Peritoneal Dialysis Fundamentals

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PD is a part of health care system

- Health care system (private or public funding)
- Physician reimbursement policy
- Availability of local fluid manufacture
- Physician attitudes, prejudices and views of patient eligibility
- Dialysis facility organization and expertise
- Patient factors (physical, cognitive and social)
- Patient support and availability of assisted peritoneal dialysis
- Confidence in the modality by the patient, their carer(s) and the clinical team
MORE THAN 10%
of all dialysis patients worldwide are treated with peritoneal dialysis.
Introduction
Basics of peritoneal dialysis anatomy and physiology
Principles of PD
Indication and contraindication
Advantages and disadvantages
Complications
Adequacy of PD dialysis
ESRD Treatment Modalities

- Renal Replacement Therapy
- Peritoneal Dialysis
- Transplantation
- Hemodialysis
- Hemofiltration
- Hemodiafiltration
- Automated PD
- CAPD
DIALYSIS

HEMODIALYSIS

PERITONEAL (PD)

FISTULA

Connecting an artery and a vein in your arm. It can take up to 3 months to be ready.

Blood to qualifier
Blood back to body

Artificial kidney

4 hours
3x/week

Outside the body

Inside the body

Dialysate solution

NEW.Dial

Fill up again

Exchange = 20-30 minutes

EXCHANGE
I do sympathize with you, sir, but I’m afraid it cannot be viewed as ‘carry on’ luggage.
Why PD

- No vascular access
- No extracorporeal circuit
- CAPD less expensive than HD
- Home treatment
- Better preservation of residual renal function
- No rapid change in blood volume and body fluid composition
Indications

- Hemodynamically unstable
- Uremic syndrome
- Fluid overload
- Pediatric patient
Indication / Contraindications of PD

80% of patients have no contra-indication to any of the dialysis methods and may choose according to their life style between HD a PD

Absolute contra-indications of PD:
1. peritoneal fibrosis and adhesions following intraabdominal operations
2. inflammatory gut diseases

Ramesh Khanna & Karl D. Nolph
Relative contraindications of PD

- pleuro-peritoneal leakage
- hernias
- significant loin pain
- big polycystic kidneys

- diverticulosis
  - colostomy
  - obesity
  - blindness

- severe deformant arthritis
- psychosis
- significant decrease of lung functions
## Absolute of contraindication

- Peritoneal fibrosis
- More than 50% intestinal resection
- Pleural preitoneal leak
- Active inflammatory bowel disease
Peritoneal dialysis  is the method of removing waste and excess water from the body using the peritoneal membrane as a filter.

Peritoneal dialysis cleans the blood without it being removed.

Patients need not to have a schedule dialysis sessions at a center but can have treatment at home, at work or on trips; in the same time he should have close contact with his health care team.
I don’t care what day it is. Four hours is four hours.
Introduction

PD

- Intracorporeal dialysis used peritoneum as dialyzer and heart as blood pump without vascular access
- PD using peritoneum as semipermeable membrane
• Solutes are transported across the membrane by diffusion.
• The driving force is the concentration gradient between the PD fluid and the blood.
• Waste products present in the blood per fusing the peritoneum will diffuse from the blood vessels into the “cleaner” dialysis fluid.
The solute transfer across the Peritoneum takes place in both directions, e.g. metabolic end products from the blood into the solution and e.g. buffers in the opposite direction.
• The dialysis fluid should be instilled for 4 to 6 hours.

• When the dialysis fluid is drained from the abdominal cavity, it contains waste products and excess fluid extracted from the blood.

• PD is most often applied and effective as a continuous therapy.
1. Continuous ambulatory peritoneal dialysis
2. Automated peritoneal dialysis (Continuous cycling peritoneal dialysis)
   a) Continuous Cyclic Peritoneal Dialysis
   b) Intermittent Peritoneal Dialysis
      - Nocturnal intermittent peritoneal dialysis
PD: Major Techniques

CAPD

APD
CAPD
APD
PD: Use of a Cycler

NIPD
Nightly
Intermittent
Peritoneal
Dialysis

CCPD
Continuous
Cycling
Peritoneal
Dialysis
CCPD

- Patient carries PD solution in the abdominal cavity throughout the day but performs no exchanges and is not attached to a transfer set.
- At bedtime, the patient hooks up to the cycler, which drains and refills the abdomen with solution three or more times in the course of the night.
- In the morning, the patient, with the last dwell remaining in the abdomen, disconnects from the cycler.
- Patient free to go about daily activities.
Choice of Modality

• Continuous ambulatory peritoneal dialysis (CAPD)

• Automated peritoneal dialysis (APD)
  – NIPD
  – CCPD
  – TPD
• CAPD is most widely used; known as the manual method where each exchange is taken care of by the patient.

• Typically regime: 4 bags x 2L/day. This means that the patient performs 4 bags during the day. Treatment Modes CAPD/APD
3 steps...??

3rd

DRAIN

1st

FILL

2nd

DWELL*
Initiation of PD

• Start → one – two wks after Cath. insertion

• Fill volume →
  – 10ml/kg/dose → increase within one week to
  – 1100ml/m2  children above one year
  – 600-800 ml/m2  children below one year

• Dwell Time → According PET
  – Low transporter
  – High transporter
  – High average/ low average
Fill process

- About 10 min and dependent on
- Amount of solution
- Height of solution bag
- Diameter of tubing
- Inta abdominal pressure
Dwell

- Time required for transport of solutes across the peritoneum
- In CAPD usually 4-5 hours per exchange during the day and 9 hours at night
- In APD 8-10 hours at night, 14 hours during day if required
Drain

- About 15-25 min depends on
- Amount of solution
- Gravity
- Diameter of tubing
- Position
Basics of peritoneal dialysis

- Anatomy of the peritoneum
- Peritoneum is a serous membrane, derived from the mesenchyma.
- It is composed of the parietal and visceral peritoneum that lines the peritoneal space
The Peritoneum
Peritoneal Dialysis

The Normal Peritoneal Membrane
The Normal Peritoneal Membrane

Mesothelial cell monolayer

Interstitium

Peritoneal vasculature
Peritoneal Membrane Anatomy

Key Points

Serosal membrane with area equivalent to body surface area, i.e. 1 to 2 metres. 280% is visceral peritoneum and gets its vascular supply via the mesenteric arteries and portal veins. 20% is parietal peritoneum and gets its vascular supply via arteries and veins of abdominal wall. Lymphatic drainage of peritoneal cavity is mainly via diaphragmatic stomata.
- Peritoneal cavity is lined by a mesothelial monolayer which produces a lubricating fluid under the mesothelium is a gel-like interstitium containing connective tissue fibres, capillaries and lymphatics.

- The effective surface area is critical for dialysis and depends on the vascularity of the peritoneum as well as its surface area.
PD access
Up to 20% of the patients are transferred HD, related to catheter problems.
PD Catheters specification

- Intended for long term use
- Soft and flexible
- Double cuff (most common)
- Radio opaque stripe
- Different sizes
- Larges practical internal diameter
- Kink prevention
- Prevents obstruction and improves the flow
- Biocompatible material to reduce inflammation
- Ease of implantation and removal
Common materials

- Silicone
- Polyurethane
- Silver impregnated
Catheters type

- A. Tenckhoff catheter
- B. T.W.H. Catheter with perpendicular discs
- C. Swan neck Missouri catheter (subcutaneous curved 170 degrees)
Catheter type

Commonly used peritoneal catheters are shown:

A) Tenckhoff catheters with preformed intercuff arc bend, two cuffs, and straight or coiled tips.
B) Tenckhoff catheters with straight intercuff segment, two cuffs, and straight or coiled tips.
C) Extended catheter with one-cuff, coiled-tip abdominal catheter, two-cuff extension catheter with preformed intercuff arc bend, and titanium double-barbed connector.
Common types of peritoneal dialysis catheter

- Straight 1 cuff catheter
- Straight 2 cuff catheter
- 2 cuff coil catheter
- Swan neck catheter
- Toronto Western catheter
A *tenckhoff catheter* provides a permanent long term access to the peritoneal cavity. It’s thin non irritating flexible tube, one end of this tube rests in the peritoneal cavity while the other extends from the body by about four inches.
Catheter implantation

- 3 types of placement
- 1. blind placement
- 2. surgical placement by lapraotomy
- 3. peritoneoscopic visualisation
Determination of catheter insertion site

- Schematic of a supine patient showing the method in which the coiled-tip catheter insertion site and deep cuff location are determined to achieve proper pelvic position of the catheter tip.
- The upper border of the catheter coil is aligned with the upper border of the pubic symphysis. With the catheter so aligned, the upper border of the deep cuff indicates the location of the insertion incision.
Catheter segments

A peritoneal dialysis catheter can be considered to have three segments:

- **The external segment** – the part that is outside the body and visible to us
- **The tunneled segment** – the part of the catheter that is tunneled through the subcutaneous tissue and the rectus muscle and
- **The intra-peritoneal segment** – the part of the catheter inside the peritoneal cavity
Good catheter

- Fluid transit occurs rapidly more than 200 ml/min
- **No** pain with fluid transit
- Drain completely (100 ml residual vol is considered)
- Discourages infection and biocompatible
Types of catheters

- Acute
- Chronic
Acute PD: THE PROCEDURE:

- Indications: Any patient who has acute kidney injury needing RRT
- Contraindications:
  - Deranged coagulation profile,
  - Presence of hernia, distended bowel loops, features of peritoneal adhesions due to repeated intrabdominal surgery
  - or intrabdominal infections like tuberculous peritonitis.
The procedure:

- Acute PD procedure can be divided into the following four sequential steps:
  - Step 1 - Preparation of the abdomen
  - Step 2 - Priming of the abdomen with fluid,
  - Step 3 - PD catheter insertion and
  - Step 4 - Conducting PD fluid exchanges
STEP 1. Preparation of the abdomen:

- The rectum and urinary bladder are to be emptied before the procedure for which rectal enema and evacuation of urinary bladder may be needed.
- The abdominal wall hair is to be clipped shaved in case of adult males.
- The skin of all patients should be cleaned initially with chlorhexidine/isoproyl alcohol or if chlorhexidine unavailable, povidone iodine scrub and later povidone iodine lotion to ensure sterility.
- The operator should use sterile gloves, gown and mask.
STEP 2. Priming of the peritoneal cavity with fluid:

- Placement of the priming needle in the correct place is a crucial step in the procedure.
- Instruments required for priming include long wide bore needle or wide bore lumbar puncture needle, two intravenous (IV) fluid of blood administration sets, surgical blade and PD fluid bottles (or bags), 2 liters in case of adults and 50 ml/kg body weight fluid in case of children.
Choose the appropriate PD catheter

Practical applications of a basic catheter inventory.

A) Straight intercuff segment catheter with a laterally directed exit site emerging above a low-lying belt line.
B) Preformed swan neck intercuff arc bend catheter with a downwardly directed exit site emerging below a high-lying belt line.
C) Extended catheter with an upper abdominal exit site for an obese rotund abdomen, lower abdominal skin folds, or incontinence.
D) Extended catheter with a presternal exit site for severe obesity, multiple abdominal skin folds, intestinal stomas, or incontinence.
• Most preferred site of PD catheter insertion is in the midline one inch below the umbilicus.
• The other sites are McBurney’s point on right side or similar position in left iliac fossa.
McBurney’s point

Approximate course of inferior and superior epigastric arteries (posterior)

Approximate course of superficial epigastric arteries (anterior)

Anterior superior iliac spine

Femoral artery
Insertion Incisions

5 cm

Upper Border of Pubic Symphysis
The anterior abdominal wall can be made taut by making the patient raise the head against resistance applied on the forehead by the assisting person at the time of introduction of the priming needle.

The needle is to be introduced vertically into the abdominal wall, and the layers of the abdominal wall which are to be pierced are skin, linea alba and finally the parietal peritoneum.
The most important phenomenon to be experienced at the time of piercing each layer of abdominal wall is initial resistance followed by a feeling of ‘giving in’.

The final ‘giving in’ feeling is felt when the parietal peritoneum is pierced after which one should be careful not to advance the needle further as the intestine might get punctured.
Correct position of the priming needle is ascertained by visualisation of good flow of fluid in the air chamber of the IV set. Wrong placement of the needle tip in the intestinal lumen will result in immediate diarrhea and, urinary bladder puncture will cause sudden increase in ‘urine’ flow which is actually the PD fluid draining out.
STEP 3. PD catheter insertion:

- instruments needed are,
- PD catheter with stylet, two IV sets,
- a 3 way connector,
- PD fluid bottles or bags and drain bag.

After priming of the required quantity of fluid the priming needle is removed.

The PD catheter is kept ready with the stylet well inside the catheter and its sharp tip protruding out.
STEP 4. PD exchanges:

- The three way connector is used to regulate the direction of PD fluid.
- Each fluid cycle has three components a) PD fluid inflow (10 minutes) b) 35 minutes dwell c) drain time (10 to 15 minutes)
Acute catheter

- Intended for short term use
- Are stiff
- Are placed via blind / Trocar method
- NOT in obese
Principles of catheter placement

- Internal deep cuff secured in musculature of anterior abdominal wall
- External subcutaneous cuff not less than 2 cm from exit site
- Exit site downwards or lateral direction
Laparoscopic procedure
• Post implantation dialysis
• Postpone flushing for 1-3 days to permit good tissue healing, then twice weekly how fill volume

• Heparin 500-1000/l to prevent fibrin or blood clot formation
• Does not start before 2 weeks of catheter insertion
peritoneal Dialysis Catheter Choice and Outcomes
Catheter survival rates

- Optimal 80% three years of use
- Minimal 50% one year of use
• RECOMMENDATIONS Catheter survival of >80% at one year desirable. Double cuffed catheter preferred to single cuff. Downward directed exit-site decreases the risk of catheter-related infections (advantage being its preformed arcuate bend).

• No catheter appears to be superior to the 2 cuff standard Tenckhoff catheter. Experience with swan-neck catheters is promising.
Peritoneal Dialysis Catheter Insertion

PRE-IMPLANTATION PREPARATION

- Fully inform patient of details of procedure
- Pre-surgical assessment (e.g. hernias)
- Determination of exit-site
- Skin preparation
- Bowel preparation
- Prophylactic antibiotics - Evidence suggests that peri-op antibiotics diminishes wound infection
Peritoneal Dialysis Post implantation 
Dialysis RECOMMENDATIONS Flush 
catheter with small volumes (e.g. 500ml) 
until effluent is clear Starting CAPD 
depends on type of implantation 
technique - generally catheter should be 
capped for 2 weeks before starting PD 
PD in the interim should be intermittent 
- small volumes - gradual increase in 
volume - patient in a supine position
Physiology of Peritoneal Dialysis

- Barriers of peritoneal transport: There are three main barriers to peritoneal transport of solutes and fluid:
  - 1. Mesothelium.
  - 2. Interstitial tissue.

- The parietal peritoneum is more important in transport than the visceral as only 25-30% of the VP it is in contact with the peritoneal fluid.
Mesothelium

- **Mesothelium** It consists of a single layer of flattened cuboidal cells (30,000 cells/cm²) lying on a basement membrane.
- **Microvilli** present on the luminal side increases the effective surface area of the peritoneal cavity up to 40 m².
- **Tight junctions** and desmosomes are present between the mesothelial cells.
- **Transport** through the mesothelium occurs via endocytosis, transcytosis.
Interstitium consists of cells (pred. fibroblast) & fibers (pred. collagen) embedded in an amorphous substance.

- Thickness of the interstitium varies from 1-2\(\mu\)m to \(\geq 30\mu\)m.
- This thickness influences transport characteristics as this also defines the distance between the mesothelium and bv’s.

Movement of solute is determined by the difference in concentration per unit distance (Fick’s law of diffusion).
Peritoneal microcirculation.

- Resistance vessels.
- Regulation of blood flow to capillaries.

Solute and fluid exchange (principle site)

- Leukocyte adhesion
- Permeability under inflammatory conditions
• Peritoneal blood flow 50-100mL/min. Peritoneal clearance is **not** blood flow limited as long as blood flow is >30% of normal.

• Similarly **UF** also does **not** appear to be blood flow limited.

• Vasoactive agents can affect peritoneal clearance by means of capillary recruitment & increasing the micropore diameters.
Principle of dialysis

Dialysis works on the principles of the diffusion of solutes and ultrafiltration of fluid across a semi-permeable membrane. Diffusion describes a property of substances in water. Substances in water tend to move from an area of high concentration to an area of low concentration.
Diffusion

Diffusion is the movement of a solute across a membrane via a concentration gradient. For diffusion to occur, another fluid must flow on the opposite side of the membrane. In blood purification this fluid is called dialysate.
Convection

Convection is the movement of solutes through a membrane by the force of water. Convection is sometimes called “solvent drag”. Convection is able to move very large molecules if the flow of water through the membrane is fast enough.
Pathways of Glucose Flow

Glucose transport is mediated minimal in the capillary and >90% intercellular.
Pathways for Peritoneal Transport

- **Capillaries**
  - Small solutes
  - Macro molecules
  - Water

- **Interstitium**
  - Glucose
  - Crystalloid osmosis

- **Mesothelium**
  - Colloid osmosis

**Peritoneal tissue layer**

**Dialysate**
The three pore model.

Aquaporin-1

Inter-endothelial cleft

Large Inter-endothelial clefts

Figure 92.1 Three-pore model. The small pores in the middle represent the major pathway across the peritoneum through which small solutes move by diffusion and water moves by convection driven by hydrostatic, colloid osmotic, and crystalloid osmotic pressure differences. Across large pores (to the right), macromolecules move out slowly by convection from plasma to the peritoneal cavity. The smallest pores (to the left) are represented by aquaporins permeable to water but impermeable to solutes. Water moves here exclusively by crystalloid osmotic pressure.
Factors that influence solute diffusion

- Concentration gradient.
- Effective peritoneal surface area.
- Intrinsic membrane permeability characteristics.
- Solute characteristics.
- Blood flow (no significant role).
- Dwell time and total volume of the dialysate.
Factors affecting transport of solute

- Solute characteristics
- Dialysate to plasma D/P concentration gradient
- Dialysate influences (temperature, PH)
  - vasoconstriction with cold solute, increase kinetic activity with warm solution
- Dialysate flow rate (bags Number and size of exchange)
Principles of PD

- **Osmosis** is the process in which water moves through a semi-permeable membrane from an area of high water concentration (i.e., low solute concentration) to an area of low water concentration (i.e., higher solute concentration).
- An **osmotic pressure gradient** is applied by the addition to the dialysis fluid of an osmotic agent which will "suck" fluid from the blood.
- The concentration of this osmotic agent is chosen to give just the fluid removal needed. In most cases **glucose** is used to create the osmotic pressure.
- Fluid is removed by **ultrafiltration** driven by an osmotic pressure gradient. (Eg. **Yellow/Green/Red Bags**)

**Principles of PD**
To understand how fluid removal is achieved, we need to understand how osmosis works.

Osmosis is the process in which water moves through a semi-permeable membrane from an area of high water concentration (i.e., low solute concentration) to an area of low water concentration (i.e., higher solute concentration).

**Fluid Removal**
Both solute and fluid removal in PD is controlled by:

1) glucose concentration
2) dwell time
3) volume
4) peritoneal membrane characteristics

Fluid Removal
Factors affecting osmosis

- Peritoneal surface area
- Peritoneal permeability
- Oncotic pressure
- Hydrostatic pressure gradient
- Osmotic pressure gradient
- Hyperglycemia or hyperosmolar
Factors affecting osmosis

- Prolonged dwell time will decrease fluid removal
  - osmotic pressure ↓
  - dialysate is diluted
  - dextrose is absorbed
  - lymphatic absorption continuous
  - transcapillary absorption occurs

Shorter dwell enhance fluid removal
• Solutes are transported across the membrane by diffusion.
• The driving force is the concentration gradient between the PD fluid and the blood.
• Waste products present in the blood per fusing the peritoneum will diffuse from the blood vessels into the “cleaner” dialysis fluid.
• The dialysis fluid should be instilled for 4 to 6 hours.

When the dialysis fluid is drained from the abdominal cavity, it contains waste products and excess fluid extracted from the blood.

• PD is most often applied and effective as a continuous therapy. In this way it is a more physiological treatment than Haemodialysis (HD)
The osmotic agent normally used in PD fluid is **glucose**. □ Not an ideal osmotic agent, as it is readily transported across the peritoneum.
□ Large concentration glucose creates a temporary osmotic gradient before being adsorbed into the blood. □ The higher the glucose concentration, the larger the osmotic pressure, resulting in a larger fluid removal.
□ If PD exchanges are missed or dwell more than 8-6 hours, fluid may be gained by the patient rather then lost. □ The Volume of dialysis solution administered is also important for the total fluid removal, as it will take longer for the concentration gradient to decline in a large volume of fluid.
The major osmotic agent used today is glucose.

- As the rate of fluid transport is related to the osmotic strength of the PD solution, the ultrafiltration can be controlled by an appropriate glucose concentration.

Normal range of concentrations include

- 1.5%, 2.3%, & 4.25%.

- Glucose is not ideal, as it is rapidly absorbed from the PD fluid. This may lead to problems with fluid removal, patient gains calories and can lose their appetite. Resulting in overweight and malnourishment.

- Disturbances of the carbohydrate and lipid metabolism may also occur.
Osmotic Pressure of Dextrose Solution

1.5% Solution

2.5% Solution

4.25% Solution
- Peritoneal transport: Two clinical end-points
  - Clearance of solutes (by diffusion and convection)
    - Fluid removal (transcapillary UF – fluid absorption)

- Peritoneal Transport: Three Distinct Processes
  - Diffusion
  - Ultrafiltration
  - Fluid Absorption
What Happens with Solute Removal During a CAPD Dwell?

- **Diffusion** is at a maximum, and urea and creatinine equilibration are fastest, in the first hour but become slower as the gradient lessons with time.

  By 4 hours, urea is >90% and creatine > 65% equilibrated in most patients.

- **Dialysate to plasma (D/P) ratios** measure degree of equilibration at a given dwell time (e.g. D/P Urea, D/P Creatine).
- Natural functions of the peritoneum
  - Facilitate motion
  - Minimize friction
- To conduct vessels and nerves to the viscera.
- Solute transfer and exchange.
- Regulation of fluid dynamics and UF.
Peritoneal dialysis solution

- Buffer compositions
  - Lactate 35 - 40 mEq/L
  - Bicarbonate 25 - 39 mEq/L

- Osmotic compositions
  - Glucose (Dextrose): 1.36%, 2.25%, 3.86% glucose
    1.5%, 2.5%, 4.25% dextrose

- Electrolytes
  - Sodium: 132 - 134 mEq/L dialysate
  - Magnesium: 0.5 - 1.0 mEq/L
  - Potassium: 0 - 2.0 mEq/L
PD solutions

EXTRANEAL
- Non-glucose
- Iso-osmolar
- Low GDPs

NUTRINEAL
- Non-glucose
- No GDPs

BALANCE
- Non-glucose
- Ph 7.0
- No GDPs

PHYSIONEAL
- Physiological pH
- Bicarbonate/lactate mixture
- Bicarbonate [physiological]
- Low GDPs: lower pH of glucose compartment results in lower GDP formation during sterilisation

BICAVERA
- Non-glucose
- Bicarbonate [physiological]
- Physiological pH
- Low GDPs
# Prescription of PD

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>Composition of peritoneal dialysis solutions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium (mmol/L)</td>
<td>132–134</td>
</tr>
<tr>
<td>Potassium (mmol/L)</td>
<td>0–2</td>
</tr>
<tr>
<td>Calcium (mmol/L)</td>
<td>1.25–1.75</td>
</tr>
<tr>
<td>Magnesium (mmol/L)</td>
<td>0.25–0.75</td>
</tr>
<tr>
<td>Chloride (mmol/L)</td>
<td>95–106</td>
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<tr>
<td>Lactate (mmol/L)</td>
<td>35–40</td>
</tr>
<tr>
<td>Glucose (g/dL)</td>
<td>1.5–4.25</td>
</tr>
<tr>
<td>pH</td>
<td>5.5</td>
</tr>
</tbody>
</table>
• Research to find alternative osmotic agents has resulted in new products which are still not widely used. Amino acids are an interesting alternative as they provide nutritional supplement.

• High molecular weight glucose polymer (extraneal/icodextrin) provide sustained ultrafiltration for long overnight dwells
• Gulcose degradation products GDPs

• Effects of GDPs
  1. inhibition of viability and function in different peritoneal cells
  2. inflow pain during initial peritoneal contact
  3. long term PD leads to morphological changes which leads to functional change (UF failure)
Biocompatibility

- Measurement of biocompatibility parameters like CA 125
Pure bicarbonate Buffer (bicavera)

- Less inflow pain
- Improved biocompatibility
- More effective in correcting metabolic acidosis and prevents further bicarbonate loss
- Pure bicarbonate obligatory in hepatic dysfunction
- Preserves the homeostasis of the body
The solutions

The sugar solutions can be a problem for diabetic patients and changes in therapy may be needed,

**New solutions are being developed protein or starch.**

**Isodextrin** (glucose polymer) produced by hydrolysis of starch, it’s effective in patients with poor UF even when using high concentration dextrose, but very expensive and metabolized to maltose resulting in high maltose levels.
EXTRANEAL is a glucose-free polymer that is indicated for a single daily exchange for the long 8-16 hour dwell during CAPD or APD.

Recent findings have shown that it improves the long-dwell ultrafiltration and clearance of creatinine and urea compared to 4.25% dextrose.
• **Amino acids**, it’s very expensive and only used if diffusion of amino acids from the dialysate into the blood compartment would be beneficial for nutrition, it’s use is limited to one bag per day as amino acids are metabolized to urea causing increased uremic symptoms.
Perspectives - New dialysis solutions protect peritoneal membrane

**Physioneal**
- ↓ GDPs and AGEs
- ↓ Lactate
- Physiologic pH and pCO₂
- ↑ Membrane and immune cell function

**Extraneal**
- Isosmolar to plasma
- No glucose exposure
- ↓ GDPs and AGEs
- ↑ Membrane and immune cell function

**Nutrineal**
- No glucose exposure
- No GDPs or AGEs
- ↑ Membrane and immune cell function

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Clinical advantages of new dialysis solutions

**Physioneal**
- ↓ Infusion pain
- ↓ Peritonitis
- ↑ Glycemic control
- ↑ Appetite
- ↑ Patient acceptance
- No ↓ UF

**Extraneal**
- ↓ Glucose load
- ↑ Glycemic control
- ↑ UF, control of fluid status
- ↓ Dyslipidemia
- ↑ Quality of life
- ↑ Time on PD

**Nutrineal**
- ↓ Glucose load
- ↑ Glycemic control
- ↑ Protein intake, nutritional status

1. Conventional PD solution

- Glucose based solutions with lactate as buffer
  - High conc. Of glucose and lactate
    - Safe, effective and cheap
    - Easily metabolized
  - Low pH
  - Hyperosmolality
  - A variety of GDPs formed during heat sterilization
The most abundant electrolyte in PD fluid is sodium. It’s hyponatremic, so it has a concentration lower than blood to ensure sufficient removal of sodium.

Standard PD fluid contains no potassium.

Today, there is a tendency to use normcalcemic PD fluid as many patients receive extra calcium from phosphate-binding drugs.

The buffer normally used in PD is lactate.

Lactate is metabolised to form bicarbonate, the most important buffer in the blood.
• If hypercatabolic state or hyperkalemia the dwell time is shortened to 10 minutes for faster correction.

• If extra ultrafiltration is necessary 25 to 100ml of high concentration dextrose (25% or 50%) is added into each PD fluid bottle/bag before instilling the fluid into the abdomen.

• Blood glucose needs to be monitored every 4 hours in diabetics and insulin is to be administered.
To increase the efficiency of PD and help the patient with the exchanges, a machine can be used, known as Automated Peritoneal Dialysis of APD.

- **Advantages of APD vs CAPD** are
  1) higher clearance of solutes, as higher volumes can be used
  2) better fluid removal, as shorter dwell time can be used
  3) more freedom during the daytime as no exchanges need to be made.

- **Drawbacks of APD** are that of a higher cost and portability. Treatment Modes CAPD/APD
Complications

- Infectious
- Non-infectious
Peritonitis

- Peritonitis can occur without cloudy effluent and can present with other symptoms, such as abdominal pain, fever, constipation, and diarrhea.
- Likewise, cloudy effluent does not necessarily indicate infectious peritonitis.
- Nevertheless, patients presenting with cloudy effluent should be presumed to have peritonitis, which is confirmed by a cell count, blood differential test, and blood culture of the peritoneal fluid.
- An effluent white blood cell count of 100/μL after a 2-hour dwell with at least 50% neutrophilic cells indicates inflammation, with peritonitis as the most likely cause.
• Initiating empiric therapy to cover Gram-positive and Gram-negative bacteria is important because these organisms account for 60% to 70% and 15% to 25% of infections, respectively.

• **No** organisms are found in up to 15% of peritonitis cases, and fungi cause 2% to 3% of episodes. **Polymicrobial peritonitis** should lead to investigation for intra-abdominal catastrophes, including pancreatitis and ruptured viscus.

• Subsequent culture results and sensitivities can guide and narrow antimicrobial therapy.

• Serious consequences of peritonitis (relapse, technique failure, and death) are more likely to occur if treatment is deferred.
• Guidelines from the ISPD offer a thoughtful approach to therapy.
• **First- and third-generation cephalosporins are typically used for empiric coverage**
• unless the patient had prior infections with resistance to first-generation cephalosporins or the institution has high rates of resistance to them.
• In either case, vancomycin can be used with a third-generation cephalosporin. Patients with minimal RKF (defined as urine output < 100 mL/d) can use aminoglycosides.

• Intraperitoneal administration is recommended unless the patient is hospitalized and acutely ill.

• Then, intravenous administration should be considered.
• The treatment course should be continued for 2 weeks, except in the case of *Staphylococcus*, *Enterococcus* species, *Pseudomonas/Stenotrophomonas* species, or multiorganism peritonitis, which require 3 weeks of therapy.

• If **No** organisms are found, Gram-negative coverage can be discontinued at 96 hours if the patient is clinically improving, and Gram-positive coverage can continue for a total of 2 weeks.
• Treatment of fungal infections usually **fails**, and early catheter removal is a prudent way to proceed.
Novel techniques are in development for earlier detection of peritonitis, but these techniques are not yet recommended for general use.

The presence of bacterial DNA fragments may be a predictor of relapse and could serve an important role in peritonitis episodes caused by infections with high relapse rates, such as those due to *S. aureus* and *P. aeruginosa*.

One study showed that patients who experience relapse have high rates of these DNA fragments *5 days before* and the day of antibiotic course completion.
• The major problem with the therapy in general, is PERITONITIS.

• The normal cause of inflammation is bacterial infection.

  Bacteria from the patients skin, equipment or from an unclean environment can be flushed into the abdominal cavity by the instilled PD fluid.

• The exit site of the catheter is also an infection route. In rare cases bacteria may enter from the intestines
PERITONITIS MANAGEMENT

- Initial symptoms may include;
- diarrhoea, vomiting, nausea, abdominal pain,
- mental confusion or feeling unwell
• COLLECT DRAINED BAG
• *See additional resources (pink section) for drainage instructions
• * Send entire bag for urgent MC&S (including WCC differential) and Fungal elements
• CLEAR BAG CLOUDY BAG
Intraperitoneal (IP) Antibiotics
• **How does bacteria gain entry into peritoneal cavity?**
  
  **During catheter connection**

• Tracking around the catheter around the exit site

• Across the bowel wall; diverticulosis

• Transvaginal

• **Rarely hematogenous**

  *Bacteremia can cause peritoneal seeding and peritonitis*

  *Peritonitis rarely causes bacteremia*

  *Use antibiotic prophylaxis for anticipated bacteremia during procedures like dental work, colonoscopy, GU instrumentation*

  *Drain effluent before colonoscopy or colposcopy*
Pathophysiology

- Multiple connection and disconnections from the transfer set
- Presence of non-physiologic fluid in the peritoneal cavity may impair host defenses
- High glucose concentration, low pH and hyperosmolality dilute resident peritoneal macrophage and cytokine levels
- Constant removal of macrophage and cytokines during each exchange
- Alteration of mesothelial cell defense properties over time
• Diagnosis

At least two of the following three features

1. Peritoneal fluid leucocytosis; >100 cells/mm$^3$ and at least 50% PMNs
2. Abdominal pain
3. Positive culture of the dialysis effluent
Specimen collection and processing

- **Effluent** fluid sent for cell count with differential, culture and gram stain
- Collection of effluent: 50ml of effluent is centrifuged for 15 min followed by re-suspension of sediment in 3-5 ml of sterile saline and inoculation to media
- **Dwell time of at least 2 – 4 hours** before effluent collection
- If peritoneal cavity is dry, 1L of dialysate infused to dwell for at least 1 – 2 hours
- Peripheral blood cultures usually not necessary
Treatment

- Non-antimicrobial measures
  1. Heparin 500 units/L can be used to lyse or prevent fibrin clots when dialysate remains cloudy
  2. Pain control

Dwell time

- Long dwell exchanges (4-6 hrs) when compared with short dwells are associated with higher number of functional macrophages

Membrane properties: changes during peritonitis

- Patients may transiently become rapid transporters, thereby requiring the use of hypertonic glucose or shorter dwells

- Alternatively, icodextrin may be helpful
Empiric Therapy

1. Initiate empiric therapy

2. Simultaneous gram +ve and gram -ve coverage

3. For prevention of fibrin occlusion, heparin 500 U/L can be used

- Gram +ve coverage: 1st generation cephalosporin or vancomycin
- Gram -ve coverage: 3rd generation cephalosporin or aminoglycoside
Empiric therapy

- **1st generation cephalosporin**: cefazolin or cephalothin
- *Vancomycin used at centers with high rate of MRSA*
- **3rd generation cephalosporin**: ceftazidime or cefepime
- Short term use of aminoglycoside is safe and does not diminish residual renal function
- **Aztreonam** can be used in cephalosporin allergic patients
- **Monotherapy** with imipenem/cilastatin is possible.
- One study with 102 patients randomly assigned to either imipenem/cilastatin or cefazolin + ceftazidime showed similar outcomes in both groups.
Mode of antibiotic administration

- **Intraperitoneal administration of abx is preferred over IV**
  Infection is usually localized to the peritoneum
  Bacteremia is exceedingly rare (<1%)
  Outpatient basis

- **IP antibiotics can be given either**
  - **Continuous**: abx given with each exchange
  - **Intermittent**: abx given once daily with a dwell of at least 6 hours

  *No sufficient data to suggest that one is better than other; usually equivalent*
Staph. aureus peritonitis

Staph. Aureus on culture

D/c gram –ve coverage, cont. gram +ve coverage for 3 weeks

If MRSA change to Vancomycin and rifampin can be added (600 mg/day for 1 week)

If clinical improvement continue for 3 weeks

If no clinical improvement reculture and reevaluate for exit-site or tunnel infection or intra-abd abscess

If peritonitis with exit-site or tunnel infection – remove catheter
Allow 2 weeks rest period before reinitiating PD

If no improvement in 5 days on appropriate antibiotics, remove catheter
Pseudomonas peritonitis

1. **Pseudomonas on culture**
   - **W/o exit-site/tunnel infection**
     - Use 2 abx with different mechanism
     - Oral quinolone, cephalosporin, piperacillin based on sensitivities
     - If clinical improvement: Treat for 3 weeks
   - **With exit-site/tunnel infection**
     - Remove catheter
     - If no improvement: reculture and evaluate
     - If no improvement by 5 days: on appropriate abx, remove catheter
Polymicrobial peritonitis

- Multiple gram -ve organisms
  - Change to metronidazole
    - In conjunction with ampicillin, Ceftazidime or aminoglycoside
  - Surgical evaluation
    - Laparotomy for suspected intra-abd pathology/abscess with catheter removal
- Multiple gram +ve organisms
  - Continue therapy based on sensitivities
  - W/o catheter infection, treat for 3 weeks
  - With catheter infection, remove catheter
Culture negative peritonitis

- Culture negative peritonitis 24-48 hours
  - Continue initial therapy
    - If culture negative for 72 hours
      - Repeat cell count and diff
        - Infection resolving, pt improving
          - Cont initial therapy for 2 weeks, But D/c aminoglycoside if used initially
            - Culture positive
              - Adjust therapy as per sensitivity patterns
        - Infection not resolving
          - Special culture techniques for Mycobacteria or legionella
            - Culture negative
              - If no improvement in 5 days, Consider catheter removal
Other causes of peritonitis

- Fungal peritonitis
  1. Catheter removal
  2. Flucytosine 1gm/day + Fluconazole 200 mg/day PO for 10 days after catheter removal

Mycobacterial peritonitis

M. tuberculosis: Rifampin + INH (for 12 months) + pyrazinamide + ofloxacin (3 months)
Consider catheter removal
# Antibiotic dosing recommendations for CAPD

<table>
<thead>
<tr>
<th>Antibiotic</th>
<th>Intermittent</th>
<th>Continuous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gentamicin</td>
<td>0.6 mg/kg</td>
<td>LD 8, MD 4</td>
</tr>
<tr>
<td>Amikacin</td>
<td>2 mg/kg</td>
<td>LD 25, MD 12</td>
</tr>
<tr>
<td>Cefazolin</td>
<td>15 mg/kg</td>
<td>LD 500, MD 125</td>
</tr>
<tr>
<td>Cefepime</td>
<td>1 gm</td>
<td>LD 500, MD 125</td>
</tr>
<tr>
<td>Cephalothin</td>
<td>15 mg/kg</td>
<td>LD 500, MD 125</td>
</tr>
<tr>
<td>Ceftazidime</td>
<td>1 – 1.5 gm</td>
<td>LD 500, MD 125</td>
</tr>
<tr>
<td>Ciprofloxacin</td>
<td>No data</td>
<td>LD 50, MD 25</td>
</tr>
<tr>
<td>Vancomycin</td>
<td>15-30 mg/kg every 5-7 days</td>
<td>LD 1000, MD 25</td>
</tr>
<tr>
<td>Aztreonam</td>
<td>No data</td>
<td>LD 1000, MD 250</td>
</tr>
<tr>
<td>Amphotericin</td>
<td>NA</td>
<td>1.5</td>
</tr>
<tr>
<td>Imipenem/cilistatin</td>
<td>1 gm bid</td>
<td>LD 500, MD 200</td>
</tr>
</tbody>
</table>

LD: loading dose in mg, MD: maintenance dose in mg
Catheter removal in peritonitis patients

- ISPD guidelines recommend catheter removal in the following:

  - **Relapsing peritonitis**: another episode with the same species that caused the preceding episode within 4 weeks of completing abx.
  
  - **Refractory peritonitis**: failure to respond to abx in 5 days
  
  - **Refractory catheter infection**
  
  - **Fungal peritonitis**, **Fecal peritonitis**
  
  - **Peritonitis associated with intra-abdominal pathology**

Consideration to catheter removal in mycobacterial and multiple enteric organisms peritonitis.
Other causes of cloudy effluent

- Eosinophilic peritonitis
- Chyloperitoneum
- Fluid that’s been dwelling for a long time
Eosinophilic peritonitis

- Relatively new PD catheter
- Effluent is cloudy w/o abdominal pain
- PD differential count: eosinophils ++
- Effluent culture: no growth
- **Cause:** immune reaction to catheter

Treatment

**Usually self limited,** goes away in few days

**Some reports of benefit with IP steroids**
Exit-site/Tunnel infection

- Exit-site infection: presence of purulent discharge with or w/o erythema of the skin at catheter-epidermal interface.
- Tunnel infection: usually occult but may be present with erythema, edema or tenderness over subcutaneous path. Rarely occurs alone.
- Staph aureus and pseudomonas exit site infections are often associated with concomitant tunnel infection.
Treatment of exit-site/tunnel infection

- Purulent discharge from exit-site
  - Do culture/gram stain

  - Gram +ve organism
    - 1st generation Cephalosporin PO
      - If slow improvement or severe cases, add Rifampin 600mg/day
        - Infection resolving; continue treatment for 2 weeks
        - Infection unresolved in 3-4 weeks; consider catheter revision/removal

  - Gram –ve organism
    - PO Quinolones
      - If Pseudomonas and no improvement, add 2nd anti-pseudomonal; cefazidime IV

- Infection resolving; continue treatment for 2 weeks
- Infection unresolved in 3-4 weeks; consider catheter revision/removal
Non infectious complications

Non-infectious complications

Catheter related

- Outflow failure
- Pericatheter leak
- Abdominal wall herniation
- Catheter cuff extrusion
- Intestinal perforation

Catheter unrelated

- GERD
- Back/abdominal pain
- Abdominal wall herniation
- Pleural effusion
- Hemoperitoneum
- UF failure
- Peritoneal sclerosis
- Metabolic
Outflow failure

- Incomplete recovery of instilled dialysate Unable to remove dialysate from peritoneal cavity
  Fluid is no longer in peritoneal cavity

Incidence: 5-20%

Etiologies

- Constipation (anytime)
- Catheter malposition (days)
- Intraluminal catheter occlusion by thrombus.
- Extraluminal catheter occlusion by omentum or adhesions (weeks)
- Kinking (soon after placement, positional)
- Loss of dialysate from peritoneal cavity
Treatment

- Constipation
  
  More than half of the cases are cured with relief of constipation

  Laxatives, stool softeners, suppositories or enema

  Fibrin clot Heparin 500 units/L of dialysate for lysis

  Urokinase – instilled in catheter for 1 hour and then removed
Treatment

- **Malpositioned catheter**
  
  Fluoroscopy with stiff wire manipulation
  Redirection either laparoscopically or surgically
  Replace catheter if not successful

- **Catheter kinking**  Usually requires catheter replacement
  
  Superficial cuff removal if kinking is due to placement of the catheter cuffs too close to each other

  *Abdominal exploration may be necessary for catheter redirection, omentectomy or adhesiolysis or catheter replacement*
Pericatheter leakage

- Early after placement
- Increased intra-abdominal pressure on CAPD 2ry to increased activity
- Weak abdominal wall (pervious surgeries, pregnancies)
- High dialysate volumes
- Catheter placement techniques: poor evidence of technique with incidence Peritoneoscopically placed catheters may be better

Double cuff catheters are considered less likely to leak
Pericatheter leakage

Treatment

- Reduce physical activity
- Reduce dialysate volumes
- Conversion to cycler
- Temporary conversion to HD
- If conservative measures fails then surgical repair of deep cuff or catheter replacement
Abdominal X-ray/Peritoneography

- Plain abdominal X-rays are performed to evaluate for malposition of the peritoneal catheter.
- The normal position of catheter is in the pelvic gutter.
- In patients with normal inflow of dialysate but problems with outflow, the most common underlying cause is constipation. However, if symptoms do not improve after resumption of normal bowel movements, abdominal X-ray should be done to assess catheter position.
- For peritoneography, the initial X ray is taken, then 100-200 ml non-ionic contrast is mixed into a 2L dialysate bag and instilled in the patient. The patient changes positions to mix dialysate and a repeat X ray is taken.
- Can be used to diagnose an entrapped catheter or a peritoneal leak.
Monitoring patients on peritoneal dialysis
PD adequacy
Optimal dose: the amount of PD yielding clinical results which cannot further improve.

Adequate dose: the amount of PD below which there is an increase in morbidity and mortality.
British Renal Association:

- A peritoneal equilibration test (PET) should be performed after 4–8 weeks on dialysis, and when clinically indicated,
- e.g. when biochemical indices or loss of ultrafiltration raise suspicion of changes in peritoneal transport characteristics, or when therapy is changed to APD.
The peritoneal function test (PFT),

- The test allows assessment of total delivered therapy for urea and creatinine, protein and calorie nutrition, fluid balance, and peritoneal transport.

- The results are expressed as Pt$_{50}$ or the time required for a solute to achieve 50% equilibration between dialysate and plasma.

- The PFT has been extensively used as part of a kinetic modeling program and the data can be displayed for individual patients, clinics, or regional groups of dialysis centers.
The peritoneal dialysis capacity (PDC)

- program was designed to measure transperitoneal passage of fluid and solutes under normal conditions with a non-invasive test.
- The PDC is based on the three-pore-model of Rippe et al\textsuperscript{13,14}.
- It describes the peritoneal membrane characteristics
The dialysis adequacy and transport test (DATT)

- was introduced by Rocco et al. in an attempt to develop an easier test for classifying peritoneal transport type
The accelerated peritoneal examination (APEX)

- test was designed by Verger et al.
- using a similar protocol as their initial equilibration test with 3.86% glucose solution, but summarizes in a single number the peritoneal permeability for both glucose and urea.
- It represents the time at which the glucose and urea equilibration curves cross.
Monitoring patients on peritoneal dialysis

- Total (peritoneal plus residual renal) weekly Kt/Vurea and
- CCr measurement and a peritoneal equilibration test (PET) should be performed approximately 4 weeks after dialysis commencement, but no sooner than 2 weeks after dialysis commencement because of unstable peritoneal permeability at this stage (Level III evidence).
The standard peritoneal permeability analysis (SPA)

- is a more sophisticated way to assess peritoneal function
- It uses intraperitoneally administered dextran 70 to study fluid kinetics during a 4-hour dwell using an infusion volume consistent with the patient’s usual prescription
Residual renal Kt/V and CCr measurements should be repeated at the following times:

i. every 2 months in automated peritoneal dialysis (APD) patients and every 4–6 months in continuous ambulatory peritoneal dialysis (CAPD) patients who are dependent on residual renal function to achieve small solute clearance targets, particularly those with a small ‘safety margin’ (e.g. patients treated with ‘incremental’ rather than ‘full-dose’ peritoneal dialysis).
ii. following a history of a substantial decline in urine output,
iii. following unexplained fluid overload, and
iv. with clinical or biochemical evidence of worsening uraemia.
**Kt/v urea**

- Total drain vol / vol of urea distribution
  \[ \times \]
- Conc of urea in dialysate / conc of urea in plasma
  \[ \times 7 \text{ (weekly)} \]
- Vol of urea distribution
- Male 60% of body wt
- Female 50-55% of body wt

21 January 2019  PD fundamentals by Dr. Jebril Elabidi
Measurement of clearance:

B: Renal Kt:
- 24 hour collection of urine
- Measure urea concentration in urine
- Estimate total urea content = urea conc. \times urine volume

Renal Kt = urea content in Urine / serum urea level

V (by Watson formula)
- \( V = 2.447 - 0.09516 \times A + 0.170 \times H + 0.3362 \times W \) (in Male)
- \( V = -2.097 + 0.1069 \times H + 0.2466 \times W \) (in female)

Where A = age (Year), H = height (cm) and W = weight (kg)
### Criteria of PD adequacy

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solute clearance</td>
<td>Weekly Kt/V urea &gt; 1.7 (including residual renal function)</td>
</tr>
<tr>
<td></td>
<td>Weekly creatinine clearance &gt; 50 L/1.73 m²</td>
</tr>
<tr>
<td>Fluid balance</td>
<td>No edema</td>
</tr>
<tr>
<td></td>
<td>No postural hypotension</td>
</tr>
<tr>
<td>Electrolyte balance</td>
<td>Serum potassium &lt; 6.0 mmol/L</td>
</tr>
<tr>
<td>Acid-base balance</td>
<td>Serum bicarbonate &gt; 24 mmol/L</td>
</tr>
<tr>
<td>Nutrition</td>
<td>Daily protein intake: 1.2–1.5 g/kg</td>
</tr>
<tr>
<td></td>
<td>Body mass index 20–30</td>
</tr>
<tr>
<td></td>
<td>Stable midarm muscle circumference</td>
</tr>
<tr>
<td></td>
<td>Serum albumin &gt; 3.5 g/dL</td>
</tr>
<tr>
<td></td>
<td>Serum cholesterol &gt; 150 mg/dL (3.8 mmol/L)</td>
</tr>
</tbody>
</table>
Assessment of peritoneal function

2. PET- peritoneal equilibration test (type of transport and ultrafiltration after 4 hours)

3. weekly clearance of creatinine and urea

4. daily UF

5. decrease of Na in dialysis fluid after 60 minutes using 3,8% G (test of aquaporines)
Results of baseline PET

![Diagram showing results of baseline peritoneal equilibrium test.](image)

- **Baseline peritoneal equilibrium test**
  - High transporter D/P creatinine: 16%
  - High average transporter D/P creatinine: 68%
  - Low average transporter D/P creatinine: 16%
  - Low transporter D/P creatinine

Ramesh Khanna & Karl D. Nolph
## PET (peritoneal equilibration test) 2

<table>
<thead>
<tr>
<th>Transporter</th>
<th>Waste removal</th>
<th>Water removal</th>
<th>Best type of PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Fast</td>
<td>Poor</td>
<td>Frequent exchanges, short dwells – APD</td>
</tr>
<tr>
<td>Average</td>
<td>OK</td>
<td>OK</td>
<td>CAPD or APD</td>
</tr>
<tr>
<td>Slow</td>
<td>Slow</td>
<td>Good</td>
<td>CAPD, 5 exchanges daily + 1 exchange at night</td>
</tr>
</tbody>
</table>
Interpretation of peritoneal equilibration test

Interpretation of peritoneal equilibrium test

- Glucose D/D₀
  - High: 0.61
  - Low: 0.49
  - Low average: 0.38
  - High average: 0.26
  - High: 0.12

- Creatinine D/P
  - High: 1.03
  - Low: 0.81
  - Low average: 0.65
  - High average: 0.50
  - Low: 0.34

Graph illustrates the changes in glucose and creatinine levels over time (h) for different conditions.
Peritoneal equilibration test

95 children 1.1 L/1.73 m² PD 2.5%.

D/P

Creatinine

0.88
0.77
0.64
0.51
0.37
0.8
0.6
0.5
0.35
0.25

High
High avg.
Low avg.
Low

Time (hour)
© J Stefanidis 2001
Adequacy goals of Peritoneal Dialysis

- Patients with residual kidney function (RKF) (>100 mL/day):
  1) “Minimal” Kt/V Urea of at least 1.7/week (PD and RKF).
  2) Kt/V urea should be measured within the first month of PD and, subsequently, at least once every four months.
  3) A 24 hour urine collection for urine volume and solute clearance should be obtained, at a minimum, every 2 months.
For patients without RKF (urine volume is <100 mL/day):

1) “Minimal” Kt/V Urea of at least 1.7/week.

2) The dose should be measured within the first month of starting dialysis and, subsequently, at least every four months.
Why different Kt/V in PD vs HD

- BUN may not be a good index uremic toxin and middle molecule clearance may be different between PD and HD
- Peak BUN concentration may be related to uremic symptoms and maybe to survival?
Peritoneal Membrane Function

- Ultrafiltration (UF)
- Clearance (KT/V)
- PET
  - D/Pcr
  - D/D0 Glucose

Dialysis Mode
Dwell time
PD solution
Fill volume/ Number of exchange
Factors determining clearance in peritoneal dialysis patients

1: Nonprescription factors
- Residual renal function
- Body size
- Peritoneal transport characteristics

2: Prescription factors
(a) CAPD
- Frequency of exchange
- Dwell volume
- Tonicity of dialysis solution

(b) APD
- Number of day dwells
- Volume of day dwells
- Tonicity of day dwells
- Time on cycler
- Cycle frequency
- Cycler dwell volume
- Tonicity of cycler solution
Measurement of clearance:

- **CrCl (Creatinine clearance)**
- \( \text{CrCl} = \text{Total CrCl corrected for 1.73 m}^2 \text{ body surface area} \)
- \( \text{Total CrCl} = \text{Peritoneal CrCl} + \text{Renal CrCl} \)

- **Peritoneal CrCl** = 24 hour dialysate creatinine content / Serum creatinine
- **Renal CrCl** = 0.5 [ 24 hour urine creatinine content / serum creatinine + 24 hr urine urea nitrogen content / serum urea nitrogen ]

Body surface area (DuBois formula)

- \( \text{BSA (m}^2) = 0.00718 \times W^{0.425} \times H^{0.725} \)

C: Determinants of clearance:
Choice of Prescription

A: Clearance Targets.
   • Target Kt/V for all modalities of PD is 1.7 per week

B: Measurement of clearance:
   Kt/V
   Kt = Total Kt = Peritoneal Kt + Renal Kt

A: Peritoneal Kt =
   • 24 hour collection of peritoneal dialysate effluent
   • Measure urea concentration in dialysate
   • Estimate total urea content = urea conc. × volume of effluent

Peritoneal Kt = urea content in dialysate / serum urea level
Initial prescription

- Fill volume related to body size
DOQI guidelines for initial prescription

- GFR More than 2 ml/min

<table>
<thead>
<tr>
<th>Patient size</th>
<th>CAPD</th>
<th>Cycler</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSA &lt; 1.7 m²</td>
<td>4 cycles × 2 L</td>
<td>4 C × 2L</td>
</tr>
<tr>
<td>BSA 1.7 – 2 m²</td>
<td>4 × 2.5 L</td>
<td>4 × 2.5 L</td>
</tr>
<tr>
<td>BSA &gt; 2.0 m²</td>
<td>4 × 3 L</td>
<td>4 × 3 L</td>
</tr>
</tbody>
</table>
East, west and south, Libyan nephrologists are together.