HaemoDialysis: New Technology

Peter G Kerr
Monash Medical Centre
and
Monash University
Clayton, Vic, Australia
HDF

- Large ultrafiltration component – often 80-100 ml/min
- Therefore, need replacement fluid – now usually ultrafiltered dialysate
- Improved middle molecule clearances
- Initially stated to have improved phosphate clearance – dubious
- Improved cardiovascular stability – thermal balance
- Up to 40% in Europe (and SA!). Nil in USA.
- Virtually all new machines HDF capable
- Minor expense
The sorbent cartridge

**Cartridge Effluent**

- Zirconium Oxide & Zirconium Carbonate Layer
  - Binds:
    - Fluoride
    - Phosphate
    - Heavy Metals
  - Releases:
    - Acetate
    - Bicarbonate (more)
    - Sodium
- Zirconium Phosphate Layer
  - Binds:
    - Ammonium
    - Calcium
    - Magnesium
    - Potassium
    - Metals
    - Other Cations
  - Releases:
    - Sodium (less)
    - Hydrogen
- Urease Layer
  - Binds:
    - Nothing (Converts Urea)
  - Releases:
    - Ammonium Carbonate
- Activated Carbon & Purification Layer
  - Binds:
    - Heavy Metals
    - Oxidants
    - Chloramine
    - Creatinine
    - Uric Acid
    - Other Organics
    - Middle Molecules
  - Releases:
    - Nothing

**Used Dialysate**
Function of Sorbent Cartridge

• To purify tap water to make initial dialysate

• To regenerate used dialysate for return to dialyzer
  – Removing uremic wastes from used dialysate
  – Providing bicarbonate in exchange for urea
  – Removing unused K\(^+\), Ca\(^{++}\), Mg\(^{++}\)
  – Regeneration means minimal water usage (6 L per session)

• To remove bacteria and endotoxin(s) from dialysate
  – Bacteria: to < 1 cfu/ml
  – Endotoxin: to < 0.3 EU/ml
Sorbent HD Systems

**Advantages**

- Transportable
- No water treatment
- Uses tiny volume of potable (ordinary tap) water
- Inherently safe
- No disinfection, decalcification or machine cultures necessary
- Water quality approaches ‘ultra-pure’

**Disadvantages**

- Somewhat more expensive to use
- Unfamiliar technology
- Requires more staff education, interaction
Blending Technology - Portability

- Renal Solutions Technology Allient™
- Sorb Technology HiSorb+™
- FMC NA Technology 2008 Sorbent System Optiflux 180NRE™
- Xcorporeal Technology PAK

Not FDA Approved

Expected Release 2012 for Institutional Use
Fresenius PAK

- Provides sorbent-regenerated HCO3 dialysis fluid using:
  - Sorbent technology continuously renews dialysis fluid
  - Dialysis flow rate = 150 to 500 ml/min
  - Blood flow = 100 to 600 ml/min
  - Is a truly portable dialysis system by splitting into two halves …
    - A 20.4 kg pump unit
    - A 10 kg reservoir unit

Also features:
- Disposable cartridge with dialysis fluid lines, blood lines and HFAK
- No air blood interface (reduces clotting and heparin needs)
- Wipe down disinfect
- Automated prime and rinse back
- Heparin pump and medication port
- Data storage
Medtronic’s Hemodialysis Platform

Reduced infrastructure and water with improved access for patients

- Reduced water usage
- Accommodates any dialyzer – both high and low flux
- Highly flexible, portable size and features
- Easy to deploy, improving patient access
- Advanced connectivity for remote monitoring and informatics
- Advanced sensors and automation
Baxter Home HD System - Vivia

• Baxter ‘partners’ DEKA to access AKSYS patents … 2007
• Work begins on new Home HD system … 2008
• Completion of clinical trials expected … 2013
Baxter Home HD System

• Standard sized machine – but splits into two (for OH&S)
• Provides single pass HCO3 dialysis fluid
  – Infusion grade fluid
  – Dialysis fluid flow = 200 to 600 ml/min
  – Blood flow = 100 to 600 ml/min
  – An internalised hot water sterilisation system allows …
  – Multiple re-use of artificial kidney and all tubing for 30 days/set
• Also features
  – Heparin pump and medication port
  – Calculation of ultra filtrate and infuses dialysis fluid for hypotension
  – Automated prime and rinse back using dialysis fluid
  – A built-into-blood-lines venous disconnect alarm device
  – Ipad-like free standing tablet system to interface with patient
Baxter Home HD System

• Water source resides in the base of the machine
• Patient changes clip-in water filters etc. each 3 months
• Water connection same as washing machine connection

Home HD modalities supported:

– Conventional treatment (three treatments per week)
– Every other day conventional treatments
– Short Daily (five or more treatments per week)
– Every other day nocturnal treatments
– Daily nocturnal treatments (five or more treatments per week)
Baxter Vivia Update

• Trials in Canada, USA and Europe (eg Sweden)… stalled!

• ? Will be trialled in ANZ.
• Hiccups along the way – eg. Not shown at ASN or ADC
• Planned 30x uses = 7 in real life
• Expensive.
• Relies on reuse – can we cope??
Quanta SelfCare

Is smaller and lighter than NxStage

Is a single-pass dialysis system

As such, it employs conventional consumables and conventional dialysate and blood flow rates

Disposable pneumatic balancing pump system

Still requires an RO
Cartridge clicks in when door opened and ‘engages’ when door shuts
Quanta SC+ Circuit
Physidia S3

Now registered for use in France.

Main disadvantage is that it utilises bagged dialysate and runs low dialysate flows.

“A French NxStage”.
Ready-to-use devices

Its functions rely on disposable devices that are very easy to use and require very little preparation:

- **The blood line device** is placed on the front side of the machine and connected to the pressure sensor with a simple push.
- **The dialysate cassette** once in its side case will be automatically connected when the door of the machine is closed.
- **The dialysate bags with their bicarbonate buffers** lie on an external stand that analyzes the composition of the bags and conveys this information to the Physidia S³ via a Bluetooth connection in order to guarantee its conformity with the prescription.
An interactive tablet to facilitate its use

The screen of Physidia $S^3$ is an interactive tablet with a touchscreen device.

- From the moment the device is turned on, the user is guided through the different steps of the process, each procedure being displayed on the screen:
  - preparation of the device
  - identification
  - setting up of the disposable material
  - definition of the parameters of the session
  - medical prescription checking
  - disposable material checking
  - visualization of the parameters for the session

- The tablet saves the data for the dialysis that can be viewed by any authorized person or exported to a folder dedicated to the patient
Sterile dialysate bags

- The use of sterile, **apyrogenic dialysate bags** made in accordance with **pharmaceutical norms** makes it possible to use the performances of the high-permeability membranes to their full potential without any risk for the patient.
- The bags are connected through a **specific set of pipes**.
- A **system** of superposed trays that communicates with the machine will **verify the quality of the instantaneous mixture** before it is used.
Korean C-PAK* … does HD, and HDF too

* Carry-on Pulse Artificial Kidney
The WAK
Current ‘artificial’ membrane

= current ‘artificial’ polysulphone membrane used in standard dialysis technology

Nano-scale biological membrane

= a structured, designed, regular reproducible, bio-mimetic but ‘built’ membrane
Nanorod Templated Porous Membranes

Gold coated sapphire substrate, 3x5 mm

Spin-coat pmma

ZnO, Carbon

Epitaxially ZnO nanorod array
20-200 nm diameter, 50 -20 microns long
density $10^6$-$10^{10}$/cm$^2$

Oxygen plasma etching

Polymer encased Nanorod array

Exposed nanorod tips

1. Dilute HCl
2. Peal off sapphire

Free standing pmma film with aligned nanopores

http://www.lbl.gov/pbd/energy/membranes/Arnold%20Nanomembranes.ppt
Towards the implantable, bio-inert kidney

Future outlook

2009 sorbent regeneration

2010 animal trials

2011 miniaturisation

2012 clinical trials

2013 production

Nanodialysis