute access
- Local anaesthesia
- Percutaneous insertion (Trocar)

Surgical Catheter Placement

- General anesthesia
- Partial omentectomy
- Cuffs
  - Soaked in sterile saline
  - Inner cuff: in the rectus muscle; Outer cuff: s.c. tunnel

Peritoneal dialysate

- A polyionic solution with the approximate electrolyte composition of plasma
  - Sterile
  - Pyrogen free
  - Biologically inert
  - Formulated to remove uremic solutes and excessive fluid
  - Correct acidosis
  - Supply solutes depleted by uremia

Composition of Dialysate

- Sodium
  - Frequently lower than serum
  - Accelerates sodium transport
  - Obviates hypernatremia associated with ultrafiltration
- Potassium
  - No potassium in standard solutions
  - Hypokalemia: add KCl (2-4 mmol/L)

Improvised Dialysate Solution

- 30 mL (50, 85 mL) of 50% dextrose add to 1L of Lactated Ringer’s solution (LR)
  - 1.5% (2.5%, 4.25%) dextrose in LR
- Mg: 71.5 mg of MgCl₂ + 1L dialysate → 1.5 mEq/L
- Sodium Bicarbonate: 0.45% or 0.9% NaCl (30-45 mEq/L)
- Potassium: 4 mEq/L

“Baxter” Dialysate

- DIANEAL PD-2 PD solution with 1.5% (2.5%, 4.25%) Dextrose
  - Na 132, K - , Ca 3.5, Mg 0.5, Cl 96, Lactate 40, Osm 346/396/485
- DIANEAL Low Calcium (2.5 mEq/L) PD solution with 1.5% (2.5%, 4.25%) Dextrose
**Bio-Incompatibility of Conventional PD solution**
- High glucose concentration
- Presence of lactate
- Low pH
- High osmolality
- Problems related to sterilization procedure:
  - GDP (glucose degradation product)

**New Dialysate**
- Extraneal (Icodextrin 7.5%) PD solution
- Nutrineal PD4 with 1.1% amino acids
- Physioneal 40 bicarbonate/lactate based peritoneal dialysis solutions
- Fresenius Stay Safe Balance PD solutions

**Types of PD**
- Intermittent regimens
  - DAPD (Daytime Ambulatory PD)
  - IPD (Intermittent PD)
  - NIPD (Nightly IPD)
- Continuous regimens
  - CAPD (Continuous Ambulatory PD)
  - CCPD (Continuous Cyclic PD)
  - APD (Automated PD)

- Dogs and Cats
  - Manual Continuous PD
  - Most commonly used form
  - Short cycle times
  - Cycler-assisted PD
  - APD with either continuous or intermittent delivery
  - CAPD
  - CKD
  - Long dwell time, 6-8 cycles per day
  - Ambulatory and unrestrained

**The Five Steps of PD**
- Dialysate preparation
- Infusion (inflow) of dialysate
- Dwell time
- Drainage (outflow) of dialysate
- Serial monitoring of the patient

**Baxter 雙連袋系統換液步驟**
- 清潔桌面
- 準備所需用物：雙連袋管組、口罩、迷你帽
- 將雙連袋管組由外袋中取出，
  - 檢查有效期限、濃度、出口
  - 拉環、管路、出口塞、和透析液袋是否正常
- 將身上輸液管露出衣服外，
  - 且確定流量控制夾是關閉的
- 戴上口罩並徹底洗淨雙手
- 若有處方，請依醫師指示將
  - 藥物加入透析液中
連接
1. 關閉雙連袋管組中注入管路的藍色管夾
2. 斷開新鮮透析液的綠色出口塞
3. 取下身上輸液管的迷你帽
4. 拉開雙連袋管組的病人端的出口拉環
5. 立即接駁輸液管與管組的病人端(注意: 須穩固地握住輸液管並旋轉病人端之連接頭到完全接合為止)

引流
1. 將新鮮的透析液袋掛高至適當位置
2. 將引流袋放低至引流位置
3. 旋開輸液管上流量控制夾並觀察引流液是否混濁
4. 待引流完畢，關閉輸液管之流量控制夾

排氣及沖洗
1. 打開注入管路上的藍色管夾，以排氣及沖洗管路
2. 慢數1到5，並檢視新鮮透析液是否流入引流袋中
3. 關閉引流管路的白色管夾

注入
1. 旋開輸液管上的流量控制夾，讓新鮮透析液注入腹腔
2. 待注入完畢，關閉輸液管上的流量控制夾
3. 關閉注入管路的藍色管夾

蓋上迷你帽
1. 打開迷你帽的包裝，並檢查碘酒海棉是否潮濕
2. 分開管組的病人端與身上的輸液管
3. 將輸液管接頭朝下，護帽口朝上，旋轉迷你帽至完全與輸液管接合為止

Dialysate Preparation
1. Dialysis solution additives
   - Heparin (500U/L) for the first 3-5 days to minimize fibrin clots
   - Potassium chloride (4 mEq/L)
2. Warming of the dialysate
   - 38°C (2-3 degrees above body temperature)
3. Heating pad
Infusion of Dialysate

- 30-40 ml/kg over a 10 minutes period
- 15-20 ml/kg for the first 12 exchanges
- Small volumes: shortened equilibration times and minimized cardiovascular complications
  - More fluid exchanges must be performed
- Large volumes: Longer equilibration, greater surface area for diffusion
  - Decrease cardiac output and cause frank dyspnea and respiratory distress

Dwell time and Drainage

- Dwell time:
  - 45~60 minutes
  - 3-6 hours (CAPD): stabilized patients
- Drainage:
  - 20-30 minutes
  - 90-100% recovery of dialysate is expected

Prevent Infection during PD

- Aseptic handling.
- Povidone-iodine dressings covered with sterile gauze over all line connections
- Scrub injection ports for 2 min / allow povidone-iodine to sit on injection ports for 5 min
- Avoid multiple dose vials
- "Flush before fill"

Serial monitoring of the patient

- Detailed record of exchange volumes and net fluid balance for each cycle
- Patient monitoring
  - Body weight (twice daily using same scale, prior to dialysate infusion)
  - Urine output (q4h)
  - Hydration status
- Heart rate and respiratory rate (q2h)
- Body temperature
- Blood pressure / Central venous pressure
- Blood exam: CBC, BUN, Creatinine, electrolytes, albumin, and venous blood gas analysis once to twice daily. Mg every three days.
- Effluent dialysate (infection)
- Peritoneal catheter exit site care and evaluate for exit site infection daily
Adjusting Prescription

- If there is evidence of overhydration...
  - Evaluate for catheter obstruction by omental entrapment of fibrin clots
  - Consider utilizing dialysate with higher dextrose concentration to facilitate ultrafiltration
- If there is evidence of dehydration...
  - Discontinue hyperosmotic dialysate
  - Supplement the patient with intravenous fluids

- Hyperglycemia (BG>250, 300)
  - Discontinue hyperosmotic dextrose solutions (Extraneal)
  - Begin insulin therapy (CRI or add to dialysate)
    - For human: 1.5% dextrose dialysate + 0.175U regular insulin/kg for short dwell times (<4 hours)
- Hypomagnesemia (Mg<1.89 mg/dL)
  - 0.75 – 1 mEq Mg/kg/day IV or 2 mg Mg/dL of dialysate infused

- Hypokalemia
  - Add KCl to dialysate (3-4 mEq/L)
  - If there is evidence of pain or respiratory distress during exchanges...
    - Evaluate for omental entrapment, too large infusion volume or pleural effusion

Factors Affecting Peritoneal Clearance

- Molecular size
- Molecular charge
- Protein binding
- Peritoneal blood flow
- Surface area available
- Inter cellular channel size
- Dialysate flow rate (volume/time)
- Dialysate composition
- Dialysate temperature

Factors That May Improve Peritoneal Clearance

- Increasing dialysate volume
- Decreasing dwell time to 30 or 45 min
- Increasing temperature of dialysate to slightly above body temperature
- Using hypertonic dialysate (e.g. 2.5% or 4.25% glucose)
- Consider use of vasodilator drugs

Complications of PD
**Poor Drainage / Catheter obstructions**

- 20-30% (Crisp MS, et al., 1989; Beckel NF, et al., 2005)
- Fibrin/Clot/Omentum → dialysate retention
- Careful catheter placement and management; omentectomy
- Heparin: decreased fibrin formation
- Clot: high pressure saline flush +/- 15,000U urokinase for 2-3h
- Catheter repositioned or replaced

**Hypoalbuminemia**

- Protein malnutrition is a significant risk for morbidity and mortality in dialysis patients
- Causes
  - Low dietary protein
  - GI/renal protein loss
  - Loss in dialysate fluid
- Human PD patients
  - 5-20g protein loss per day (50%: albumin)
  - Peritonitis: 50-100%

**Adequate protein intake**

- Dogs: 0.6-2.0 g/kg/day
- Cats: 1.7-3.0 g/kg/day
- Feeding tubes, intravenous parenteral nutrition
- Plasma transfusions
- Amino acid dialysate solutions (Baxter Nutrineal): 1.1% amino acid
  - 70-80% of a.a. are absorbed (6hr)
  - Adequate caloric intake, post-prandially
  - Rise in nitrogenous waste, metabolic acidosis

**Subcutaneous edema**

- Dialysate leakage; hypoalbuminemia; overhydration
- Intermittent wrapping of the limbs
- Optimal surgical technique and good postoperative care
- Low initial exchange volumes

**Pleural effusion**

- Contributing factors
  - Hypoalbuminemia
  - Dialysate retention
  - Overhydration
  - Passage of dialysate to the pleural cavity via diaphragmatic lymphatics (pressure gradients across the diaphragm)
- Dyspnea → thoracocentesis

**Dialysis Dysequilibrium**

- Rare complication
- Dementia, seizures or death
- Occur during early exchanges
  - Extreme azotemia, acidosis, hypernatremia, or hyperglycemia
  - Matching the dialysate osmolality to that of patient
  - Diazepam, Mannitol
Peritonitis

- Potential route of infection
  - Intraluminal: dialysate or improper handling
  - Periluminal: exit-site/tunnel infection
  - Transmural: intestinal origin
- Monitor the gross appearance of the effluent dialysate on a daily basis
  - Turbid: cytologic evaluation and bacteriologic culture

Diagnosis: 2 of the following 3 criteria

- Cloudy dialysate effluent
- > 100 inflammatory cells/μL (neutrophils ↑), or organisms in gram stain or cultures
- Clinical signs of peritonitis

Saline-Saline Plus Iodine Flush

- Rapidly inflow 0.9% NaCl (no glucose)
- Outflow immediately (no dwell)
- Inflow 0.9% NaCl containing 0.2 mL of a 0.2% iodine USP/L
- Allow to dwell for 4 min
- Drain
- Resume dialysis
- Repeat procedure daily

Treatment:

- Choice of antibiotics: based on bacterial culture and antimicrobial susceptibility test
- Empirical treatment:
  - Gram (+): Cefazolin or cephalothin
    - Loading dose: 1000mg/2L; Maintenance dose: 250mg/2L
  - Gram (-): Aminoglycosides or Ceftazidime
    - Aminoglycosides: 4 mg/kg im and 10 mg/2L for maintenance
    - Ceftazidime: 1000mg/2L; Maintenance dose: 250mg/2L

- Heparin: 500-1000 IU/L

Results:

- Responsive within 72 hours: extend the therapy to 14 days
- Not clinical improvement after 96 hours of aggressive medical therapy: remove the peritoneal catheter

Exit Site and Tunnel infection

- Signs: redness, swelling, purulent discharge, pain on pressure (exit-site scoring: > 4)
- Bacterial culture and antimicrobial susceptibility test
- Exit site care: twice daily
- Refractory infection → catheter removal

DiBartola SP: Fluid Therapy in Small Animal Practice. 1992
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**Conclusion**

- PD is a realistic option for veterinary patients with acute nonresponsive renal failure or dialyzable toxin exposure.
- The protocol requires careful intraperitoneal catheter placement and care, aggressive exchange prescriptions, and careful monitoring for complications.

Thank You.