Dialyzer

There's a user manual in that box!

John Sweeny

Old Dialysis Guy

Wednesday – March 26th, 2014

Definitions

- Precaution
  - A measure taken beforehand to ward off negative results or insure success
  - Example: Putting on a seat belt prior to driving.
- Caution
  - Careful avoidance of undue risk
  - Heedful prudent forethought to minimize risk or danger
  - Example: Let someone else test the ice on a pond.
- Warning
  - The action of putting one on his guard by intimating danger from an act or course of conduct
  - Example: Put down that rattlesnake Harold, you don't know where it's been.

Webster's Third New International Dictionary; Editor in Chief, Philip Babcock Gove, Ph.D.;

Definitions

- Indication
  - Show or make known with a fair degree of certainty
  - Reveal in a fairly clear way
  - State or express in a brief or cursory way
  - Example: "In case of collapse, the immediate indication is artificial respiration." – JAMA
- Contraindication
  - A symptom or condition that makes inadvisable a particular treatment or procedure
  - Example: People who live in stone houses shouldn't throw glass.

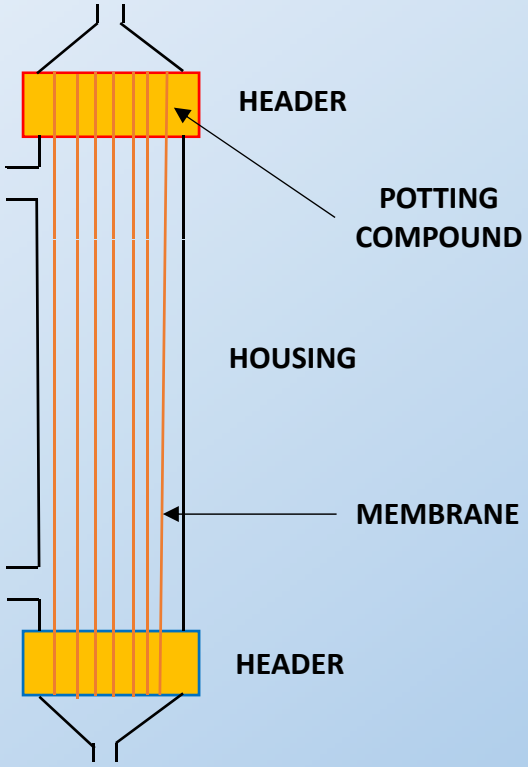
Insert - Outline of Information

- Specifications and In-Vitro Data
  - Technical Information
  - Clearance data
  - In-vitro test conditions
- Directions for use
  - Storage conditions
  - Warnings/Cautions/Indications/Contraindications
  - Adverse and Hypersensitivity Reactions
  - High Permeability Dialyzers
  - Dialysate Fluid

Insert – Outline of Information

- Treatment Procedure
  - Set-up Procedure
  - Initial Assembly
  - Priming
  - Treatment Procedure
  - Treatment Monitoring
  - Termination of Treatment
- Warranty Clause

Technical Information



Header = Polypropylene
Housing = Polypropylene
Potting Compound = Polyurethane
Membrane =
- Cellulose Triacetate (CTA)
- Ethylene Vinyl Alcohol Copolymer (EVAL)
- Polyacrylonitrile (PAN)
- Polyester Polymer Alloy (PEPA)
- Polyethersulfone (PES)
- Polymethylmethacrylate (PMMA)
- Polysulfone (PSF)

In-vitro Test Conditions

- All testing done to American National Standard Institute's (ANSI) standard BS EN 1283: 1996. $171.00 at the ANSI web store.
- Clearance measured at 37^{o}C with a UFR = 10 mL/min
- Ultrafiltration Coefficient measured using Bovine blood with a hematocrit of 32% and a blood flow of 300 mL/min
- Priming volume done using oil.
- Blood and Dialysate pressure drops across the dialyzer at various flow rates are done at a TMP of 50 mmHg.
- Sieving coefficients were determined after plasma exposure to the membrane with a blood flow of 300 mL/min and a UFR of 60 mL/min.
- Blood flow rate testing: Min - 200 mL/min, Max – 500 mL/min
- Dialysate flow testing: Min – 500 mL/min, Max – 800 mL/min

Sieving Coefficient

- Sieving coefficient is defined as the ratio of the concentration of a substance on the downstream side of the membrane divided by the concentration of the substance on the upstream side.
- A sieving coefficient of 1. 0 means that the substance passes completely through the membrane.
- A sieving coefficient of 0.0 means that the substance does not pass at all.
- In general, the higher the molecular weight, the lower the sieving coefficient.
- With synthetic membranes proteins can coat the membrane during dialysis and slightly reduce the sieving coefficient.

Sieving Coefficient

Molecule	Molecular Weight	Sieving Coefficient	Blood:Dialysate
Sodium	23	0.94	16:15
Urea	60	1.00	100:100
Creatinine	113	1.00	100:100
Phosphate	134	0.78	50:39
Vitamin B12	1,355	0.99	100:99
Inulin	5200	0.93	100:93
β_2 Microglobulin	11,818	0.54	50:27
Myoglobin	17,200	0.22	50:11
Albumin	66,000	<0.01	<100:1

Dialyzer Fluid Parameters

Surface Area	1.1 m^2	1.3 m^2	1.5 m^2	1.7 m^2	1.9 m^2	2.1 m^2
Kuf (mL/hr/mmHg)	59	64	67	74	76	82
Priming Volume (mL)	69	83	93	106	115	128
Pressure Drop:						
Blood (mL/min)	200 500	200 500	200 500	200 500	200 500	200 500
Dialysate (mL/min)	500 800	500 800	500 800	500 800	500 800	500 800
Blood Side (mmHg)	78 166	76 153	70 158	67 157	67 153	65 149
Dialysate Side (mmHg)	21 26	19 29	21 29	17 25	19 29	17 25

Venous Pressure + Blood Pressure Drop = Post pump Arterial Pressure

As the dialyzer gets bigger, the blood pressure drop gets lower because there is more fiber.

Dialyzer Clearance
In Vitro

Surface Area	1.1 m^2	1.3 m^2	1.5 m^2	1.7 m^2	1.9 m^2	2.1 m^2
Blood Flow (mL/min)	300 400	300 400	300 400	300 400	300 400	300 400
Dialysate Flow (mL/min)	500 800	500 800	500 800	500 800	500 800	500 800
Urea (60 daltons)	257 327	272 316	278 359	285 368	288 345	291 378
Creatinine (113 daltons)	233 297	250 318	259 333	268 349	273 358	275 363
Phosphate (134 daltons)	213 263	230 291	241 305	254 322	258 335	265 339
Vitamin B_{12} (1,355 daltons)	148 173	165 197	180 215	190 231	200 245	206 254
Inulin (5,200 daltons)	94 97	102 113	112 125	121 132	132 149	145 159

In-vitro vs. In-vivo

Leading Nephrologists Recognize Clinical Significance

"In conclusion, prescribing dialysis treatments using manufacturer *in vitro* generated clearances can lead to marked under dialysis of patients. We recommend measuring Kt/V and adjusting dialysis prescription accordingly. When initially prescribing dialysis, if possible, *in vivo* data should be used. If this is not possible, then the K value should be taken approximately 20% less than the in vitro generated values."

Saha, L. K. & Van Stone, J.C. Differences between Kt/V measured during dialysis and Kt/V predicted from manufacturer clearance data. The International Journal of Artificial Organs (1992): 15 (8).

In-vitro vs. In-vivo

Leading Nephrologists Recognize Clinical Significance

"The prescription must recognize that manufacturers' published *in vitro* dialyzer urea clearance for a given dialyzer may be as much as 20% greater than the clearance achieved *in vivo* at the same blood and dialysate flow rates."

Renal Physicians Association Working Committee on Clinical Practice Guidelines. Clinical Practice Guideline on Adequacy of Hemodialysis. Clinical Practice Guideline, Number 1. Washington, D.C. December 1993.

Clearance vs. Treatment Time

- How is the treatment time affected by using different dialyzers at different blood and dialysate flows?
  - Patient volume = 42,000 mL (Patient weight = 70 kg)
  - Desired URR = 70%

Dialyzer Surface (m^2)	Clearance (mL/min) Q_B = 300, Q_D = 500 In vitro – In vivo		Treatment Time (minutes) Vitro - Vivo		Clearance (mL/min) Q_B = 400, Q_D = 800 In vitro – In vivo		Treatment Time (minutes) Vitro - Vivo	
1.1	257	206	197	245	327	262	155	193
1.3	272	218	186	232	347	278	146	182
1.5	278	222	182	228	359	287	141	176
1.7	285	228	177	222	368	294	137	172
1.9	288	230	176	220	373	298	136	170
2.1	291	233	174	217	378	302	134	167

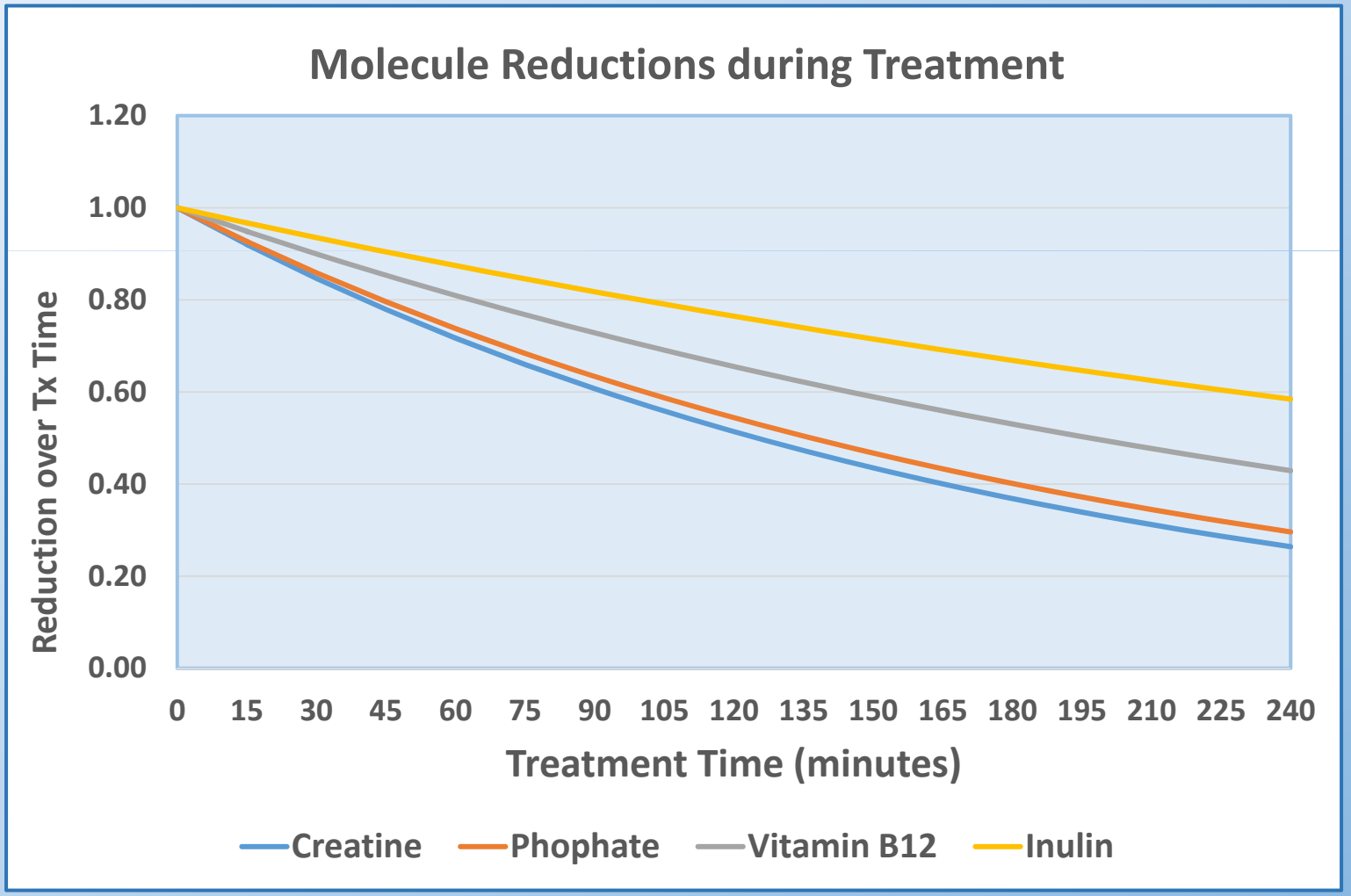
Treatment time vs. Patient weight

- How does treatment time vary with changing patient weights using the same dialyzer?
  - Dialyzer = 1.7 m^2 Desired URR = 70%
  - Weight range = 50 – 100 kilograms
  - Desired URR = 70%

Patient Weight (kg)	Clearance (mL/min) Q_B = 300, Q_D = 500 In Vitro – In Vivo		Treatment Time (minutes) Vitro - Vivo		Clearance (mL/min) Q_B = 400, Q_D = 800 In Vitro – In vivo		Treatment Time (minutes) Vitro - Vivo	
50	285	228	123	153	368	294	95	119
60	285	228	147	184	368	294	114	143
70	285	228	172	214	368	294	133	166
80	285	228	196	245	368	294	152	190
90	285	228	221	276	368	294	171	214
100	285	228	245	306	368	294	190	238

Reducing clearance by 20% increases treatment time by about 25%

What about other Reduction Ratios besides Urea?



Reduction Ratios for the other Guys

Treatment time = 240 minutes, Patient Volume = 42,000 mL

Therapy Dialyzer = 1.1 m^2	Urea	Creatinine	Phosphate	Vitamin B12	Inulin
QB = 300 mL/min QD = 500 mL/min	80 %	74%	70%	57%	42%
QB = 400 mL/min QD = 800 mL/min	85%	82%	78%	63%	43%
Therapy Dialyzer = 2.1 m^2	**Urea**	**Creatinine**	**Phosphate**	**Vitamin B12**	**Inulin**
QB = 300 mL/min QD = 500 mL/min	81%	79%	78%	69%	56%
QB = 400 mL/min QD = 800 mL/min	88%	87%	86%	76%	60%

Directions for Use

- Cautions
  - Federal law restricts this device to sale by or on order of a physician
  - Store at $0^{o}C$ to $40^{o}C$ avoiding direct exposure to sunlight and vibrations
- Indications
  - This device is for use with patients requiring acute or chronic hemodialysis
  - This device may also be used for patients intoxicated with poisons or drugs (think water soluble)
  - No mention is made of the use of the dialyzer as a dialysate filter for the production of ultrapure water

Adverse Reactions

- Adverse reactions may occur due to interactions between blood and the artificial surfaces of the entire extracorporeal circuit
- Symptoms of patient hypersensitivity (allergic) reactions include:
  - Asthmatic reactions, respiratory arrest, pruritus, urticaria, erythema, peripheral and facial edema, hypertension, hypotension and cardiac arrhythmia.
- Symptoms that can be controlled through the use of proper fluid and electrolyte balance management include:
  - Hypertension, hypotension, nausea, and headache

Warnings and Precautions

- Air Embolism and Hypersensitivity reactions
  - Discontinue treatment
  - Do not return blood
- Dialysate Fluid
  - Use an in-line conductivity monitor
  - Dialysate temp should not exceed 42^{o}C (107.6^{o}F)
- High permeability dialyzers
  - UFR rates can greatly exceed patient requirements
  - Under these conditions, the use of sterile reinfusion fluid is mandatory

Priming Instructions

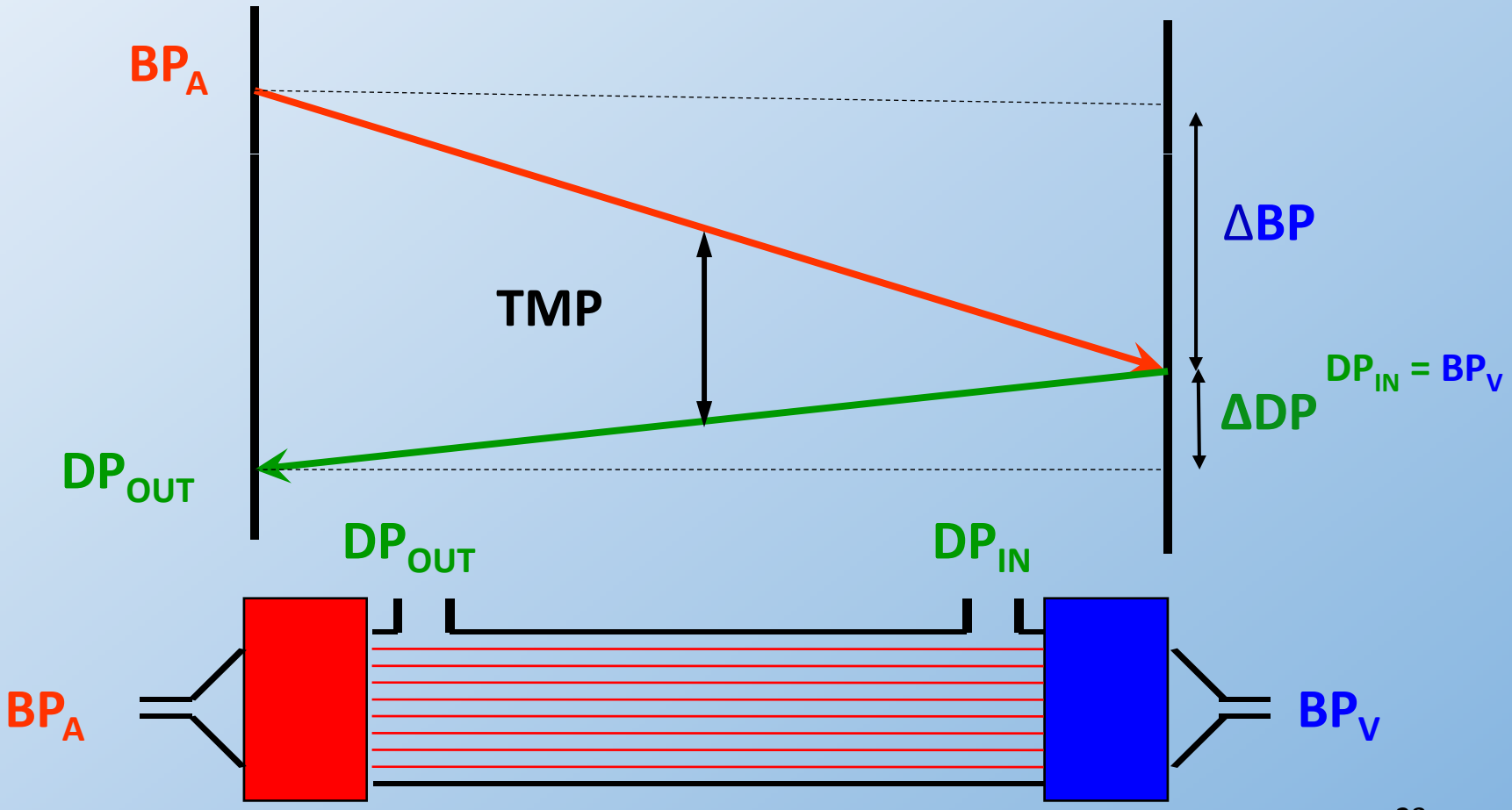
- Prime the blood site first with isotonic saline (0.9% Sodium Chloride solution)
- Rinse the dialyzer with 300 cc's of saline
- Attach patient connectors together and purge the blood lines of air
- Attach dialysate lines and prime the dialysate compartment
- Stop the blood pump and dialysate flow
- Clamp the patient connectors

UFR/TMP Caution

"Operation of the dialyzer at a zero net ultrafiltration rate or at extremely low net ultrafiltration rates may cause the dialysate-side pressure to exceed the blood-side pressure in a portion of the dialyzer. Because the likelihood of reverse ultrafiltration of nonsterile dialysate into the blood is increased under these conditions, the ultrafiltration rate must be carefully adjusted as directed by a physician."

Preventing Reverse Ultrafiltration

$$TMP = (BP_A + BP_V) / 2 - (DP_{IN} + DP_{OUT}) / 2$$
$$TMP = (\Delta BP + \Delta DP) / 2$$

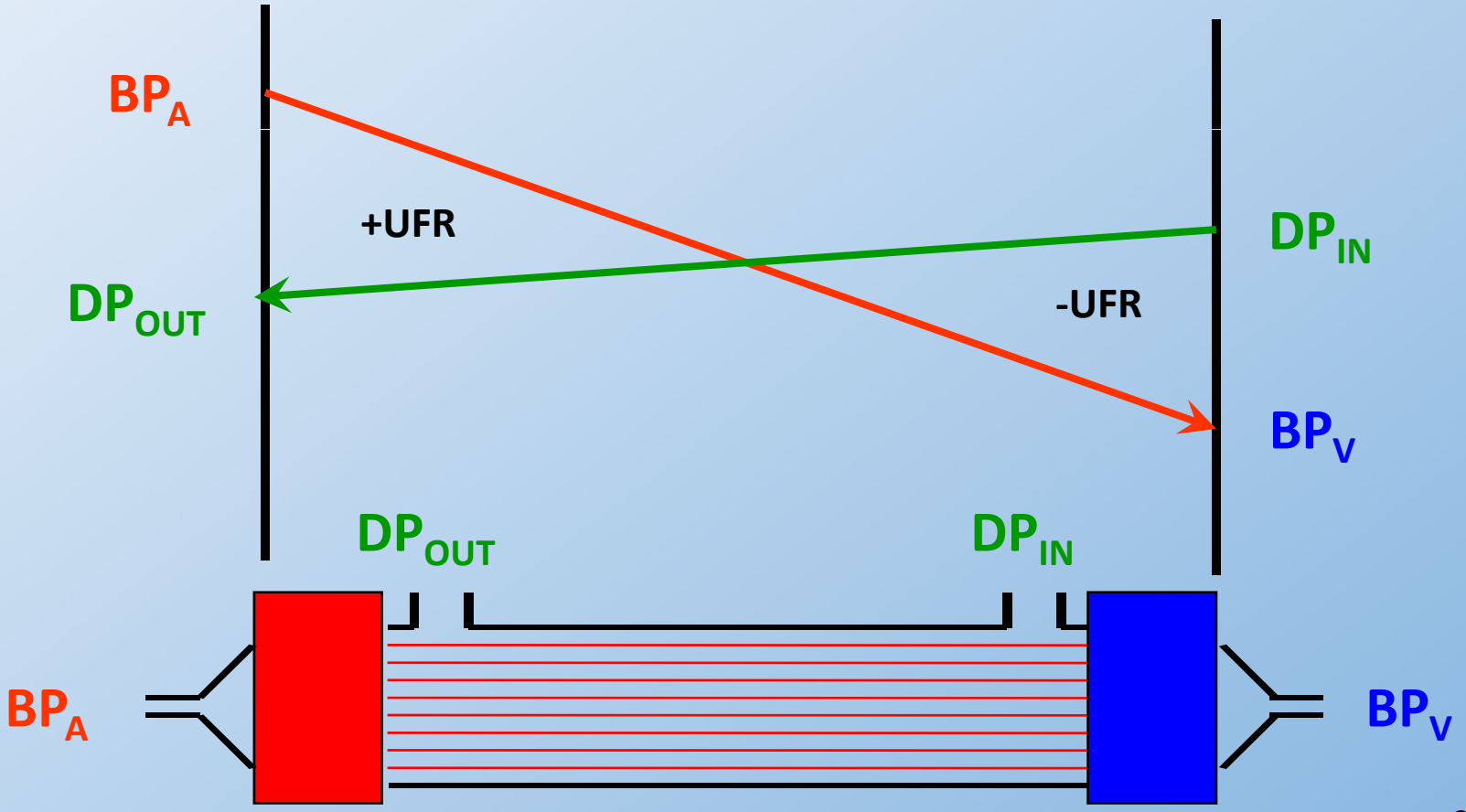


UFR and TMP for Zero Reverse UFR

Surface Area	1.1 m^2	1.3 m^2	1.5 m^2	1.7 m^2	1.9 m^2	2.1 m^2
Kuf (mL/hr/mmHg)	59	64	67	74	76	82
Pressure Drop:						
Blood (mL/min)	200	200	200	200	200	200
Dialysate (mL/min)	500	500	500	500	500	500
Blood Side (mmHg)	78	76	70	67	67	65
Dialysate Side (mmHg)	21	19	21	17	19	17
TMP = (ΔBP + ΔDP) / 2	50	48	45	42	43	41
-UFR = TMP x Kuf (mL/hr)	2,950	3,072	3,015	3,108	3,268	3,362
-UFR @ Qb = 400, Qd = 800	4,779	4,992	5,293	5,772	5,852	5,986

Reverse UFR at a Zero Ultrafiltration rate

$$TMP = (BP_A + BP_V)/2 - (DP_{IN} + DP_{OUT})/2 = 0 \text{ mmHg}$$



UFR and TMP for Zero Reverse UFR

Surface Area	1.1 m^2	1.3 m^2	1.5 m^2	1.7 m^2	1.9 m^2	2.1 m^2
Kuf (mL/hr/mmHg)	59	64	67	74	76	82
Pressure Drop:						
Blood (mL/min)	200	200	200	200	200	200
Dialysate (mL/min)	500	500	500	500	500	500
Blood Side (mmHg)	78	76	70	67	67	65
Dialysate Side (mmHg)	21	19	21	17	19	17
TMP = (ΔBP + ΔDP) / 4	25	24	23	21	22	20
-UFR = TMP x Kuf/2 (mL/hr)	740	770	755	775	820	840
-UFR @ Qb = 400, Qd = 800	1,195	1,250	1,325	1,445	1,465	1,490

Warranty Statements

- The dialyzer is designed and manufactured to written specifications in compliance with industry standards and regulatory requirements.
- The manufacturer's sole liability to the purchaser for breach of warranty shall be to replace the dialyzer.
- The manufacturer shall not be liable for any incidental loss, damage, injury, or expense directly or indirectly arising from the breach of warranty.
- The manufacturer will also not be responsible for any consequences resulting from reuse, noncompliance with warnings and instructions, or failure to ensure the product is in proper condition prior to use.

Thanks for your attention!

John Sweeny
jsweeny@tampabay.rr.com