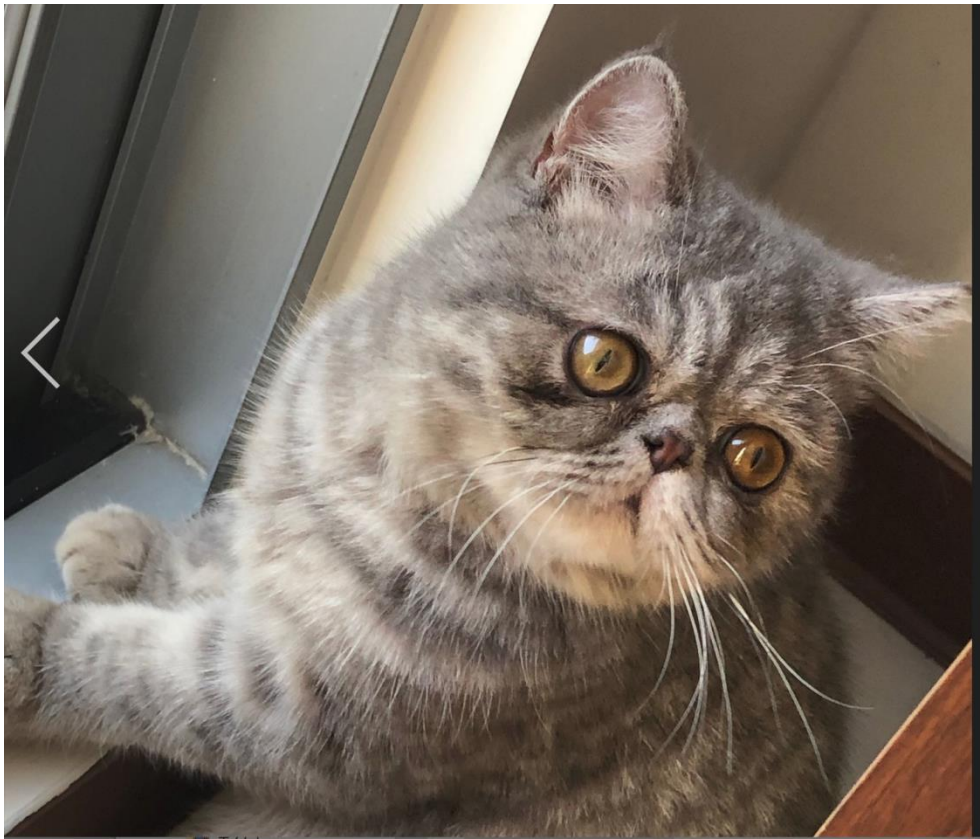
住院醫師讀書會
透析原理介紹

2022/08

裘亮德

大綱

1. 透析原理
2. 透析機組成
3. 透析血管通路
4. 透析處方
5. 特殊透析模式



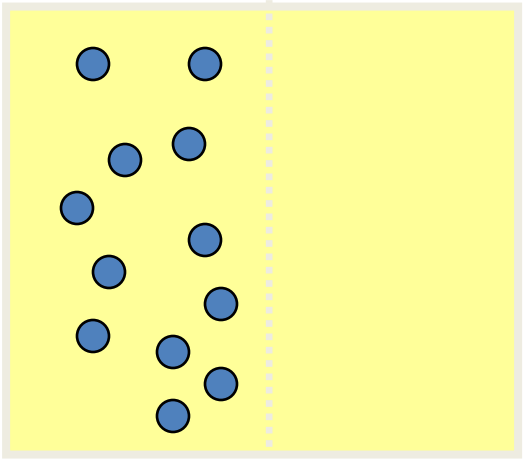
1. 透析原理

血液透析

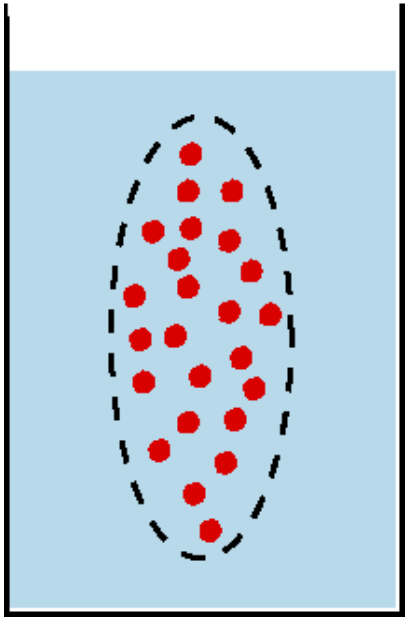
- HD= Hemodialysis
- **擴散 (diffusion)** 及**超過濾 (ultrafiltration)**

Basics of RRT

- Diffusion 擴散
  - random motion
  - **molecule** strikes pore
- Variables
  - molecular weight
    - speed
    - size
  - **membrane** resistance
  - unstirred layer



equilibrium

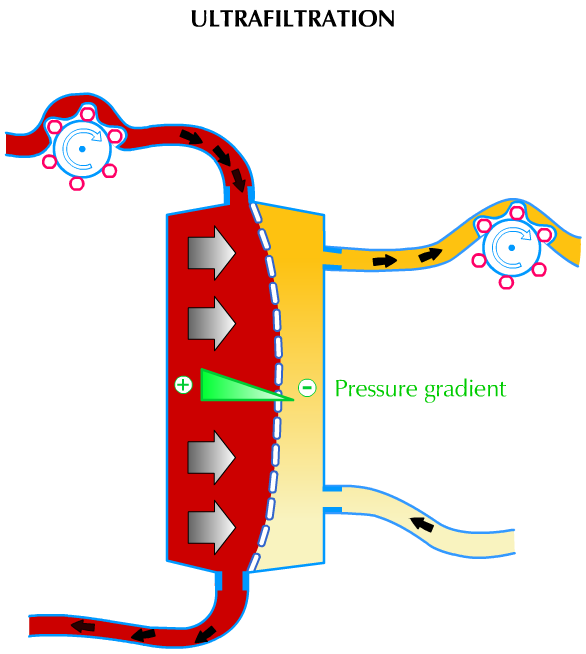


Ultrafiltration超過濾 = 脫水

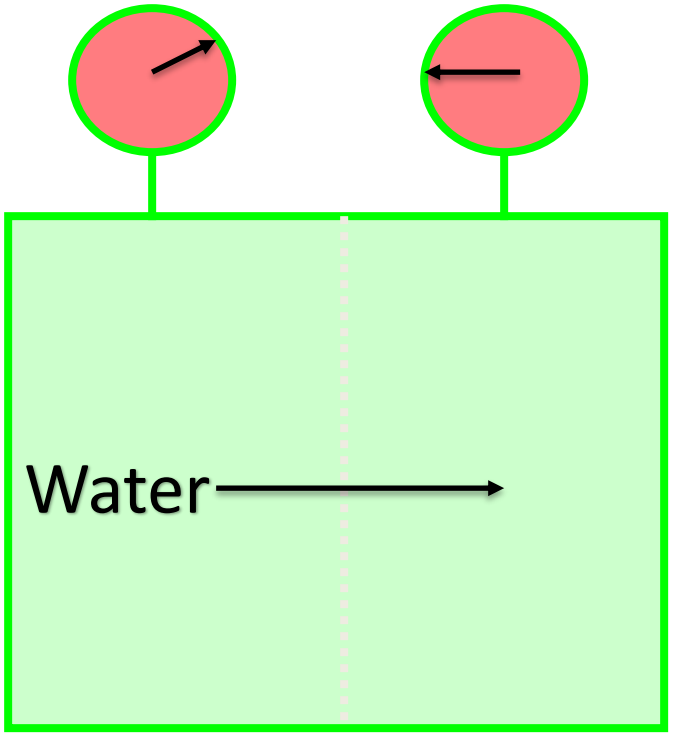
hydrostatic/osmotic

pressure gradient drives H_2O across membrane

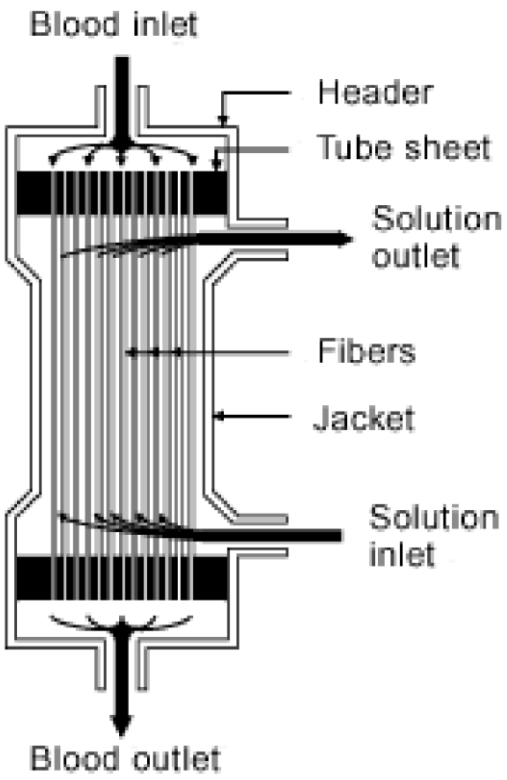
with osmotic UF there is an osmotic driving force



Basics of RRT



Hollow Fiber Dialyzer



- Blood flows through the **fiber lumens**. Typical clinical blood flow rates are 200–450 ml/min
- Dialysate flows around the external surface of the fibers. Typical dialysate flow rates are 500–800 ml/min
- Blood and dialysate flow in **opposite directions** (countercurrent flow) to maximize diffusive solute transfer

Dialyzer = artificial kidney= AK= 人工腎臟

比較:
血液過濾

- HF= Hemofiltration
- **對流 (convection)**
- 類似人體腎臟的清除尿毒分子的方式
- **血液過濾需大量補充液，在人工腎臟之前或之後加以補充**
- **中大分子清除率較佳**
  血液透析移除尿毒分子 MW 1000 以下
  血液過濾 MW 可達 25000
  (理論上，但隨著 AK 的進化，High flux HD的中大分子清除率也變好了)

- **# HDF= HD + HF**

Convection對流

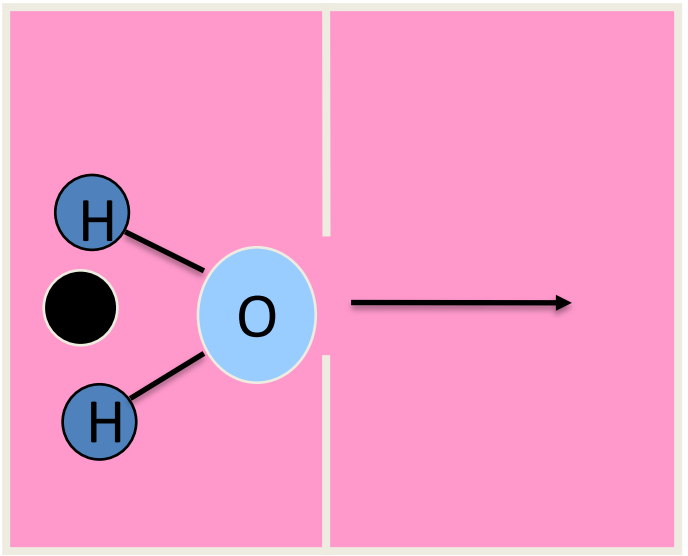
Basics of RRT

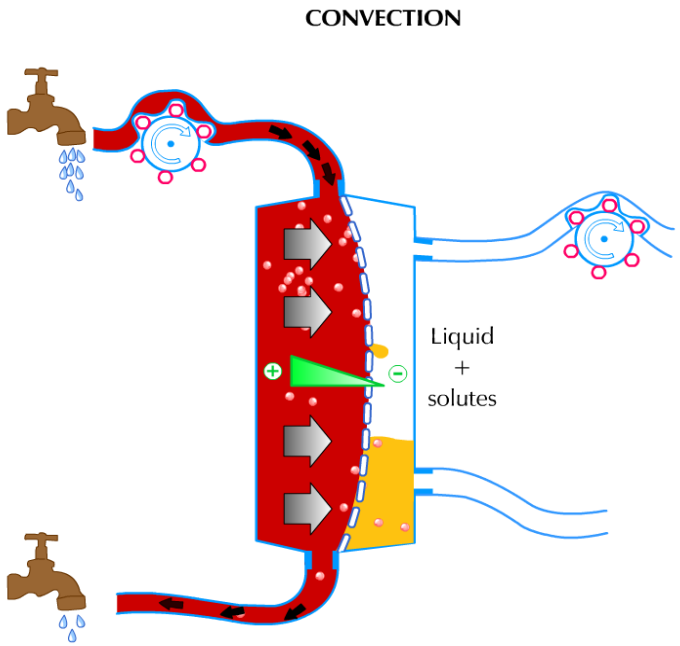
solutes swept along with water

removes **middle molecular wt.** solutes

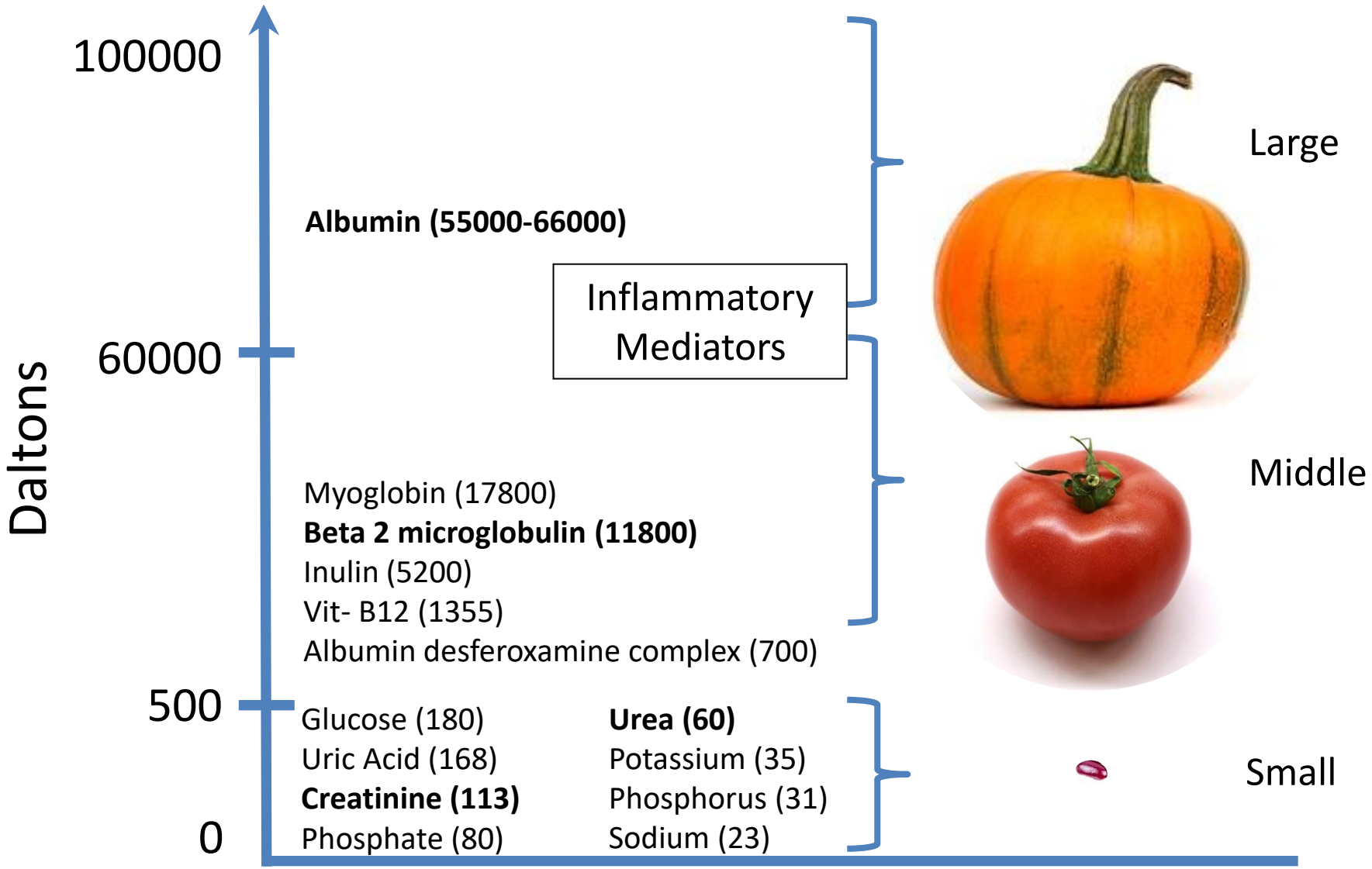
must be small enough to fit through pore

the more UF you have the more solutes you clear



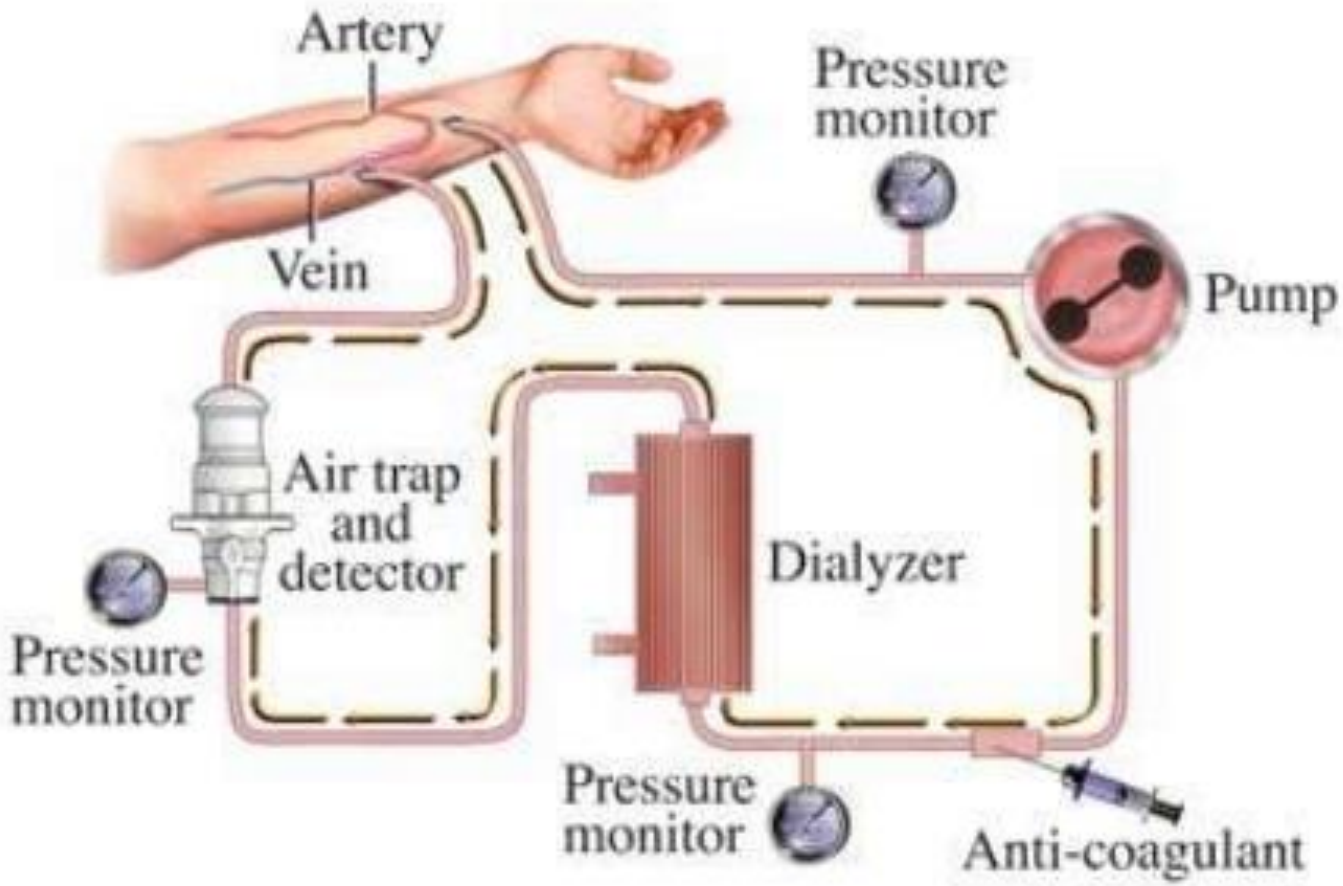


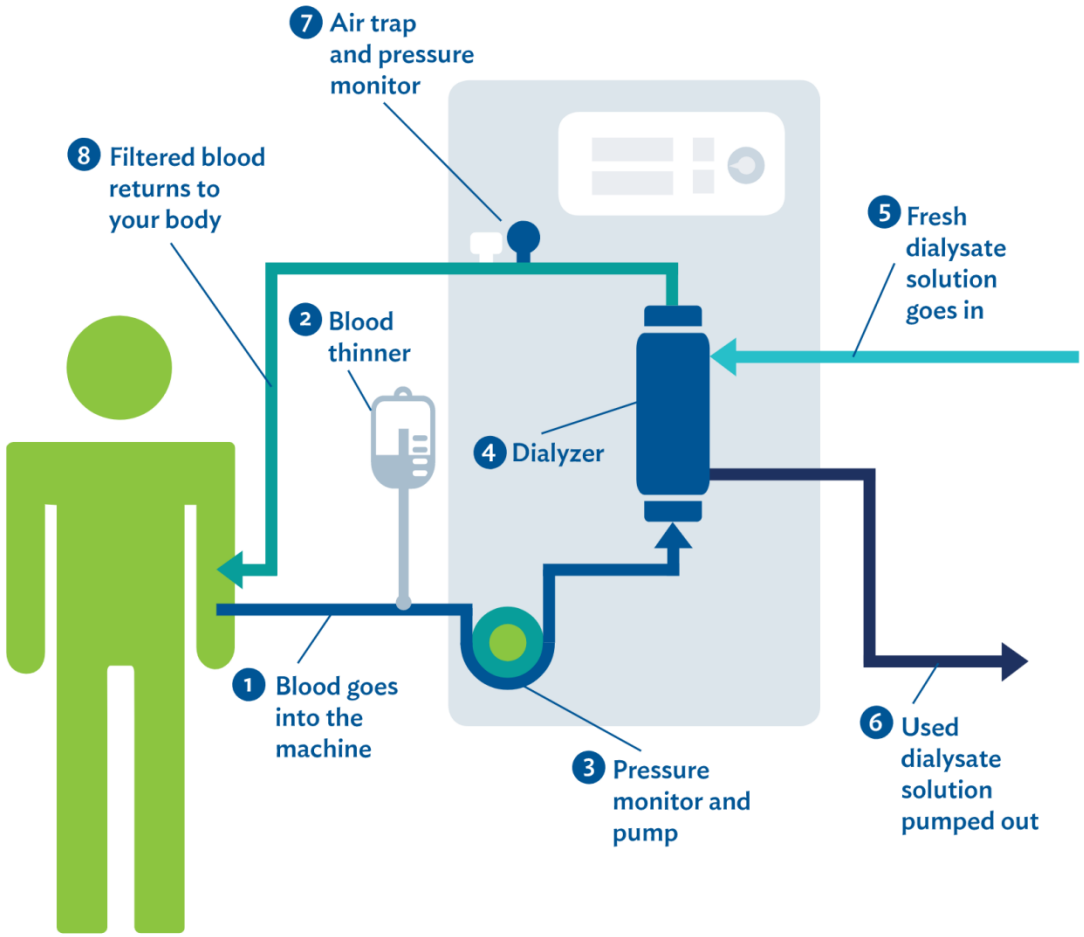
Molecular Weights



2.透析機組成

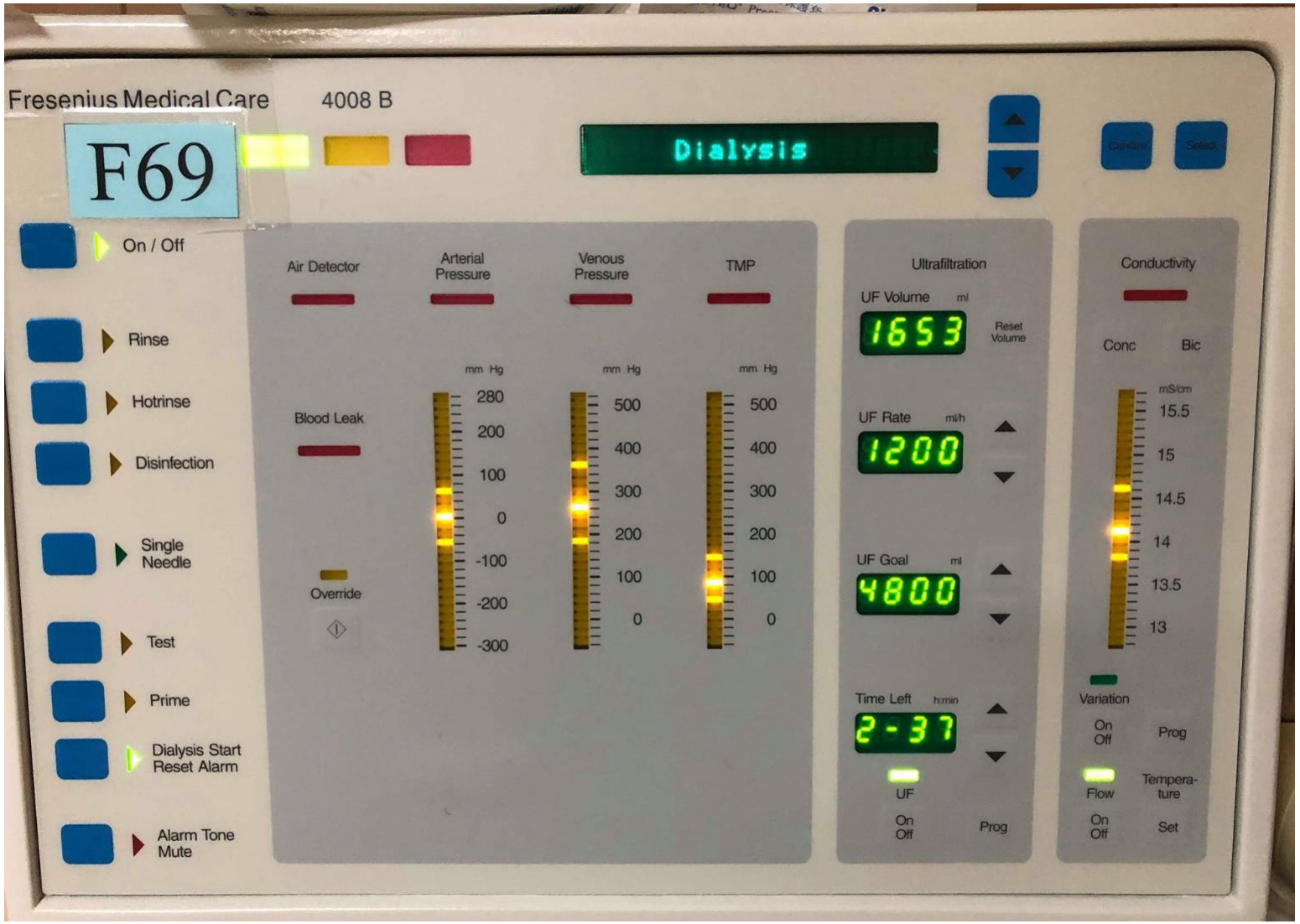
Hemodialysis Circuit





https://www.freseniuskidneycare.com/treatment/dialysis/hemodialysis-machine

本院最常用機種


Fresenius Medical Care
4008 B
F69
Dialysis
On / Off
Rinse
Hotrinse
Disinfection
Single Needle
Test
Prime
Dialysis Start Reset Alarm
Alarm Tone Mute
Air Detector
Arterial Pressure
Venous Pressure
TMP
mm Hg
280
200
100
0
-100
-200
-300
500
400
300
200
100
0
Blood Leak
Override
Ultrafiltration
UF Volume ml
1653
Reset Volume
UF Rate ml/h
1200
UF Goal ml
4800
Time Left h:min
2-37
UF
On Off
Prog
Conductivity
Conc
Bic
mS/cm
15.5
15
14.5
14
13.5
13
Variation
On Off
Prog
Flow
On Off
Tempera-ture
Set

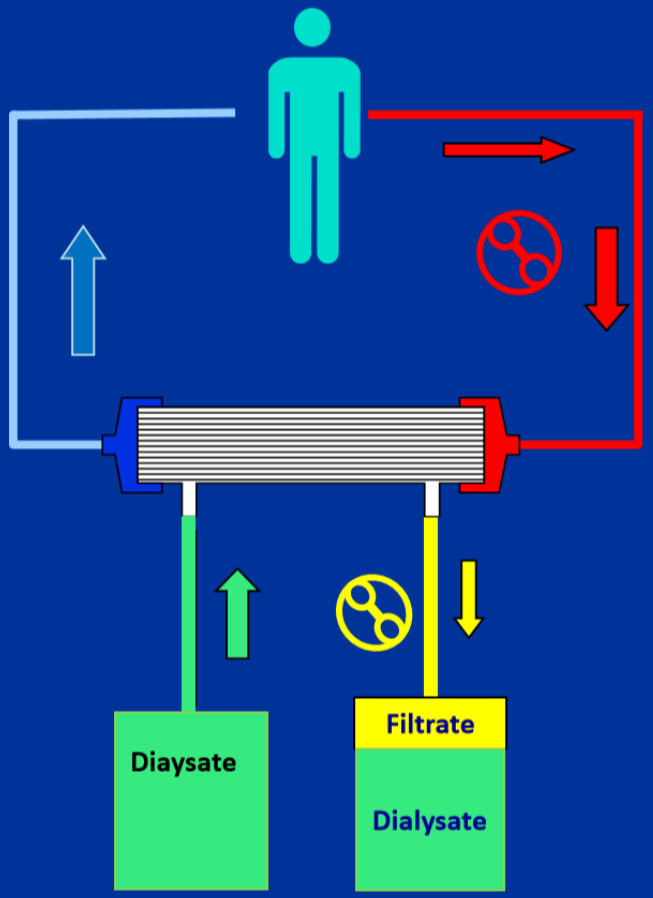
下一代機型

OCM® – Online Clearance Monitor

血液透析

Hemodialysis

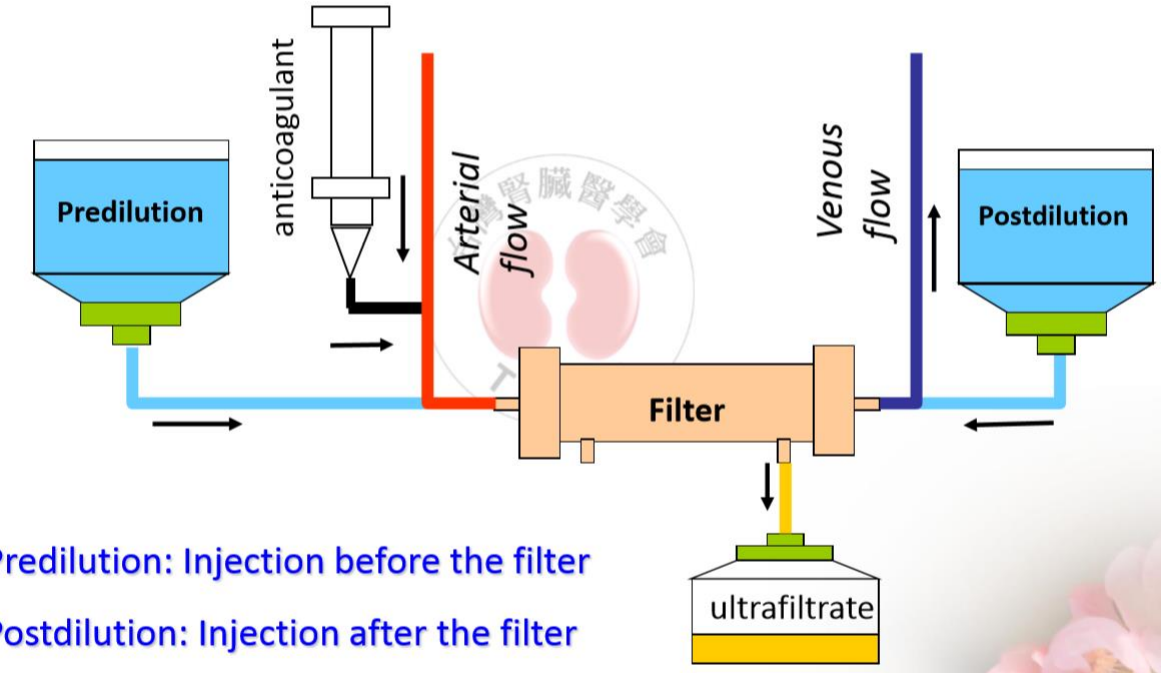
以透析（擴散作用）為主
過濾量一般少於 0.5-1.0 L/hour
有透析液、無補充液
非連續性治療



Dialysate (diffusion)
- Low ultrafiltration (convection) , usually BW loss
- No substitution fluid

血液過濾 (HF)

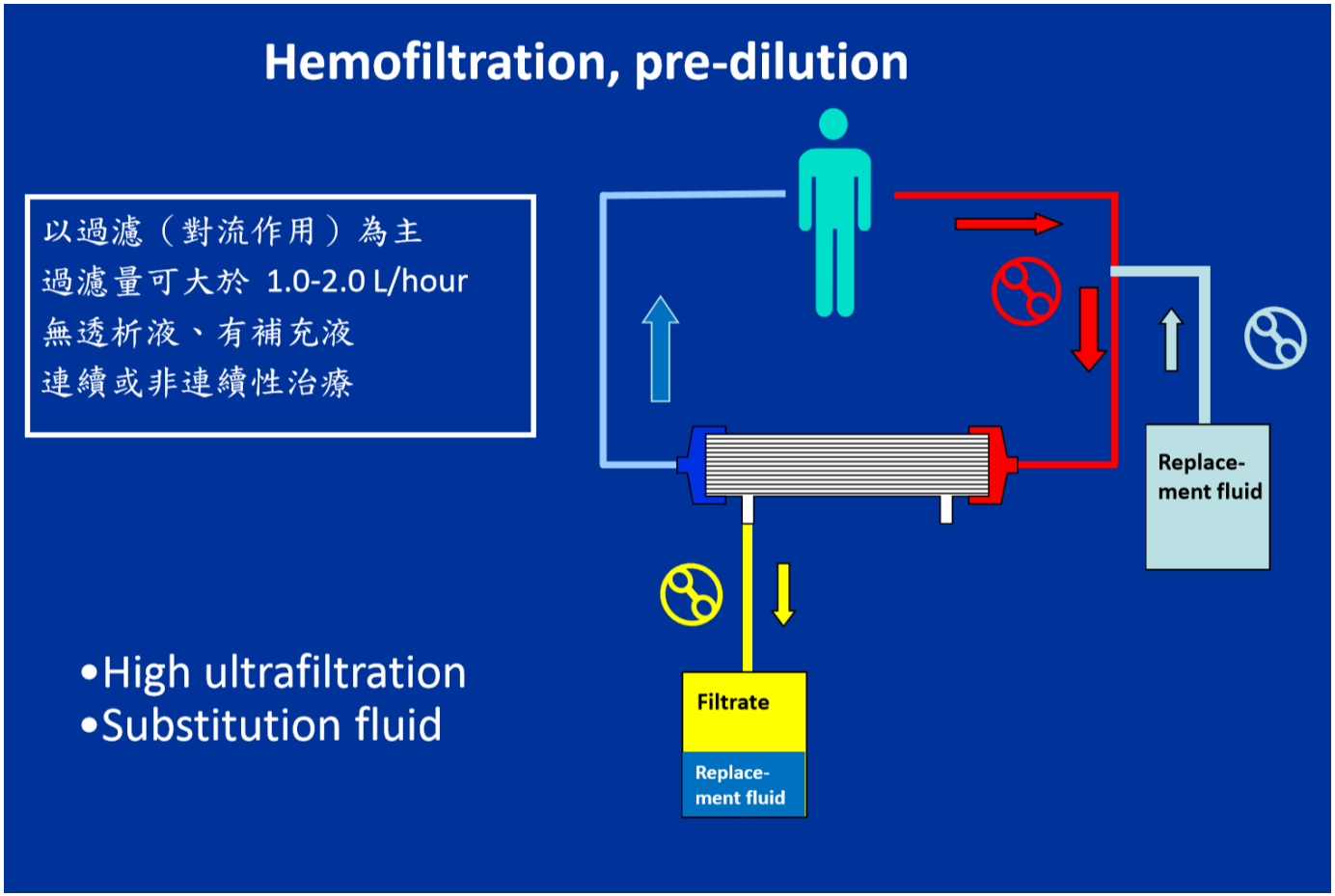
Pre- vs. Post-dilution methods



Predilution: Injection before the filter

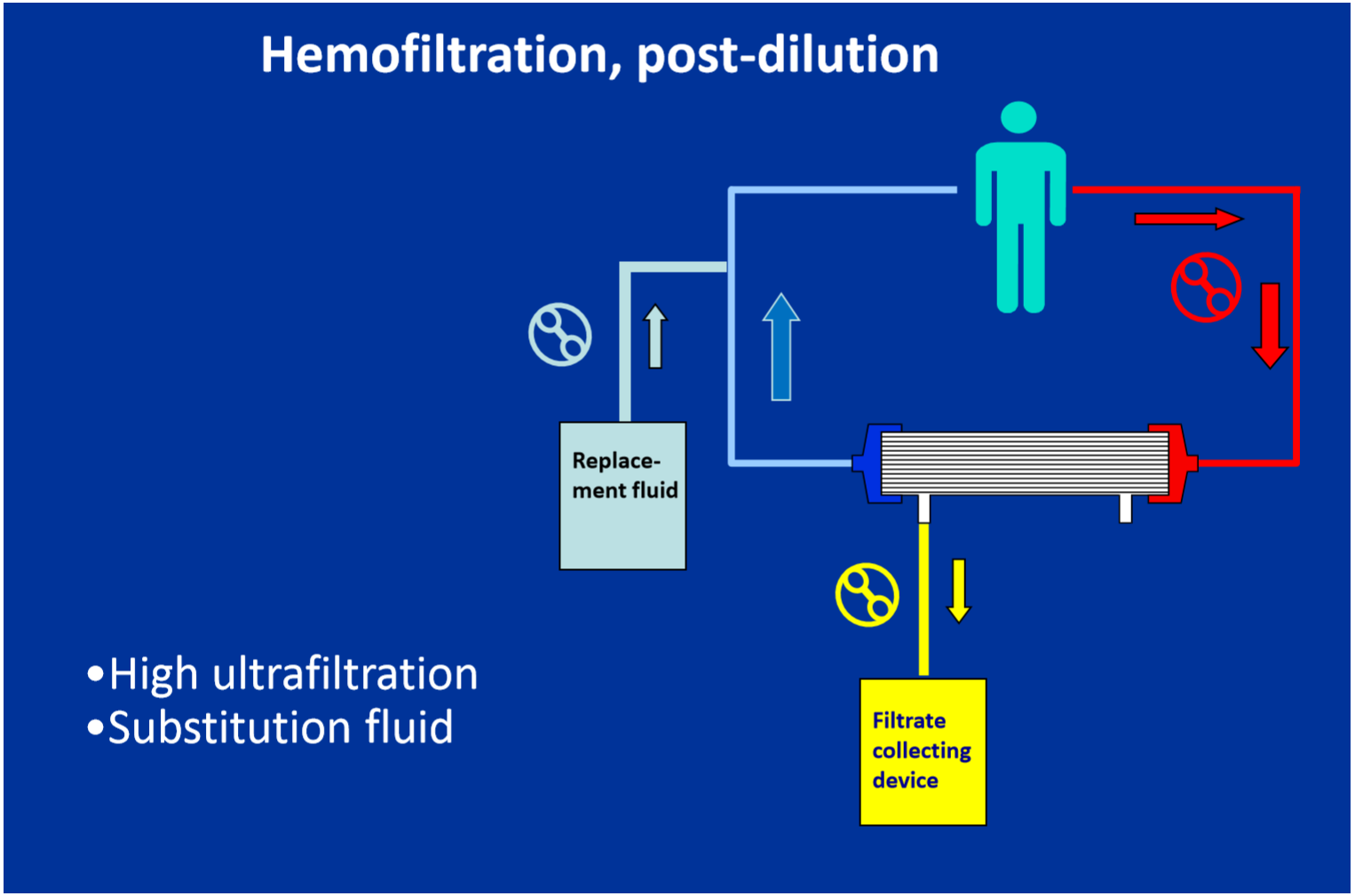
Postdilution: Injection after the filter

血液過濾:前稀釋法



- 補充液在人工腎臟之前即先輸入、再經由人工腎臟以超過濾方式，將大量水份及毒素移除

血液過濾: 後稀釋法



- 先經由人工腎臟以超過濾方式， 將大量水份及毒素移除。補充液在人工腎臟之後再輸入

前稀 vs 後稀

Improved membrane permeability
- filtration from diluted blood!

But ...

dilution also reduces efficiency

- lower diffusion gradient
- reduced clearance for small molecules

Best removal of small and middle size uremic toxins – filtration from undiluted blood!

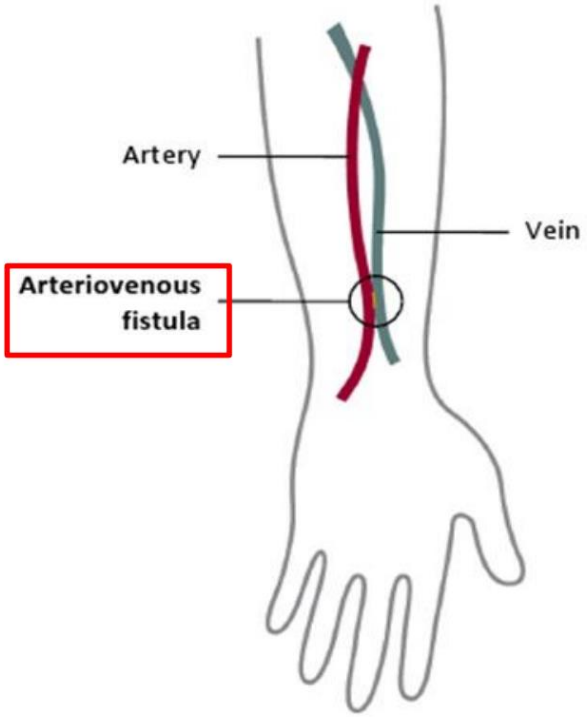
But ...
ultrafiltration *limited* by

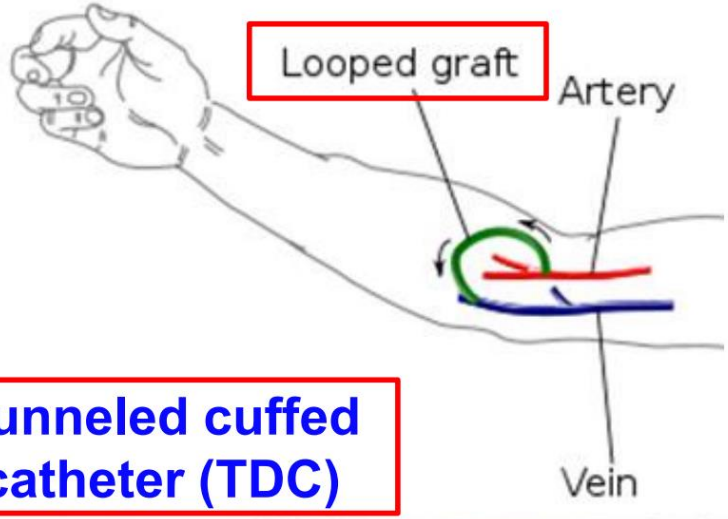
- haemoconcentration
- high blood viscosity
- secondary protein layer
- membrane polarization

and high blood flow rates are needed

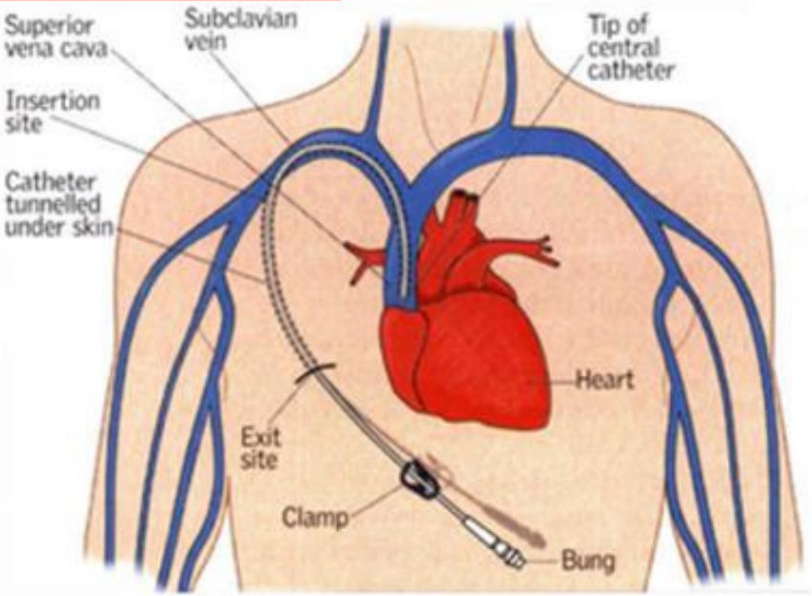
3.透析血管通路

Dialysis Vascular Access

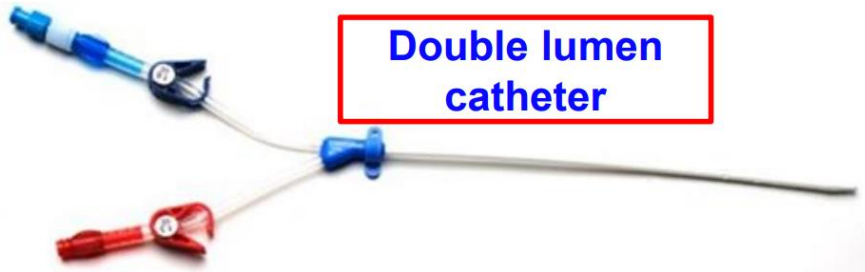


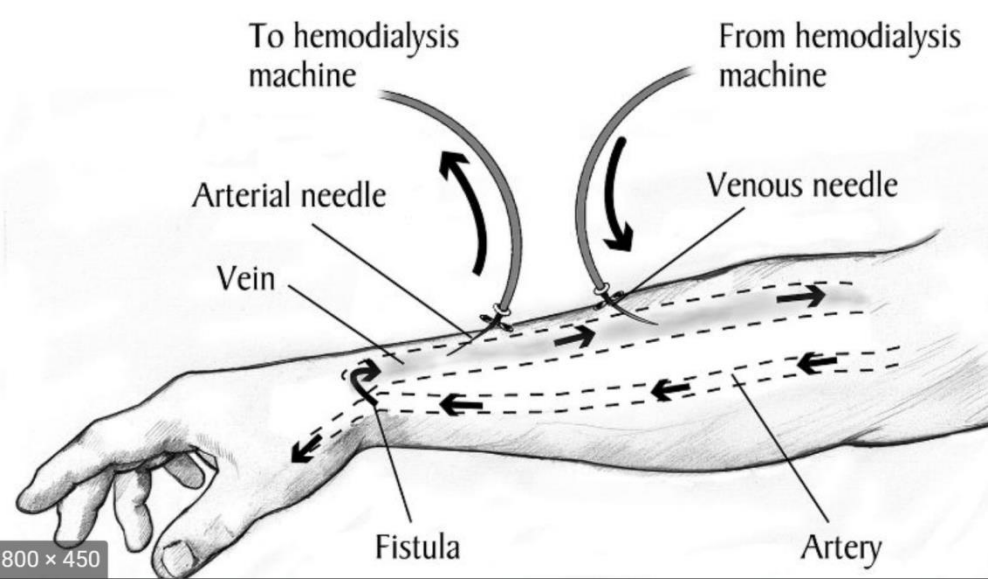


Tunneled cuffed catheter (TDC)



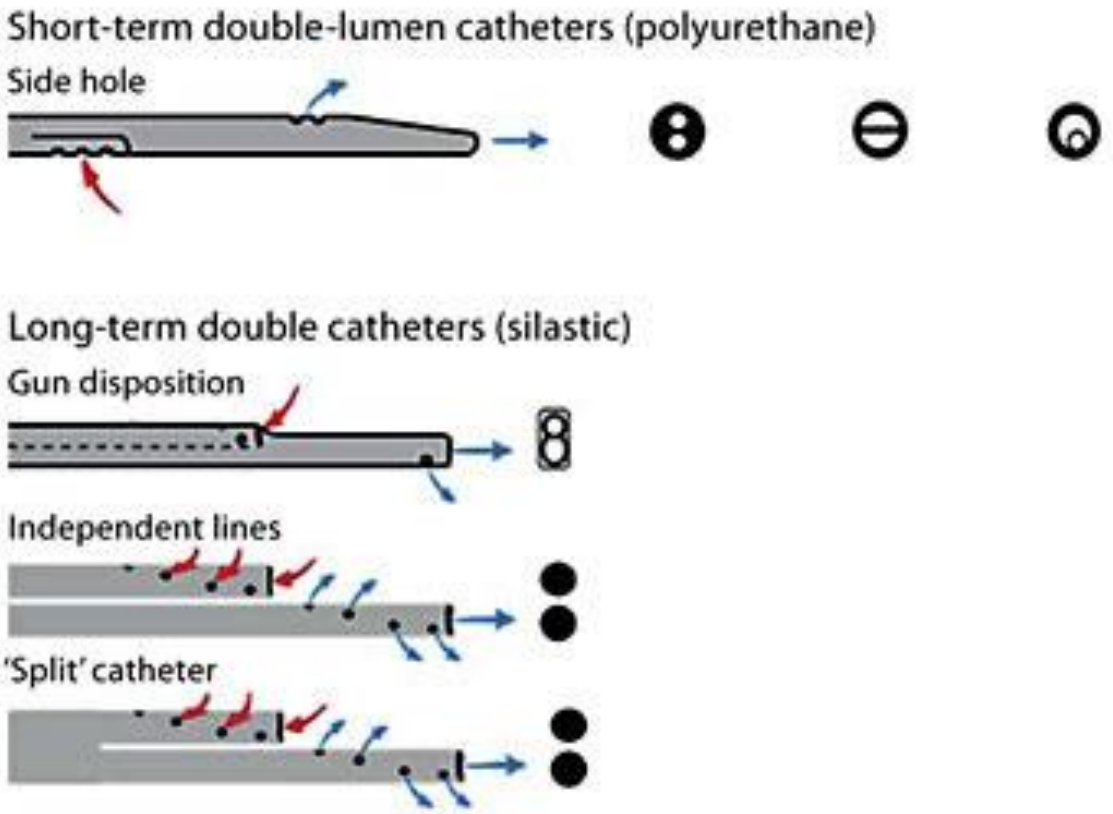
Double lumen catheter





Recirculation

= The reflux of dialyzed blood from the venous outflow back into the arterial line



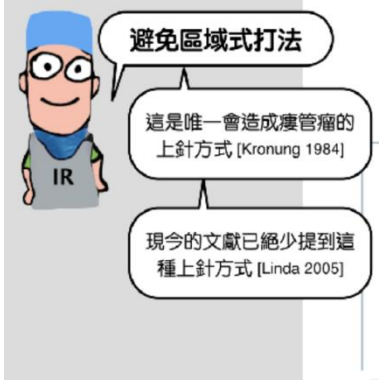
https://www.researchgate.net/figure/Different-designs-of-hemodialysis-catheters-for-the-ICU_fig1_232698850

血管通路之比較選擇

血管通路類別	通 暢 率	優 點	缺 點
AV fistula 動靜脈廔管 ~80%	第一年 60~75% 第2~4年 50~65%	*栓塞及感染率低 *較低併發症 *較少需要介入性治療	平均需要3~4個月，甚至6個月才成熟；24~27%無法成熟
AV graft 人工血管 <10%	第1年 62~83% 第2年50~70% 第3年< 50%	2~3週即可成熟	栓塞率及感染率高;較多併發症 較常需要介入性治療
Tunneled cuffed catheter 有袖口導管 >10%	**第一年** **30~74%**	*立刻可使用 *透析時不需穿刺皮膚 *不會造成肢體遠端缺血	長期使用血流變低會造成透析效率降低，較易造成菌血症及嚴重之轉移性感染

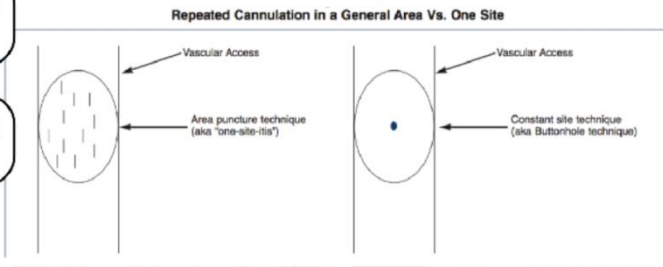
繩梯式(RopeLadder)穿刺法

Linda K. Ball. Improving Arteriovenous Fistula Cannulation Skills Nephrology Nursing Journal 2005



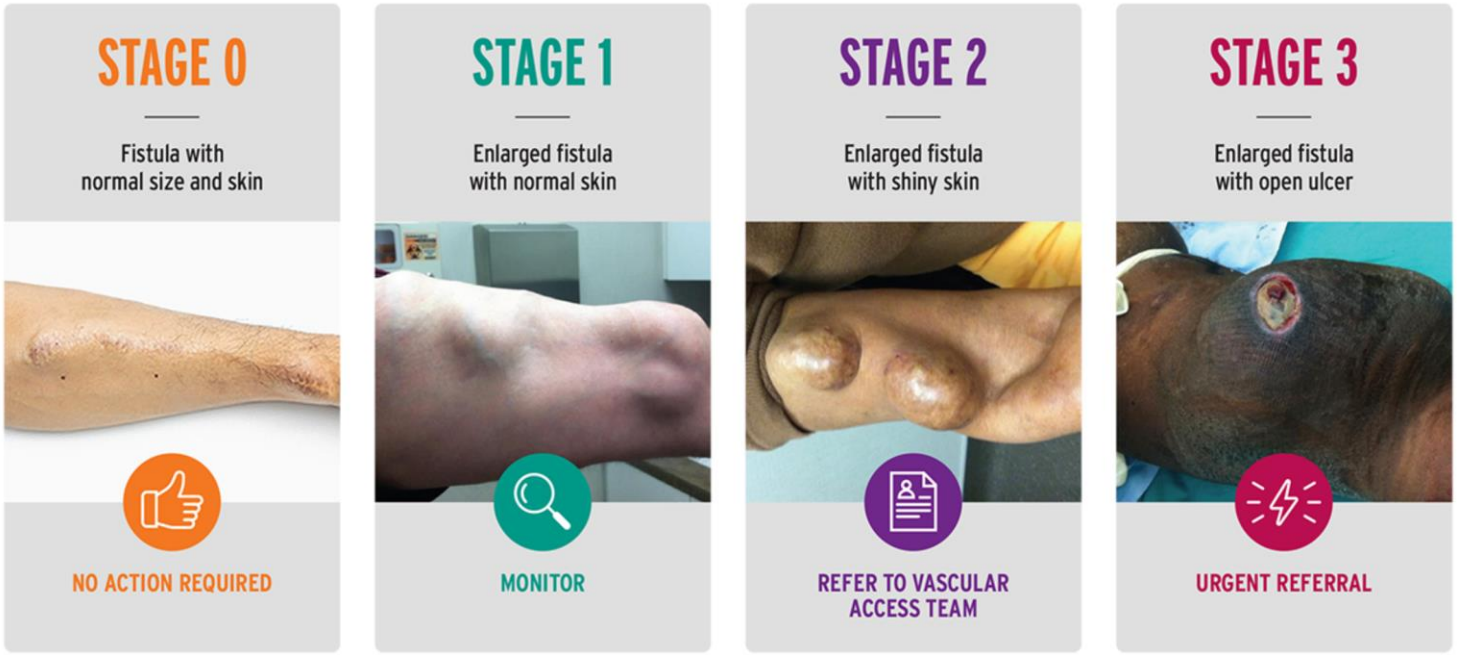
區域式(Area)穿刺法

Linda K. Ball. Improving Arteriovenous Fistula Cannulation Skills Nephrology Nursing Journal 2005



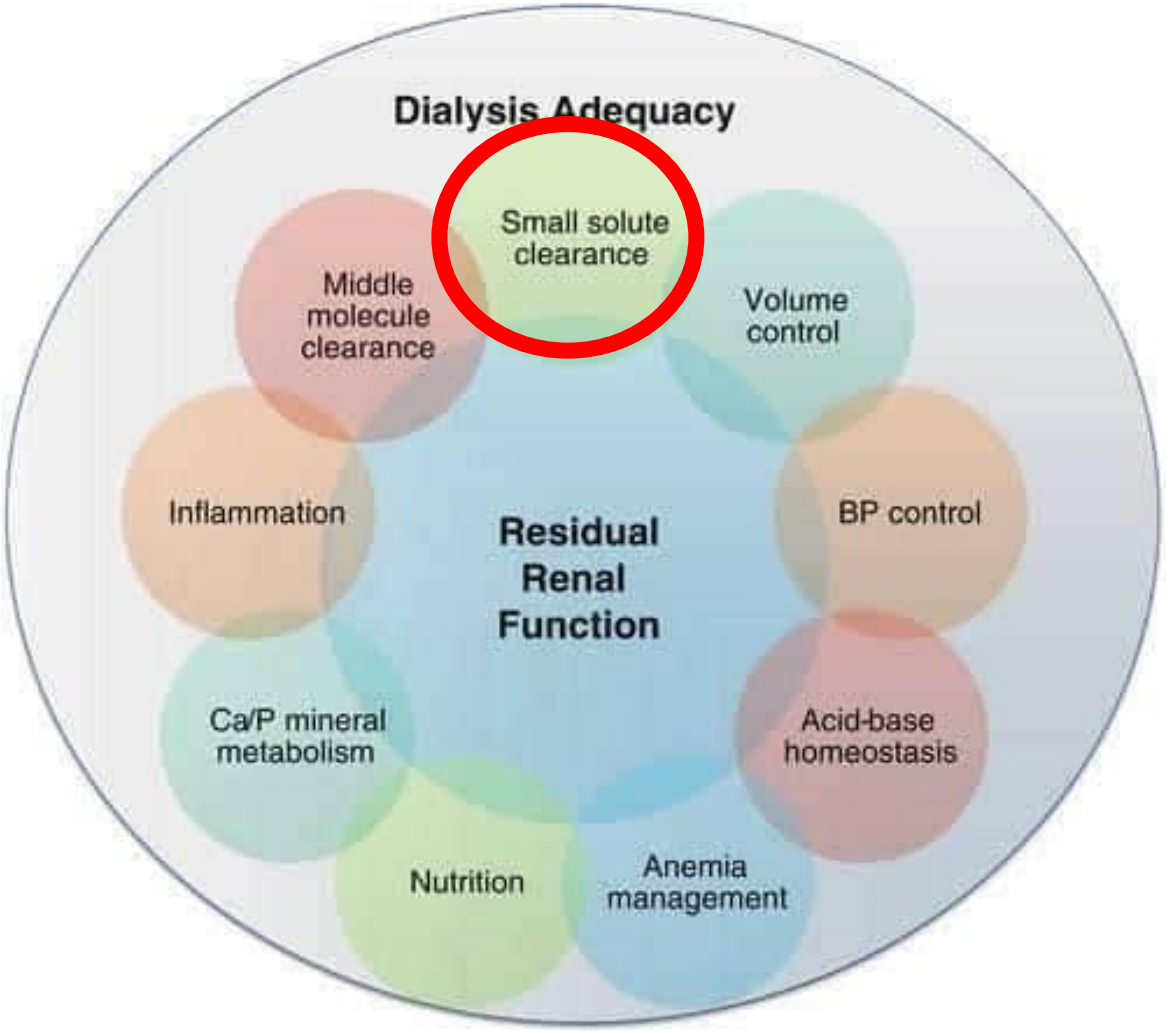
阮綜合醫院

https://fmcna.com/insights/amr/2020/aneurysm-classification-app/



4.透析處方

Dialysis Adequacy
足量透析
適量透析



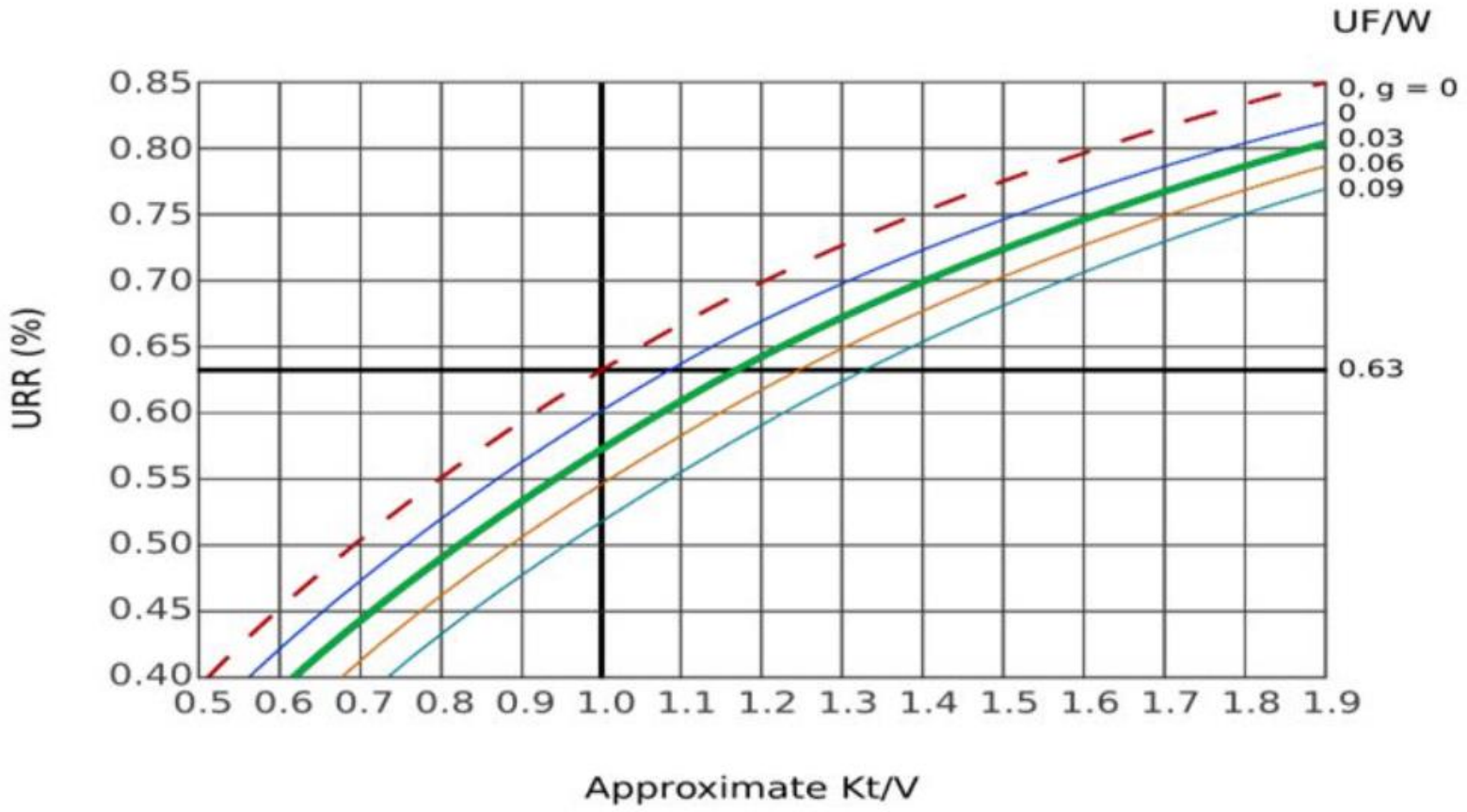
The Renal Standards Document recommends that all patients stable on three times a week haemodialysis should show :

A urea reduction ratio > 65%

Or ***Kt/V > 1.2 (dialysis and residual renal function)***

	單位	檢驗所 參考區間	透析病人 參考範圍	備註
BUN 尿素氮	mg/dl	9~23	50~100	
Creatinine 肌酸酐	mg/dl	0.5~1.1	6~10	
Uric acid 尿酸	mg/dl	3.0~6.0	通常略高	
BUN 尿素氮(洗後)	m/dl	9~23	無	
URR	%		>65%	尿素氮(洗前)-尿素氮(洗後) 尿素氮(洗前) 代表透析效率
Kt/V			>1.2	代表透析效率

URR 會受脫水量影響



(Reproduced with permission from Daugirdas JT. Urea kinetic modeling.Hypertens Dial Clin Nephrol [HDCN] http://www.hdcn.com)

處方的 Kt/V (prescribed dose)

Hemodialysis Dose Measurement

- **Kt/V**
  - K= dialyzer urea clearance L/h
  - t = dialysis session length hr
  - v = distribution volume of urea L
- **URR**

Calculate the dose of Dialysis

- K= clearance of hollow fiber
  - Available from producer
  - Urea clearance for a given blood flow
- V= Calculated by any method
  - Weight, height, age, gender ..etc
- You decided on the duration of dialysis
  - t= time expected on dialysis in minutes

CALCULATE DOSE OF DIALYSIS =Kt/V

- Depends on three factors
  - 1. The time of dialysis (t) ↑↑
  - 2. The amount of urea a hollow fiber can clear when blood passes through it (K) ↑↑
  - 3. The total volume of urea in the patient's body that needs to be dialyzed (V) ↑↓

Kt/V= dose of dialysis

https://www.slideshare.net/Melkholy/adequacy-hd

T= 4 hrs, V= about 0.6*BW, target Kt/V= 1.4 (> 1.2)

- **K**= urea clearance of a dialyzer
  - This depends on two factors
    - the ability of the hollow fiber to clear urea
      - The pore size and specification
      - The surface are of the dialyzer
    - The rate of blood flow through the hollow fiber
  - Supplied by manufacturer and should be checked
- **t** =during a certain time of dialysis (minutes)
- **V** =Volume of dissolved urea in the body
  - urea is equally distributed in all body compartments
  - water is also equally distributed in all body compartment **Volume of urea almost eq total body water**

High efficiency hemodialysis

- **高效率血液透析**
- 大表面積(>1.4m2)的透析器（人工腎臟），加上高速的血液流速(>300 ml/min)或透析液流速(>700 ml/min)
- 達到小分子尿毒，**尿素氮(BUN) 快速清除(>200ml/min)的目的**

https://www.greencross.org.tw/dialysis/HD_type/hi-efficiency-HD.htm

High flux hemodialysis

- **高透量血液透析**
- 高透量透析，即是使用高透量膜的透析器進行透析治療的稱呼。
- **凡是透析器的膜有較大的洞，及較高的水份超過濾率**(Ultrafiltration, **Kuf>15** ml/h/mmHg) 即稱為高透量膜。
- 高透量膜可清除**中、大分子的尿毒**，並在短時間移除大量水份及小分子尿毒。

https://www.greencross.org.tw/dialysis/HD_type/hi-flux-HD.htm

K= urea clearance

In vitro performance data/technical data

	FX 40	FX 50	FX 60	FX 80	FX 100
Ultrafiltration coeff. (mL/h x mmHg)	20	33	46	59	73
Clearance Q_B = 200 mL/min					
Urea	170	189	193	197	– *
Creatinine	144	170	182	189	–
Phosphate	138	165	177	185	–
Vitamin B_{12}	84	115	135	148	–
Inulin	54	76	95	112	–
Clearance Q_B = 300 mL/min					
Urea	– *	250	261	276	278
Creatinine	–	210	230	250	261
Phosphate	–	201	220	239	248
Vitamin B_{12}	–	130	155	175	192
Inulin	–	81	104	125	142

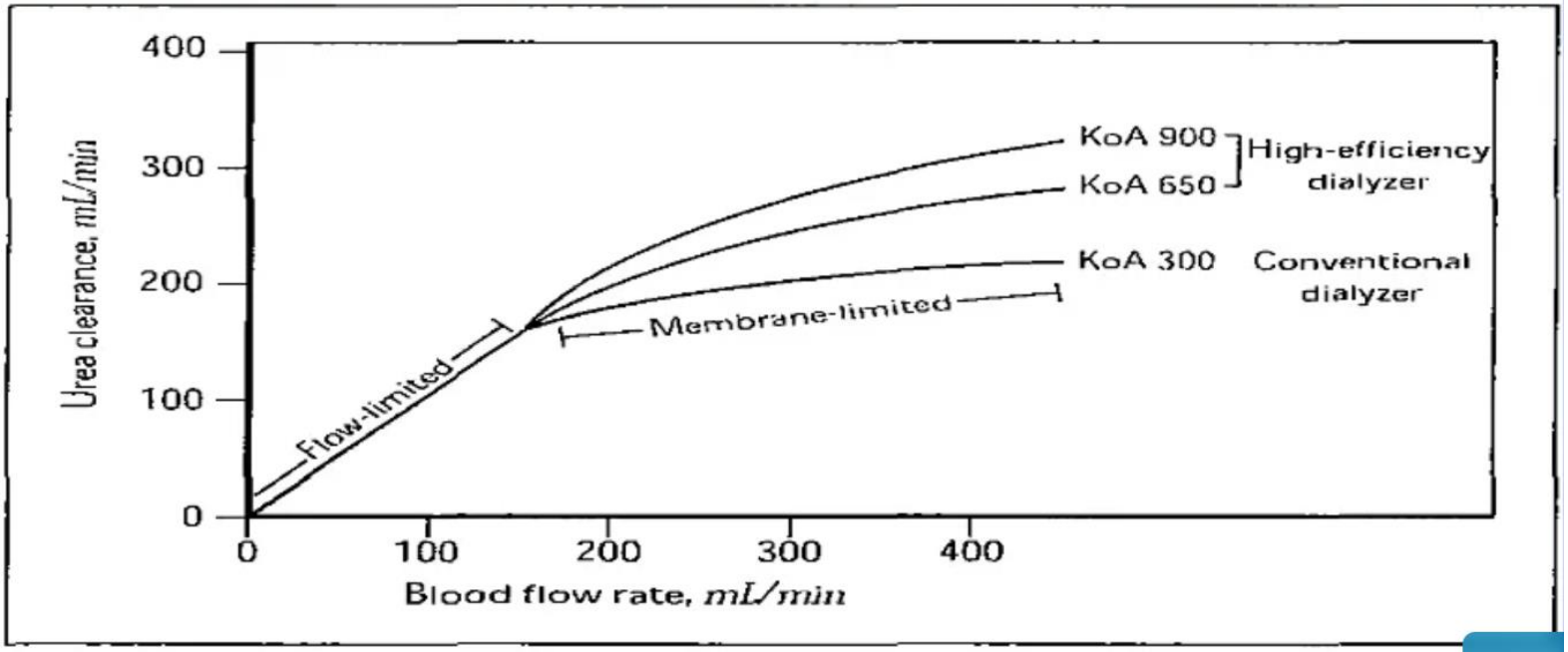
In vitro performance: Q_D = 500 mL/min, Q_F = 0 mL/min, T = 37 °C (EN 1283. ISO 8637).
Ultrafiltration coefficients: human blood, Hct 32 %, protein content 6 %.

* refer to recommended blood flow range

Effective surface (m^2)	0.6	1.0	1.4	1.8	2.2
Blood flow range (mL/min)	50 – 200	100 – 300	150 – 400	200 – 500	250 – 600
Wall thickness / lumen (µm)	35/185	35/185	35/185	35/185	35/185
Priming volume (mL)	32	53	74	95	116
Membrane material			Helixone®		
Housing material			Polypropylene		
Potting compound			Polyurethane		
Sterilisation method			INLINE Steam		
Form of treatment	HD	HD	HD	HD/HDF/HF	HD/HDF/HF

BF 對 K 有顯著影響~

Blood flow and Clearance



Delivered dose: measured Kt/V (實際的 Kt/V)

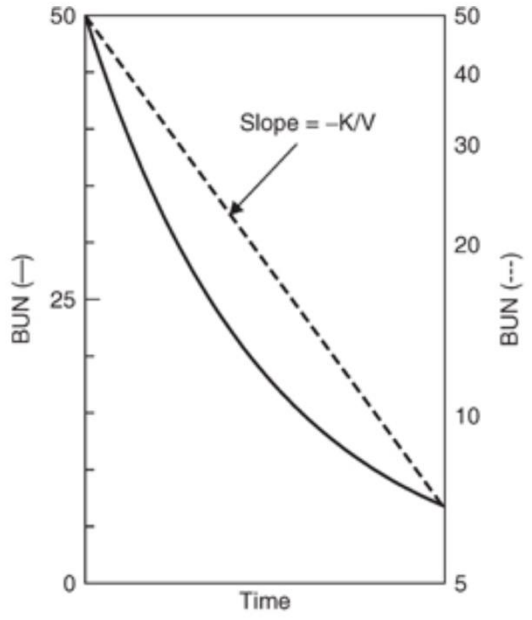


FIGURE 5.3 Blood urea nitrogen (BUN) concentrations fall logarithmically during hemodialysis treatments (**left axis**). The slope of the log decline (**right axis**) is −K/V. (Adapted from Depner TA. Quantification of dialysis. Urea modeling: the basics. *Semin Dial* 1991;4:179–184, with permission.)

Kt/V

Computerized software

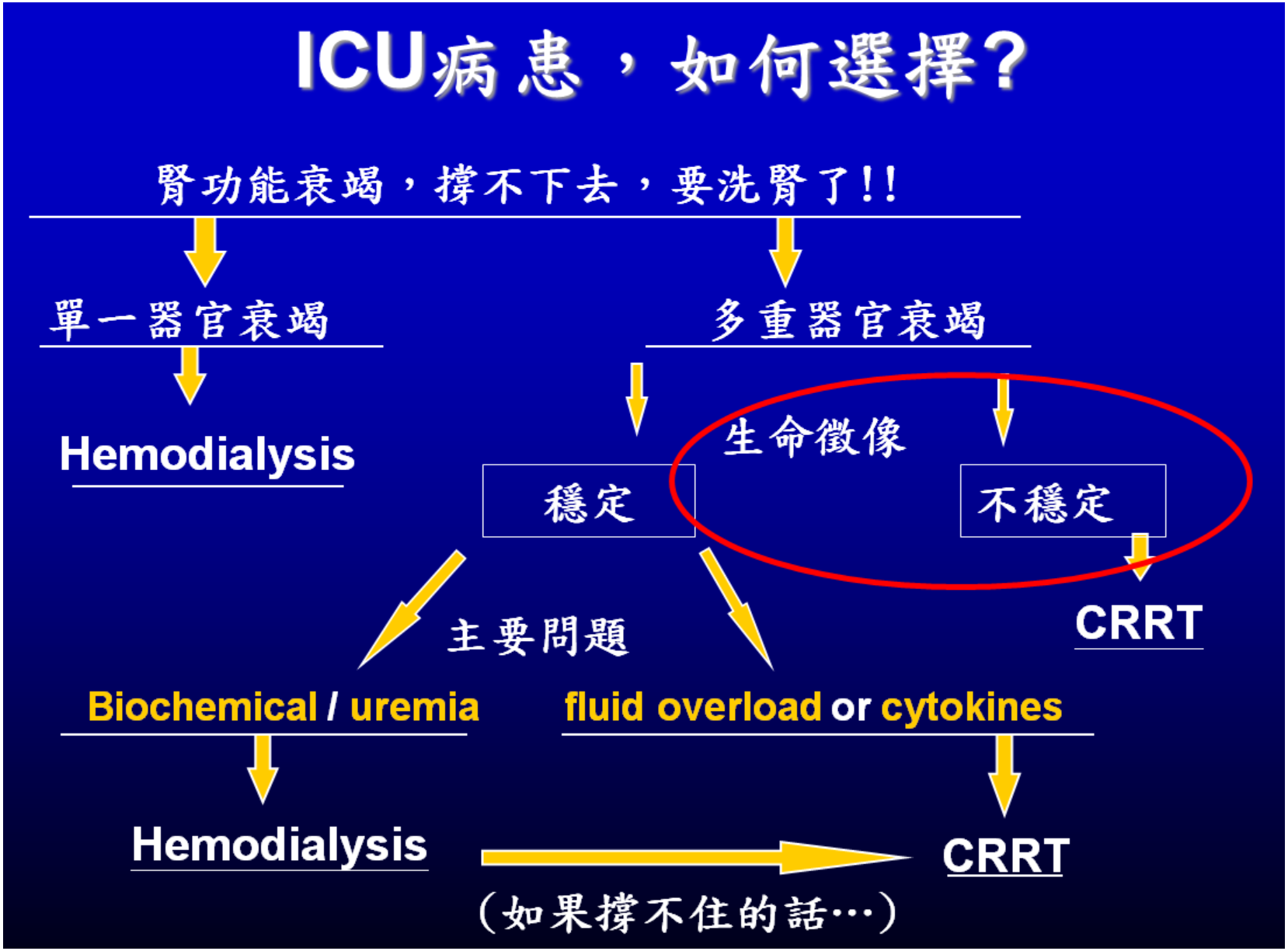
Mathematical logarithm

$$Kt/v = -Ln\,(R-0.008t)+(4-3.5\times R)\times \frac{UF}{W}$$

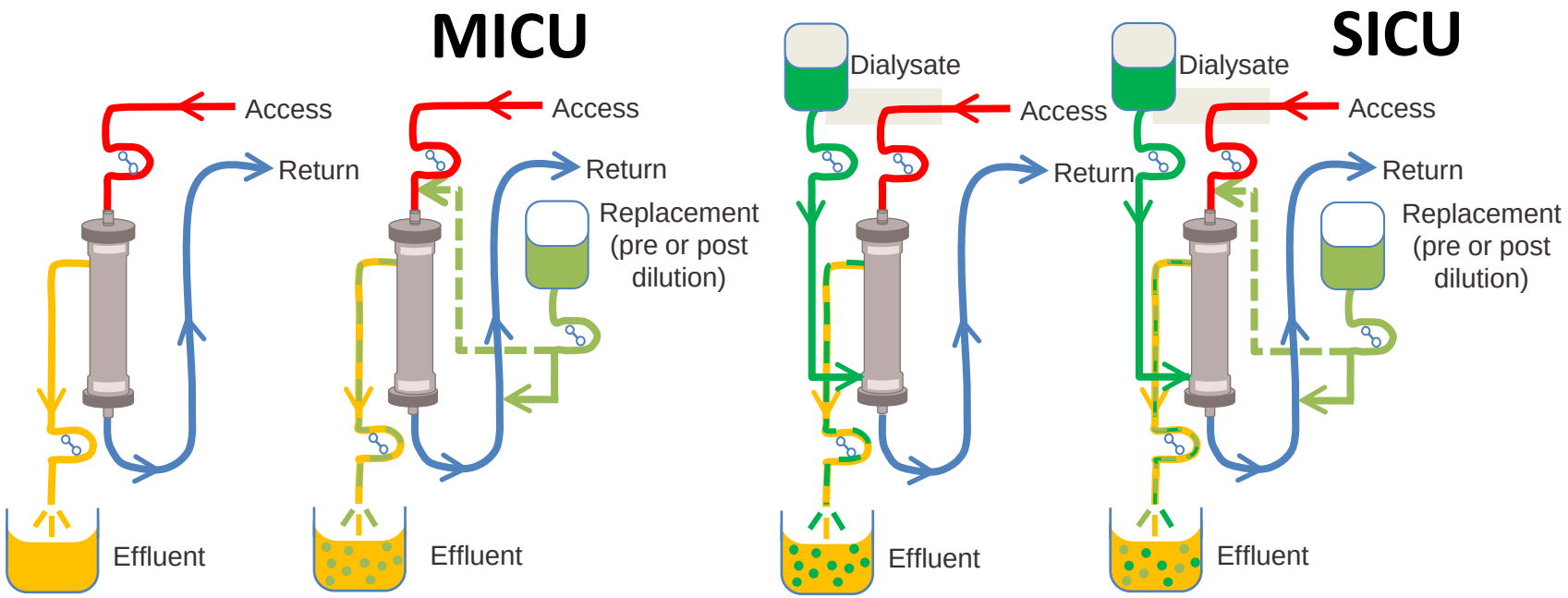
Ln	=	natural logarithm
R	=	postdialysis BUN / predialysis BUN
UF	=	Ultrafiltration volume in liters
W	=	Postdialysis weight in kg

https://abdominalkey.com/measuring-hemodialysis-using-solute-kinetic-models/

5.特殊透析模式


ICU病患，如何選擇?
腎功能衰竭，撐不下去，要洗腎了!!
單一器官衰竭
多重器官衰竭
Hemodialysis
生命徵像
穩定
不穩定
CRRT
主要問題
Biochemical / uremia
fluid overload or cytokines
Hemodialysis
CRRT
(如果撐不住的話…)

CRRT Modalities



SCUF

- No solute clearance
- Used for fluid removal

CVVH

- Solute clearance: convection
- Operative fluid: RF

CVVHD

- Solute clearance: diffusion
- Operative fluid: dialysate

CVVHDF

- Solute clearance: diffusion and convection
- Operative fluids: RF and dialysate

CVVH- HF440

CVVH order: (樣板)

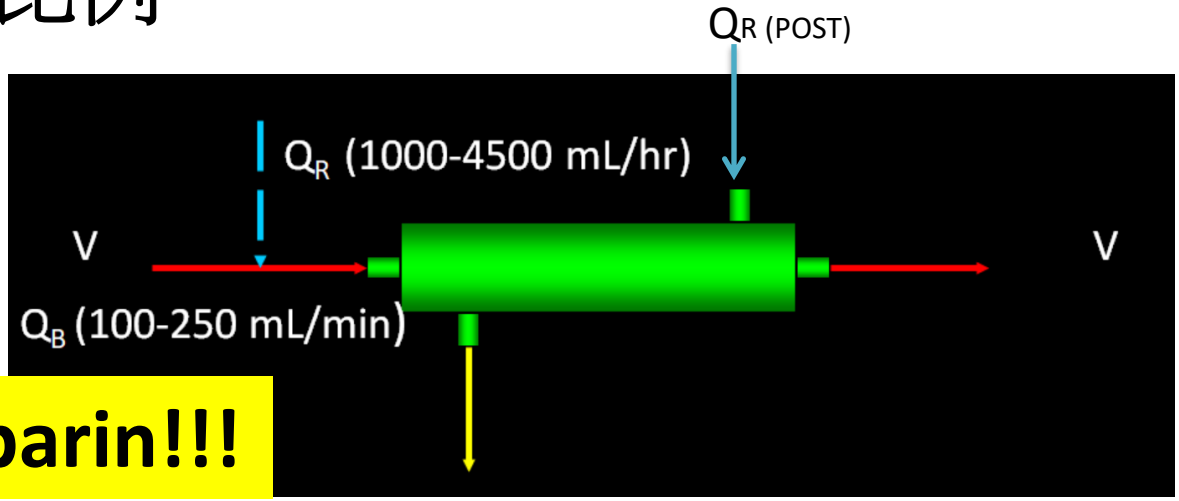
- Blood flow= **150** cc/min
- Ultrafiltration rate BW(kg)* (**25~30**) cc/hr
- Pre-dilution **50**%, dialysate temperature 36-41 degrees celsius.

如何下降FF (才不容易clot)

FF (Filtration Fraction) = $Q_{TotalUF}/Q_P$

Total UF = Replacement Fluid Rate + Fluid Removal Rate

- 1. **增加 blood flow**
- 2. 減少脫水量、減少補充液總量
- 3. **增加前稀釋比例**



***或是直接用 **heparin!!!**

如何增加CVVH效率?(洗更乾淨)

- Effluent Rate (Q_E) = Total UF rate ($Q_{TotalUF}$) = Replacement Fluid Rate + Fluid Removal Rate*
- Dilution factor = $Q_{BW} / Q_{BW} + Q_{R\ (PRE)}$

- 1. 增加補充液總量 (就是增加UF rate)=>
  但小心FF也上升!!! (Blood flow rate一併調升才可避免)
- 2.下降前稀釋比例

Thank you~~~~