FACULTY OF
MEDICINE & DENTISTRY
UNIVERSITY OF ALBERTA
Division of Critical Care Medicine

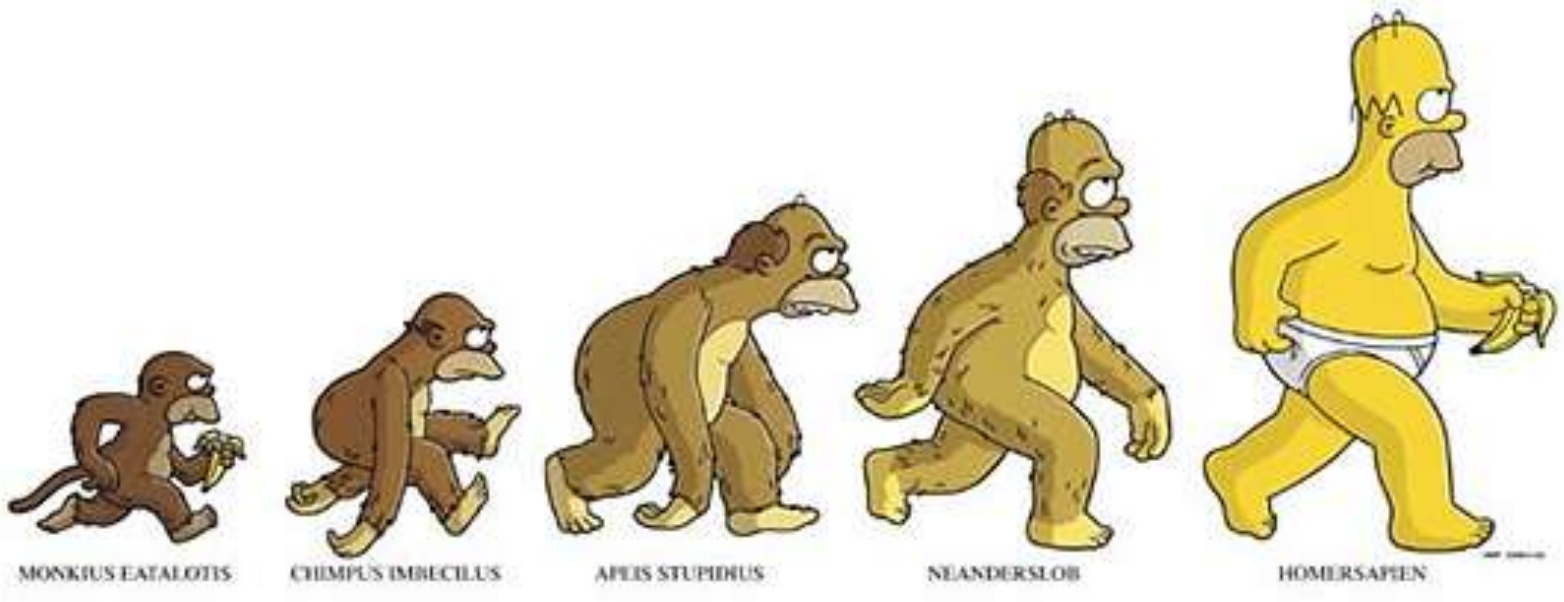
CRRT Machine Comparisons

Noel Gibney MB FRCP(C)
Professor, Division of Critical Care Medicine
Faculty of Medicine and Dentistry University of Alberta
Edmonton, AB
Canada

Content

- Evolution of CRRT and machines
- Ideal CRRT machine
- Gravimetric or volumetric?
- Outline of available technologies in USA
  - Prisma
  - Prismaflex

Evolution


MONKIUS EATALOTIS
CHIMPUS IMBECILUS
APEIS STUPIDIUS
NEANDERSLOB
HOMERSAPIEN
HOMERSAPIEN

Evolution of CRRT Machines

Ronco et al., Crit Care 2006

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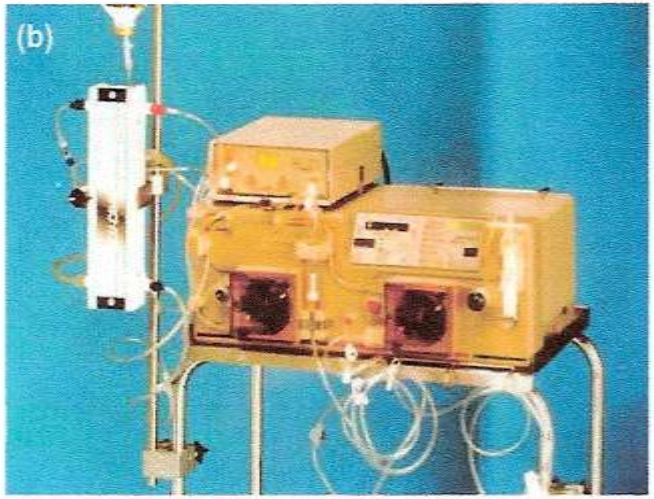

CRRT:Historical Perspective

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- Continuous arteriovenous hemofiltration (CAVH): first CRRT modality described in 1977 for hemodynamically unstable AKI patients
  - Considered a “derivative” therapy to chronic hemofiltration
  - Continuous arteriovenous hemodialysis (CAVHD) developed in mid-1980’s to improve small solute clearance
- Problems with continuous AV therapies
  - Circuit blood flow dependent on patient‘s blood pressure
  - Need for large-bore arterial catheter (bleeding, thrombosis)

CRRT: Historical Perspective

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Hospal BSM 35

- Development of early venovenous CRRT systems: “adaptive technologies”
- (late-1980’s to mid-1990’s)
  - Blood pump + ancillary pumps to control rates of dialysate (CVVHD) or replacement fluid (CVVH)
  - Semi-integrated systems: blood pump, ultrafiltration controller, and fluid pump all in same module (“open loop”)

CRRT machine evolution

- Fully integrated (blood pump and all fluid pumps) venovenous CRRT systems (beginning mid-1990's)
  - First-generation (e.g., Prisma): ultrafiltration control based on gravimetric servo-feedback ("closed loop") system
  - Second-generation (e.g. Prismaflex): additional functionalities and greater blood/fluid flow rate capabilities

Ideal CRRT Device

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- Inexpensive
- User friendly
- Flexible
- Accurate
- Safe
- Thermoregulation
- Exchangeable components
- Biocompatible

Fluid Accuracy in CRRT: The Acute Dialysis Quality Initiative (ADQI)

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ADQI 1 Conference: CRRT*

Workgroup 5

Operational Characteristics

What are the optimal components of a CRRT system?

Ultrafiltration controllers

The move from adaptive CRRT machinery to industry produced CRRT machinery is in part for accuracy of ultrafiltration control. Intravenous pumps (which have a prescribed error rate of ± 5% in the absence of a pressure gradient) have been found to have error rates as great as 30% when used to regulate ultrafiltration.[23,24] Industry produced CRRT systems report ultrafiltration error rates of ± 1% to ± 30 mls/hr. Using these "accepted" error rates will factor in as minimal or more significant depending upon the hemodynamics of the patient as well as the necessity of ultrafiltration accuracy for patient care (Level V).

23. Jenkins R, Harrison H, Chen B, Arnold D, Funk J: Accuracy of intravenous infusion pumps in continuous renal replacement therapies. ASAIO J 1992;38(4):808-10.
24. Roberts M, Winney RJ. Errors in fluid balance with pump control of continuous hemodialysis. Int J Artificial Organs 1992; 15:99-102.

* Bunchman, T., Palevsky, P., Tetta, C. ADQI 1 Conference: CRRT. Retrieved October 16, 2009 from http://www.ccm.upmc.edu/adqi/adqi01.html

Gravimetric vs Volumetric Devices

- Gravimetric systems
  - Gravimetric ultrafiltration control was incorporated into CRRT devices specifically to overcome limitations of volumetric control in hemodynamically unstable patients
  - Industry standard for CRRT
  - Accuracy specification is *a defined value* over a certain time period
  - Prismaflex specification: ±30 mL/hr; ±70 mL/3 hrs; ±300 mL/24 hrs
- Volumetric systems
  - Industry standard for conventional HD
  - Accuracy specification expressed as a certain percentage of the total fluid volume exchanged ***OR*** a defined value
  - NxStage System One specification: ***greater of*** 300 mL/12 hrs or 3% of the therapy fluid exchange volume

Newer CRRT Machines

- Integrated blood modules
- Fluid balancing controls
- Both intermittent and continuous therapies capacity
- Blood flow rates up to 500 ml/min
- Increased dialysate and replacement fluid flow rates
- Highly permeable membranes

Newer CRRT Machines

- Higher surface area dialyzers
- Fluid control via gravimetric or volumetric control systems
- Simplified priming procedures
- Friendly user interface
- Data extraction capabilities
- Automatic data printing

Descriptors

- Dialyzer
  - Any dialyzer
  - Cartridge
- Pumps
  - Number
  - Purpose
- Modes
- Min/Max Ultrafiltration rate
- Min/Max Effluent flow
- Volume control
  - Volumetric
  - Gravimetric
- Alarms
- Safety features
- Blood warmer

CRRT Machines

- Prisma
- Prismaflex
- Diapact
- Aquarius
- NxStage
- Fresenius 2008 K

Prisma (Gambro)

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- Preassembled cartridge
- Automatic loading and priming
- 4 pumps
  - SCUF
  - CVVH
  - CVVHD
  - CVVHDF
  - Plasma exchange
- Flow rates
  - Q_B 0 – 180 ml/min
  - Q_D 0 – 2500 ml/hr
  - Q_{RF} 0 – 2000 ml/hr
  - Total Effluent 5000 ml/hr
- Replacement Fluid
  - Pre-
  - Post-
  - Simultaneous pre- and post-
- Blood Warmer

Prismaflex (Gambro)

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- Preassembled cartridge
- Automatic loading and priming
- 5 pumps
  - SCUF
  - CVVH
  - CVVHD
  - CVVHDF
- TPE/MARS (future use)
- Fifth pump-Pre-Blood-Pump
  - Allows for citrate infusion just after connection between arterial access and blood line
- Flow rates
  - Q_B 10 – 450 ml/min
  - Total effluent 10,000 ml/hr
  - Maximum UF of 2000 ml/hr
- Replacement Fluid
  - Pre- and / or Post
- In-line blood heater

Prismaflex

- Gravimetric fluid balance system provides check & balance for precise fluid exchange & accurate patient fluid removal
- Real-time dose indicator assesses prescription delivery
- Deaeration chamber collects & removes air while minimizing clotting
- Can change pre- and post- infusion mixing points during a treatment, using the same set
- Membranes: M and HF series

NxStage System One

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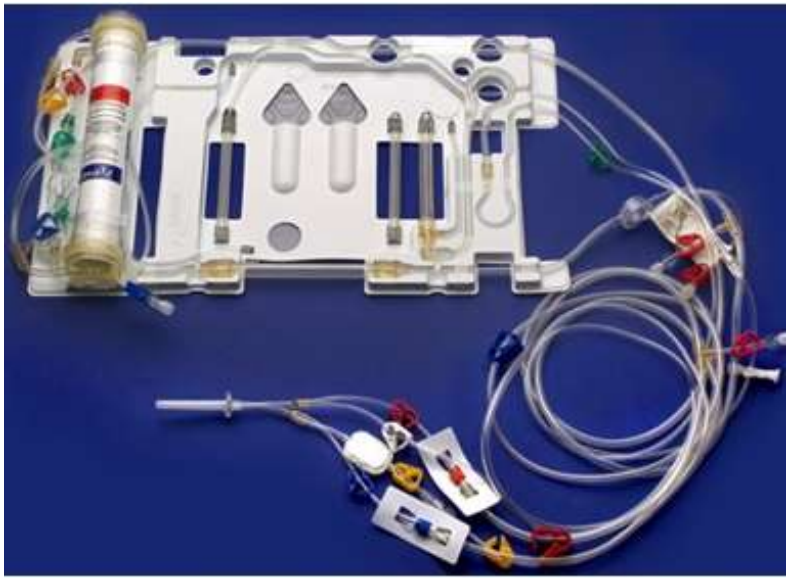
NxStage System One™

- Preassembled cartridge
- 3 pumps
- Choice of Therapy
  - IHD
  - SLED
  - CVVHD
  - Pre- or Post- dilution CVVHF
  - Pre-pump dilution HF
  - Isolated Ultrafiltration (SCUF)
- Flow rates
  - Q_B 0 – 600 ml/min
  - UF Removal: up to 2.4 L/hr
  - Prescription Fluid: up to 12 L/hr
- Fluid heater
- Comprehensive IT, print, download, remote monitoring, HIS
- Any hemofilter or Pre-attached

NxStage System One



- Bag changes
  - Free from waste bag changes
  - Eliminates blood pump stopping for bag changes
  - No fluid bag limits (20 liters at once)
- Cartridge
  - Drop-in loading and engagement of all pumps and safety systems
  - One set delivers all therapies
  - No prime intervention
  - No blood/air interface in cartridge optimizes BF and reduces clotting
- Volumetric balancing chambers incorporated into the cartridge
  - Will not allow fluid imbalance due to overridden alarms

Diapact (B Braun)

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Therapy Options

- Continuous
  - SCUF
  - CVVH
  - CVVHD
- Intermittent
  - Hemofiltration (HF)
  - Hemodialysis (HD)
  - High flux hemodialysis (HFD)
- Plasmapheresis
  - Plasma Adsorption / Perfusion (PAP)
  - Plasma Exchange (PEX)

Diapact

- Automated priming
- 3 pumps
- Flow rates
  - Q_B 10 – 500 ml/min
  - IHD QD 5-400 ml/min (300 – 24000 ml/hr)
  - Continuous QD 5 – 200 ml/min (12000 ml/hr)
  - RF rate 5 – 100 ml/min (6000 ml/hr)
  - UF rate 0 – 300 ml/min (18000 ml/hr)
  - Wt loss goal range 0 – 2000 ml/hr
- Replacement Fluid
  - Pre-
  - Post-
- Integrated fluid warmer
- Uses any hemofilter

Aquarius (Baxter)

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- Automatic priming
- 4 pump and 6 pump models
  - Citrate & calcium pumps for RCA
- Therapies
  - SCUF
  - CVVH, CVVHD, CVVHDF
  - TPE
  - Hemoperfusion
- Flow rates
  - Q_B: 30-450 mL/min (adult)
  - Dialysate/Replacement – up to 10 L/hr
  - Filtrate – up to 12 L/hr
  - Up to 20 L can be hung on scales
- Replacement Fluid
  - Pre- and/or post-dilution

Aquarius System

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- Gravimetric fluid balance system
- Membranes & tubing sets:
  - Four sizes of polyethersulfone hemofilters
  - Three sizes of plasma filters for TPE
  - Three tubing sets – same set for all therapies
- Integrated fluid warmer
- Automatic degassing unit
- New additions:
  - Patented Total Fluid Loss management (TFL): Software compensates for UF volume discrepancies in case of balance alarms
  - Renal dose display feature shows real-time delivered treatment dose

Fresenius 2008 K

- 1 + 3 pumps
  - CVVHD
  - IHD-IHFD
  - SLED
  - SCUF
- Flow rates
  - Q_B 0 – 500 ml/min
  - Q_D 0 – 300 ml/hr
  - CRRT mode dialysate fixed:
    - 100 ml/min
    - 200 ml/min
    - 300 ml/min
- Volumetric scales
- No Replacement Fluid infusion sites
- Fluid heater

Future trends

- **Refining techniques for:**
  - Anticoagulation
  - Heparin bonding
  - Ultrafiltration
  - HVHF
  - Plasma exchange
  - Plasma adsorption
  - Immunoadsorption
  - Liver failure
- **Online monitoring:**
  - Urea, K, Na, Ca sensors
  - Temperature sensors
  - Blood volume sensors
  - Citrate anticoagulation sensors
  - Biofeedback systems

Thank You For Your Attention!

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Questions?

ngibney@ualberta.ca