PRACTICAL POINT REGARDING EXTRACORPOREAL THERAPIES FOR AKI

Theerasak tangwonglert, MD

CONTENTS : ACUTE KIDNEY INJURY

- **Indications of extracorporeal therapies**
- **Time to start extracorporeal therapies**
- **Modalities of extracorporeal therapies**
- **How to prescribe acute intermittent hemodialysis**

INDICATIONS OF EXTRACORPOREAL THERAPIES

INDICATIONS OF EXTRACORPOREAL THERAPIES

A : Metabolic Acidosis

E : Electrolyte imbalance

- Hyperkalemia
- Hypercalcemia/hypocalcemia
- Hypernatremia/hyponatremia
- Hyperphosphatemia
- Hypermagnesemia

INDICATIONS OF EXTRACORPOREAL THERAPIES

I : Intoxication / Ingestion of toxic substances

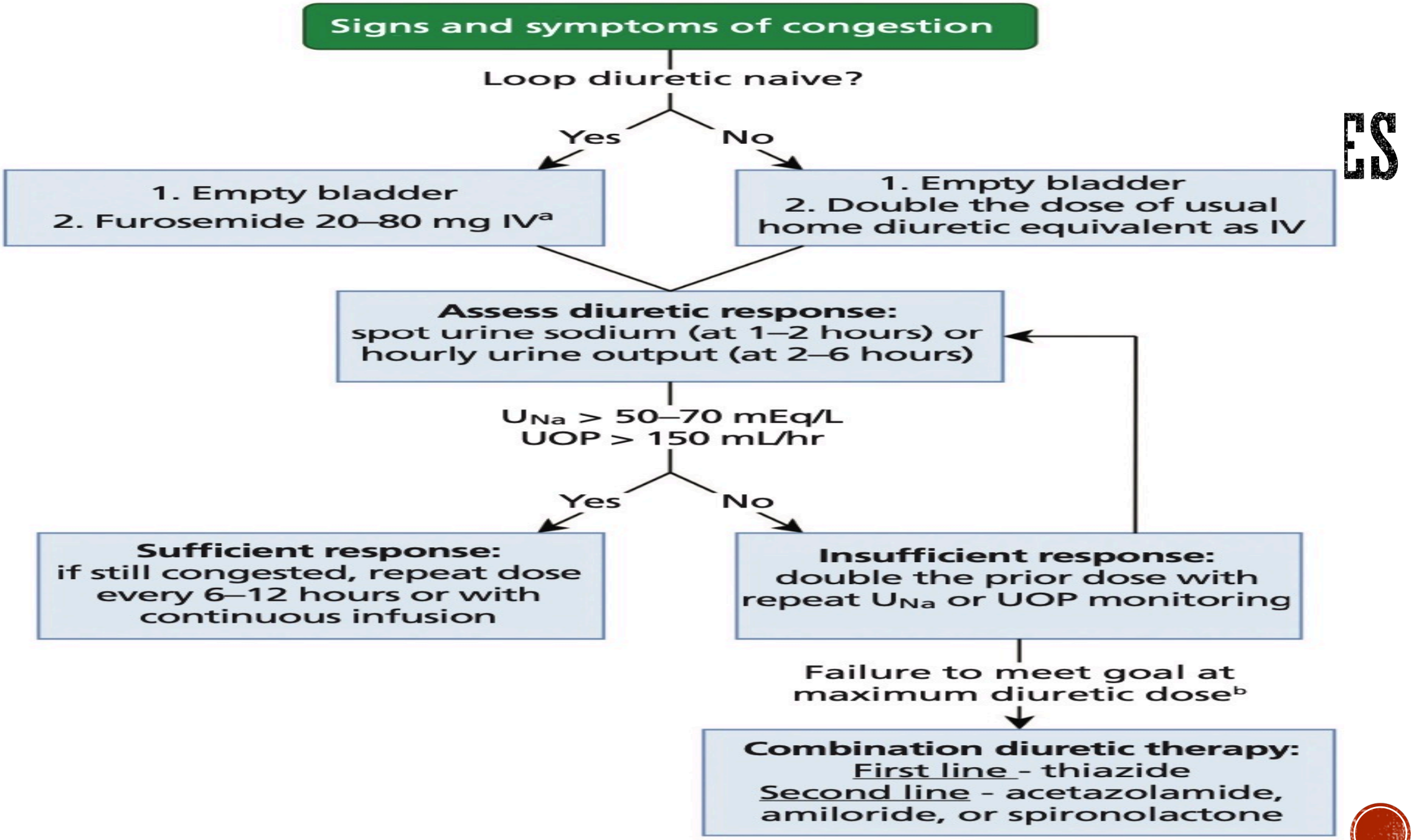
- Molecular weight
- Protein binding
- Volume of distribution
- Contribution of extracorporeal toxin removal relative to endogenous clearance

INDICATIONS OF EXTRACORPOREAL THERAPIES

Modality	Toxin Molecular Mass (Da)	Toxin Volume of Distribution (L/kg)	Protein Binding of Toxin	Examples of Toxins Amenable to Therapy	Primary Limitations of Therapy
Hemodialysis	Up to 10,000–15,000	≤1.5–2	≤80%	Salicylates, toxic alcohols, lithium	Hemodynamic stability
HCO filter HD	Up to 50,000	≤1.5–2	≤80%	Small peptide therapeutics; any therapy amenable to HD	Limited availability Limited role in poisoning
CRRT	Up to 15,000–25,000	≤1.5–2	≤80%	Lithium	Slow toxin clearance (excepting toxins with slow redistribution)
Hemoperfusion	Unclear, but high	≤1 L/kg	Any	Valproic acid, carbamazepine	Limited availability Clotting Hypocalcemia
Plasma exchange	No limit	≤1 L/kg	Any	Monoclonal antibodies, arsine	Limited availability Very slow clearance

CJASN 14: 1408–1415, 2019

ES


Signs and symptoms of congestion
Loop diuretic naive?
Yes
No
1. Empty bladder
2. Furosemide 20–80 mg IV[a]
1. Empty bladder
2. Double the dose of usual home diuretic equivalent as IV
Assess diuretic response:
spot urine sodium (at 1–2 hours) or hourly urine output (at 2–6 hours)
U_{Na} > 50–70 mEq/L
UOP > 150 mL/hr
Yes
No
Sufficient response:
if still congested, repeat dose every 6–12 hours or with continuous infusion
Insufficient response:
double the prior dose with repeat U_{Na} or UOP monitoring
Failure to meet goal at maximum diuretic dose[b]
Combination diuretic therapy:
First line - thiazide
Second line - acetazolamide, amiloride, or spironolactone

INDICATIONS OF EXTRACORPOREAL THERAPIES

U **: Signs of Uremia**

hypercatabolic state BUN 70-80 mg/dl

nonhypercatabolic state BUN 100 mg/dl

Initiate RRT emergently when life-threatening changes in fluid, electrolyte, and acid-base balance exist

INDICATIONS OF EXTRACORPOREAL THERAPIES

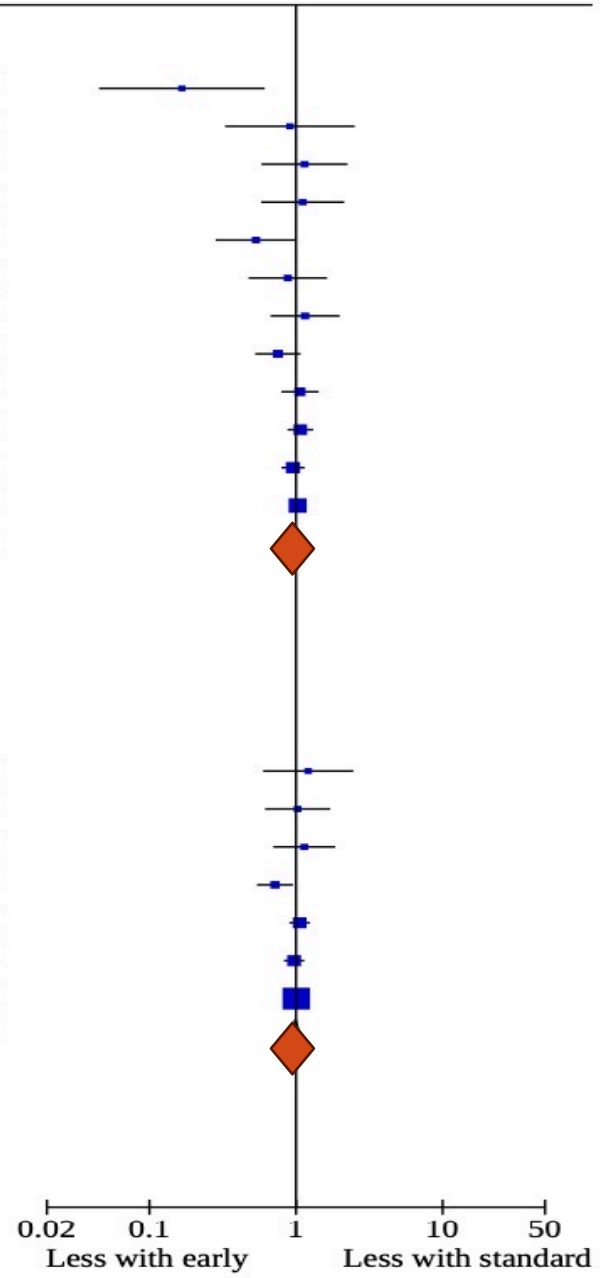
- Non-renal indications
  - Nutritional support
  - Immunomodulation
  - Respiratory acidosis
  - Volume homeostasis in multi-organ failure

TIME TO START EXTRACORPOREAL THERAPIES

	ELAIN	AKIKI	IDEAL-ICU	STARRT-AKI	AKIKI-2	FST Trial
Location	Germany Single center *n* = 231	France Multicenter *n* = 620	France Multicenter *n* = 488	Multinational Multicenter *n* = 2927	France Multicenter *n* = 278	Thailand Multicenter *n* = 297
Inclusion criteria	KDIGO Stage 2 + NGAL >150 ng/mL	Stage 3 AKI + ventilator (85%) Pressors (85%) Sepsis (56%)	RIFLE Stage F Septic shock + Pressors (100%)	Stage 2 and 3	Stage 3 AKI Oliguria >72 h or BUN 40–50 mmol/L	AKI (any stage) + clinical ATN; FST = NR
Timing of KRT	Early <8 h post-AKI	Early <6 h post-AKI	Early <12 h post-AKI	Early <12 h post-AKI	Delayed <12 h post-AKI	Early <6 h post-AKI
	Late <12 h or no initiation	Late BUN >40 mmol/L Oliguria >72 h life-threatening	Late 48 h postrandomization if no kidney recovery	Late AKI ≥72 h Life threatening	More delayed KRT postponed 1 day, or BUN >50 mmol/L or life-threatening	Standard
% of KRT early vs. late	100% vs. 91%	98% vs. 51%	97% vs. 62%	97% vs. 62%	Delayed (98%) More delayed (79%)	98% vs. 75%
Type of KRT	100% CVVHDF	IHD (55%) CKRT (45%)	IHD (43%) PIKRT/CKRT (57%)	IHD, PIKRT, or CKRT (68%)	*Delayed:* IHD (60%) CKRT (39%) Both (1%) *More delayed*: IHD (58%) CKRT 40% Both (3%)	
Mortality early vs. late	60 days: 38.4% vs. 50.4% 90 days: 39.3% vs. 54.75%*	60 days: 48.5% vs. 49.7%	90 days: 58% vs. 54%	90 days: 44% vs. 44%	28 days: 38% vs. 45% 60 days: 44% vs. 55%	28 days: 62.1% vs. 58.3%
Duration of stay in ICU	Not significant: 19 vs. 22 days	Not significant: 13 vs. 13 days	Not significant: 12 vs. 12 days	Lower in Early group	No difference: 18 vs. 16 days	No difference: 12 vs. 13.5 days
Mechanical ventilation days	125 vs. 181 hours	No difference: 7 vs. 6 days	No difference: 2 vs. 3 days	No difference	No difference	No difference: 4 vs. 0.5 days

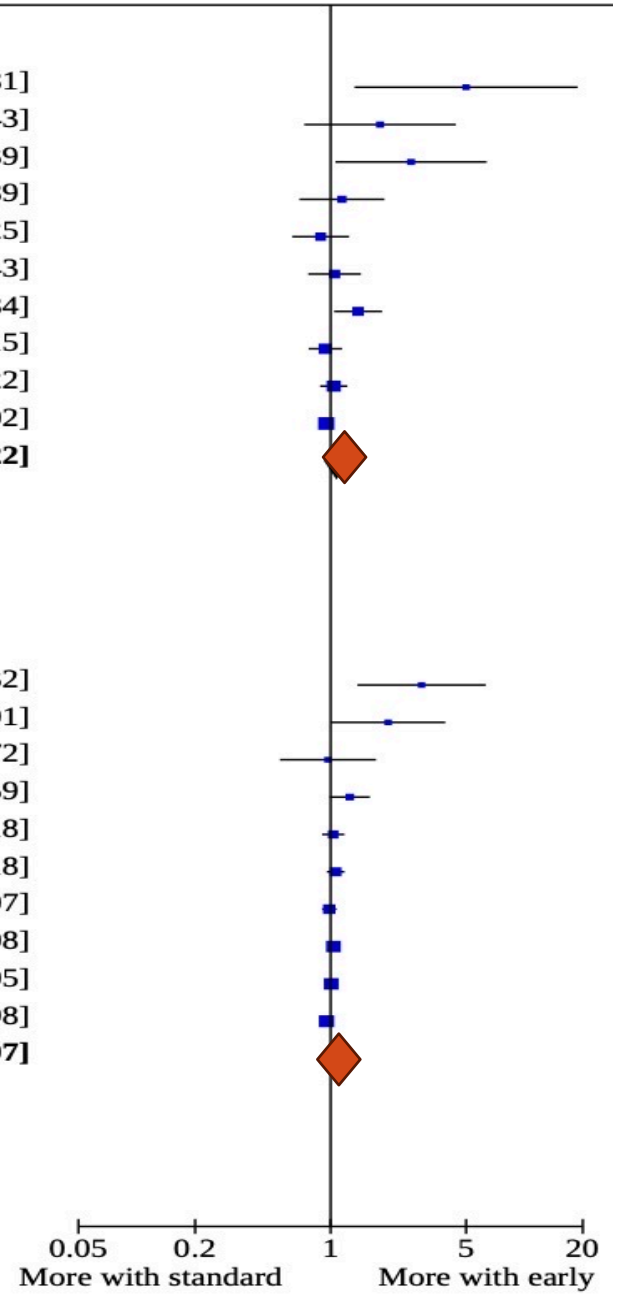
Comprehensive clinical nephrology 7th ed

Study or Subgroup	Early initiation Events	Total	Standard initiation Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
1.1.1 Death at day 30						
Sugahara 2004	2	14	12	14	0.7%	0.17 [0.05 , 0.61]
Yin 2018	6	33	6	30	1.2%	0.91 [0.33 , 2.52]
Bouman 2002	20	70	9	36	2.6%	1.14 [0.58 , 2.25]
EARLYRRT 2018	10	20	9	20	2.8%	1.11 [0.58 , 2.14]
Tang 2016	8	23	15	23	2.9%	0.53 [0.28 , 1.01]
STARRT-AKI Pilot 2013	13	48	16	52	3.1%	0.88 [0.47 , 1.63]
Xia 2019	15	30	13	30	3.8%	1.15 [0.67 , 1.99]
ELAIN 2016	34	112	48	119	7.9%	0.75 [0.53 , 1.07]
FST 2018	36	58	35	60	10.5%	1.06 [0.79 , 1.43]
IDEAL-ICU 2014	111	246	102	242	16.9%	1.07 [0.87 , 1.31]
AKIKI 2015	129	311	134	308	18.6%	0.95 [0.79 , 1.15]
STARRT-AKI 2019	538	1465	523	1462	29.0%	1.03 [0.93 , 1.13]
Subtotal (95% CI)		**2430**		**2396**	**100.0%**	**0.97 [0.87 , 1.09]**
Total events:	922		922			
Heterogeneity: Tau² = 0.01; Chi² = 15.42, df = 11 (P = 0.16); I² = 29%						
Test for overall effect: Z = 0.53 (P = 0.60)						
1.1.2 Death after 30 days						
Yin 2018	12	33	9	30	1.0%	1.21 [0.60 , 2.46]
STARRT-AKI Pilot 2013	18	48	19	52	1.9%	1.03 [0.62 , 1.71]
Bouman 2002	31	70	14	36	2.1%	1.14 [0.70 , 1.85]
ELAIN 2016	44	112	65	119	6.2%	0.72 [0.54 , 0.95]
IDEAL-ICU 2014	138	246	128	242	17.5%	1.06 [0.90 , 1.25]
AKIKI 2015	150	311	153	308	17.8%	0.97 [0.83 , 1.14]
STARRT-AKI 2019	643	1465	639	1462	53.5%	1.00 [0.93 , 1.09]
Subtotal (95% CI)		**2285**		**2249**	**100.0%**	**0.99 [0.92 , 1.07]**
Total events:	1036		1027			
Heterogeneity: Tau² = 0.00; Chi² = 6.41, df = 6 (P = 0.38); I² = 6%						
Test for overall effect: Z = 0.22 (P = 0.83)						
Test for subgroup differences: Chi² = 0.11, df = 1 (P = 0.74), I² = 0%						



Cochrane Database of Systematic Reviews 2022, Issue 11.

Study or Subgroup	Early initiation Events	Total	Standard initiation Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
1.3.1 Patients free from KRT according to ITT analysis (all patients)						
Sugahara 2004	10	14	2	14	1.0%	5.00 [1.33 , 18.81]
EARLYRRT 2018	9	20	5	20	2.0%	1.80 [0.73 , 4.43]
Xia 2019	13	30	5	30	2.0%	2.60 [1.06 , 6.39]
FST 2018	21	58	19	60	5.4%	1.14 [0.69 , 1.89]
Bouman 2002	38	70	22	36	9.5%	0.89 [0.63 , 1.25]
STARRT-AKI Pilot 2013	30	48	31	52	10.5%	1.05 [0.77 , 1.43]
ELAIN 2016	60	112	46	119	11.6%	1.39 [1.04 , 1.84]
IDEAL-ICU 2014	106	246	111	242	16.1%	0.94 [0.77 , 1.15]
AKIKI 2015	154	311	147	308	18.3%	1.04 [0.88 , 1.22]
STARRT-AKI 2019	729	1465	766	1462	23.6%	0.95 [0.88 , 1.02]
Subtotal (95% CI)		**2374**		**2343**	**100.0%**	**1.07 [0.94 , 1.22]**
Total events:	1170		1154			
Heterogeneity: Tau² = 0.02; Chi² = 20.10, df = 9 (P = 0.02); I² = 55%						
Test for overall effect: Z = 1.03 (P = 0.30)						
1.3.2 Survivors free from KRT according to ITT after 30 days						
Xia 2019	13	15	5	17	0.4%	2.95 [1.37 , 6.32]
EARLYRRT 2018	9	10	5	11	0.5%	1.98 [1.00 , 3.91]
Sugahara 2004	10	12	2	2	0.7%	0.97 [0.55 , 1.72]
FST 2018	21	22	19	25	3.7%	1.26 [0.99 , 1.59]
ELAIN 2016	60	67	46	53	8.8%	1.03 [0.90 , 1.18]
STARRT-AKI Pilot 2013	30	30	31	33	11.5%	1.06 [0.96 , 1.18]
Bouman 2002	38	39	22	22	13.7%	0.98 [0.90 , 1.07]
AKIKI 2015	154	157	147	155	19.6%	1.03 [0.99 , 1.08]
IDEAL-ICU 2014	99	101	107	110	19.8%	1.01 [0.97 , 1.05]
STARRT-AKI 2019	729	814	766	815	21.2%	0.95 [0.93 , 0.98]
Subtotal (95% CI)		**1267**		**1243**	**100.0%**	**1.02 [0.97 , 1.07]**
Total events:	1163		1150			
Heterogeneity: Tau² = 0.00; Chi² = 29.08, df = 9 (P = 0.0006); I² = 69%						
Test for overall effect: Z = 0.85 (P = 0.40)						



Cochrane Database of Systematic Reviews 2022, Issue 11.

EARLY AND STANDARD INITIATION

- Length of stay

- Complication
  - Hypotension
  - Hypophosphatemia
  - Cardiac arrhythmia
  - Infection

Early > standard initiation

Cochrane Database of Systematic Reviews 2022, Issue 11.

MODALITIES OF EXTRACORPOREAL THERAPIES

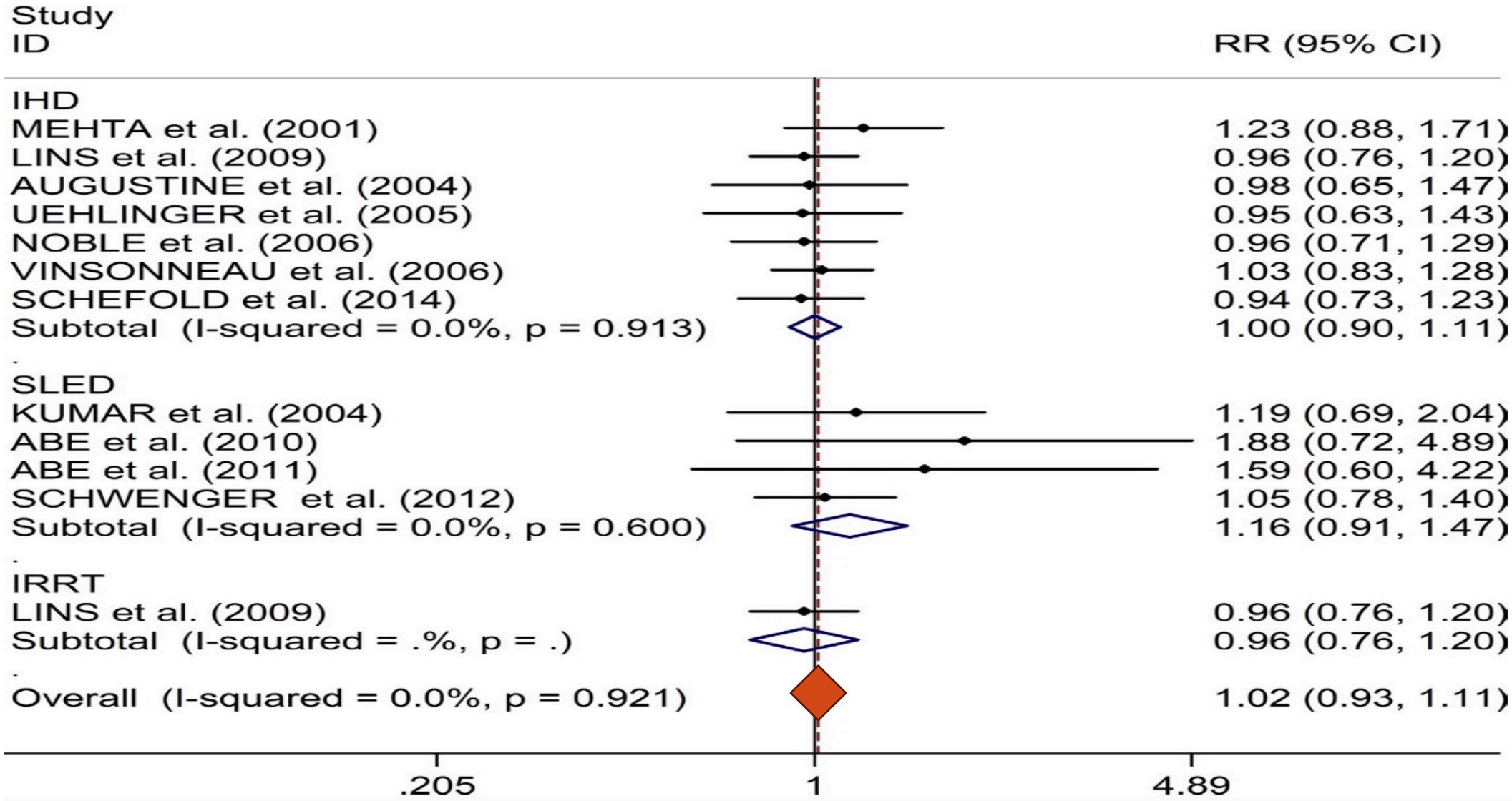
Modality	Advantages	Disadvantages	Appropriate setting
IHD	Rapid removal of toxins and low molecular weight substances	Rapid fluid removal leading to hypotension	Hemodynamically stable patients with hyperkalemia, metabolic acidosis, or poisoning with a dialyzable toxin
		Dialysis disequilibrium and cerebral edema	
	Allows "down time" for diagnostic and therapeutic procedures	Requires treated water and concentrates	
	Reduced exposure to anticoagulation; hence, lower bleeding risk	Not possible to combine with other organ support systems	
	Lower costs than CRRT		
CRRT	Continuous removal of toxins	Slower clearance of toxins	Hemodynamically unstable patients with pulmonary edema, liver disease, or increased intracranial pressure
	Less hypotension and need for escalation of vasopressors	Need for prolonged anticoagulation	Can be easily and appropriately coupled with other extracorporeal organ support systems
	Easy control of fluid balance because of unlimited fluid removal	Dedicated filter sets and sterile fluid bags required	
	Allows adequate nutrition even in anuric patients	Patient immobilization or frequent interruptions compromising adequate solute and fluid removal	
	User-friendly interactive machines	Increased infection risks	
	Some middle-molecular-weight solute possible	High costs	

Modality	Advantages	Disadvantages	Appropriate setting
SLED	Slower volume and solute removal Hemodynamic stability	Slower clearance of toxins	Hemodynamically unstable Can be coupled with other extracorporeal organ support systems
	Successfully performed without anticoagulation Allows "down time" for diagnostic and therapeutic procedures Same machines may be used for more than one treatment per day, or for acute HD, SLED, or even maintenance HD Lower cost		
PD	Hemodynamic stability	Inadequate clearance in hypercatabolic patients	Hemodynamically unstable with coagulopathy, difficult access, increased risk of cerebral edema in underresourced regions
	Technically simple	Protein loss	Stand-alone therapy not possible to combine with any other support system
	No anticoagulation No need for vascular access Lower cost Gradual removal of toxins	No control of rate of fluid removal Risk of peritonitis Hyperglycemia Requires intact peritoneal cavity Impairs diaphragmatic movement, potential for respiratory problems	

	Conventional IKRT/IHD	Optimized IKRT	PIKRT	CKRT
Clearance mechanisms	Diffusion	Diffusion	Diffusion or convection	Diffusion +/– convection
Type of machine	Standard	Standard or CKRT	Standard or CKRT	CKRT
Blood flow (mL/min)	400–500	200–350	150–350	100–300
Effluent flow (mL/min)	600–800	400–600	100–200	25–65
Duration	3–4 h	4–6 h	8–12 h	Continuous
Frequency	3x/wk	4–5x/wk	4–7x/wk	Daily
Fluid removal rate	2–5 L/session (0.75–1.5 L/h)	2–5 L/session (0.5–1 L/h)	1–5 L/session (250–500 mL/h)	0–300 mL/h
Access	AVF, AVG, catheter	AVF, AVG, catheter	Catheter (? AVF/AVG)	Catheter
Weekly cost	$	$–$$	$$ (lower with auto)	$$$
Mobilization	Easy	Easy	+/– (easier if performed overnight)	More challenging
Drug dosing	Straightforward	Straightforward	Limited data	More data
Staffing	HD RN	HD RN	HD or ICU RN	HD or ICU RN

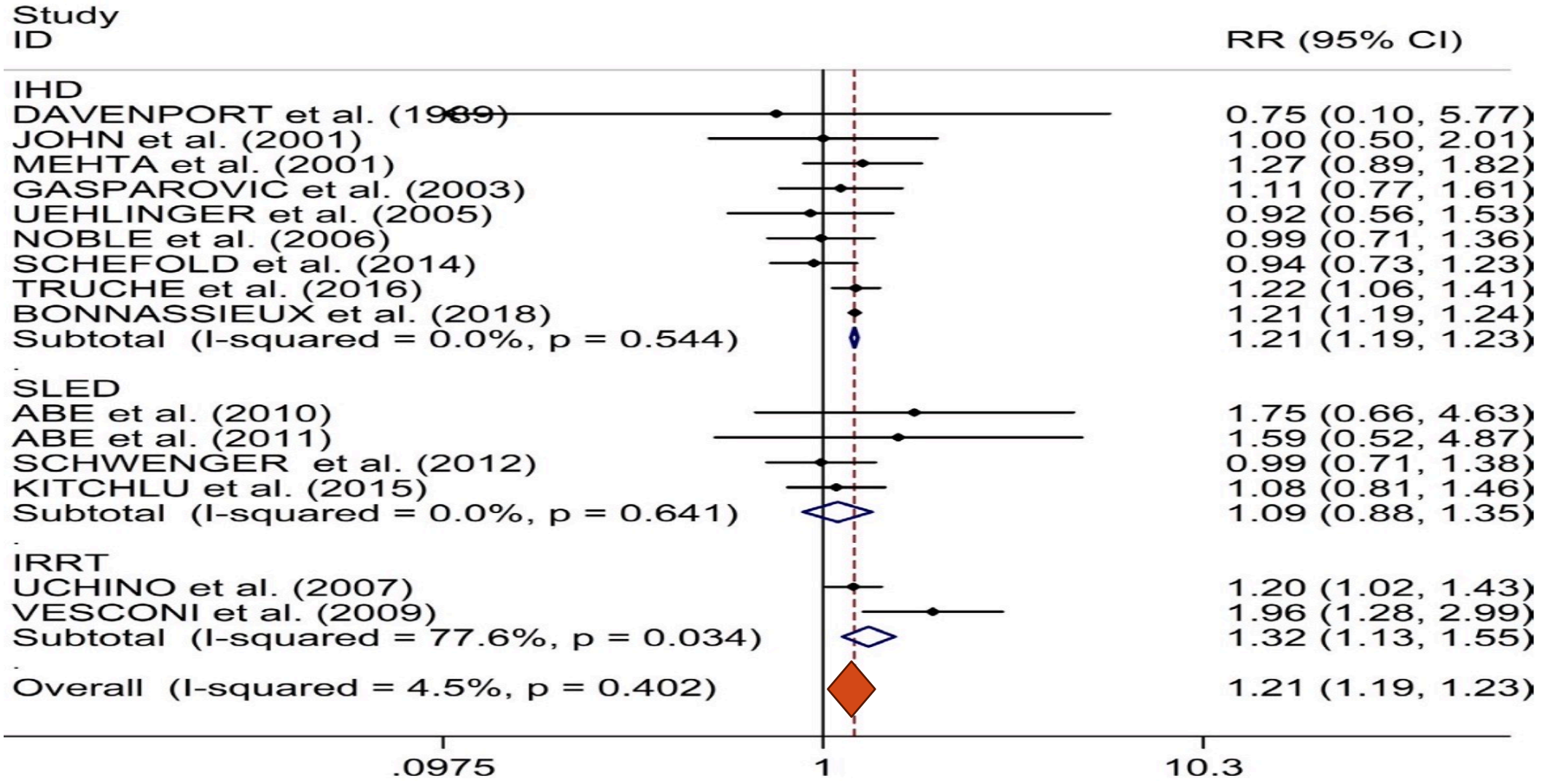
Comprehensive clinical nephrology 7th ed

IN-HOSPITAL MORTALITY



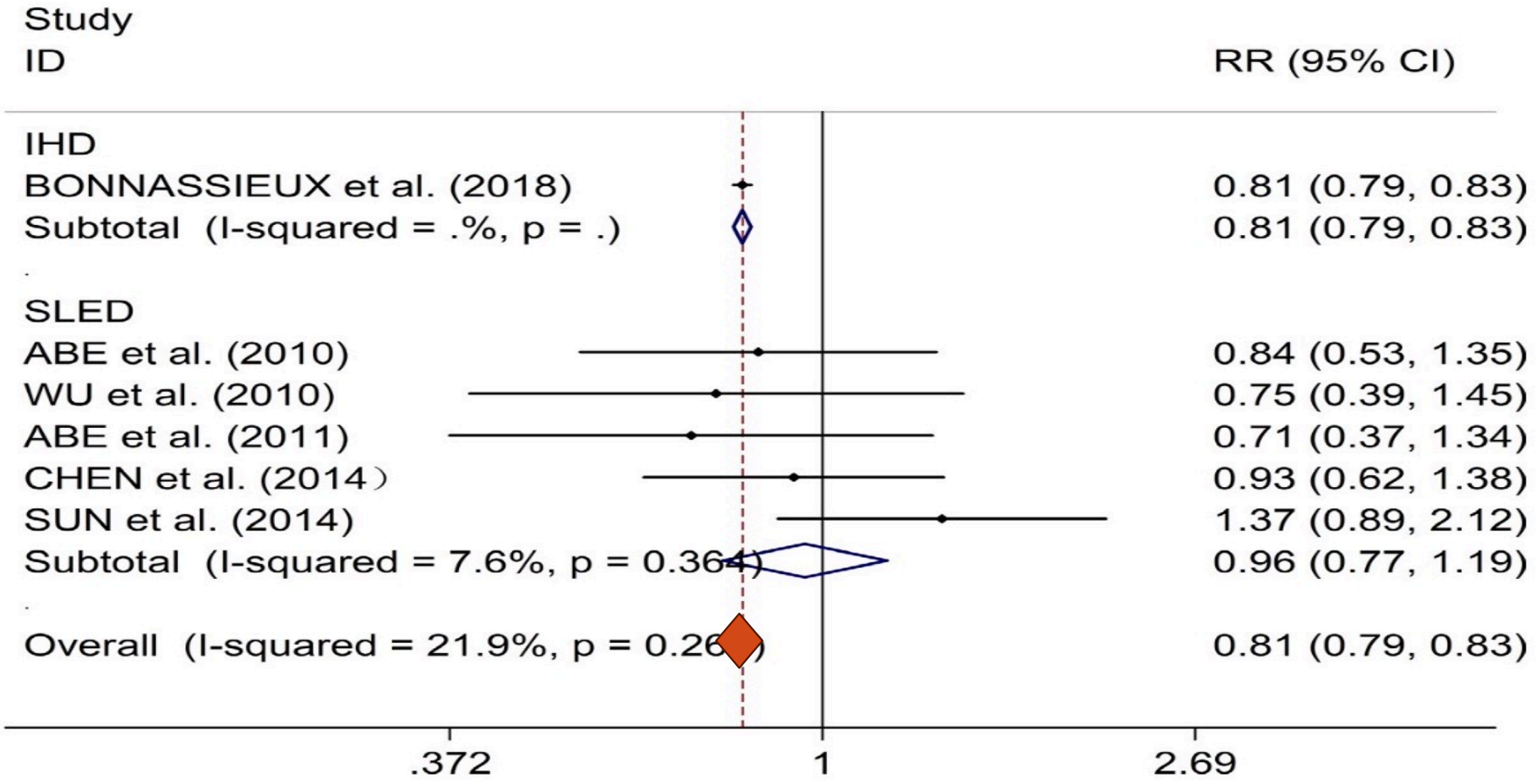
Seminars in Dialysis. 2020;00:1–6.

IN-ICU MORTALITY



Seminars in Dialysis. 2020;00:1–6.

RENAL RECOVERY



Seminars in Dialysis. 2020;00:1–6.

MODALITIES OF EXTRACORPOREAL THERAPIES

- **Suggest using CRRT, rather than standard intermittent RRT**
  - **Hemodynamically unstable patients**
  - **AKI patients with acute brain injury**
  - **AKI patients with increased intracranial pressure**
  - **AKI patients with generalized brain edema**

KDIGO 2012 Clinical practice guideline for Acute kidney injury

HOW TO PRESCRIBE ACUTE INTERMITTENT HD

Order for hemodialysis

Access				**Patient**
Dialyzer				**Machine**
Session length	h			
BFR	ml/min			
DFR	ml/min			
Net Ultrafiltration	L			
Dialysis solution				**Dialysis solution composition**
Na	mEq/l	K	mEq/l	
HCO_3	mEq/l	Ca	mEq/l	
Dialysis solution temperature	^oC			
Anticoagulant				**Medication**
Medication				
Nutrition				

ACCESS

- 2 types

- **Non-tunneled, non-cuffed catheter**
- Tunneled cuffed catheter

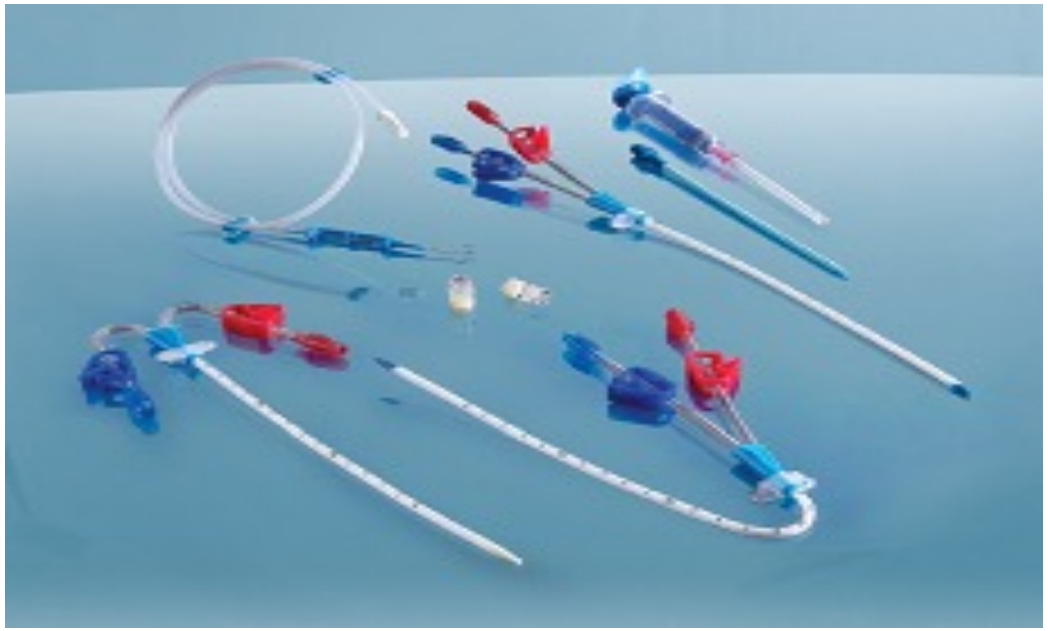
ACCESS

Length

Site	Formula	Accuracy
Right internal jugular	Height/10 cm	90%
Left internal jugular	Height/10 + 4 cm	94%
Right subclavian	Height/10 – 2 cm	96%
Left subclavian	Height/10 + 2 cm	97%

Diameter

- **11-14 French**



Comprehensive clinical nephrology 7th ed

ACCESS

Site

- **First choice : right jugular vein**
- **Second choice : femoral vein**
- **Third choice : left jugular vein**
- **Last choice : subclavian vein with preference for the dominant side**

KDIGO 2012 Clinical practice guideline for Acute kidney injury

ACCESS

- **Non-tunneled, non-cuffed catheter**
  - **Jugular vein : superior vena cava**
  - **Femoral vein : distal part of inferior vena cava**

- **Tunneled, cuffed catheter**
  - **Junction between superior vena cava and right atrium**

UpToDate

ACCESS

non-tunneled, non-cuffed catheter

- < 3 weeks : internal jugular vein, subclavian vein
- < 5 days : femoral vein

Tunneled cuffed catheter

- > 3 weeks

NKF-K/DOQI vascular access update 2000

ACCESS

Early complication

- **Arterial injury**
- **Pneumothorax**
- **Hemothorax**
- **Cardiac tamponade**
- **Cardiac arrhythmia**
- **Air embolism**
- **Retroperitoneal hemorrhage**

Recommend using ultrasound guidance for insertion
Recommend obtaining a chest radiograph promptly after placement and before first use of an internal jugular or subclavian dialysis catheter

Order for hemodialysis

Access				**Patient**
Dialyzer				**Machine**
Session length	h			
BFR	ml/min			
DFR	ml/min			
Net Ultrafiltration	L			
Dialysis solution				**Dialysis solution composition**
Na	mEq/l	K	mEq/l	
HCO_3	mEq/l	Ca	mEq/l	
Dialysis solution temperature	^oC			
Anticoagulant				**Medication**
Medication				
Nutrition				

DIALYZER

Hollow fiber dialyzers

DIALYZER

Membrane Type

1. **Cellulose**
2. **Substituted cellulose**
3. **Noncellulose, synthetic**

Biocompatible
Infectious complication
Renal recovery

Handbook of dialysis, 5th ed. 2015

DIALYZER

- **Membrane**
  - **Efficiency : K_oA urea**
    - **Ability to clear solutes**
  - **Flux : K_{UF}**
    - **Ability to remove water**
  - **Permeability : B_2-microglobulin clearance**
    - **Ability to clear B_2-microglobulin**

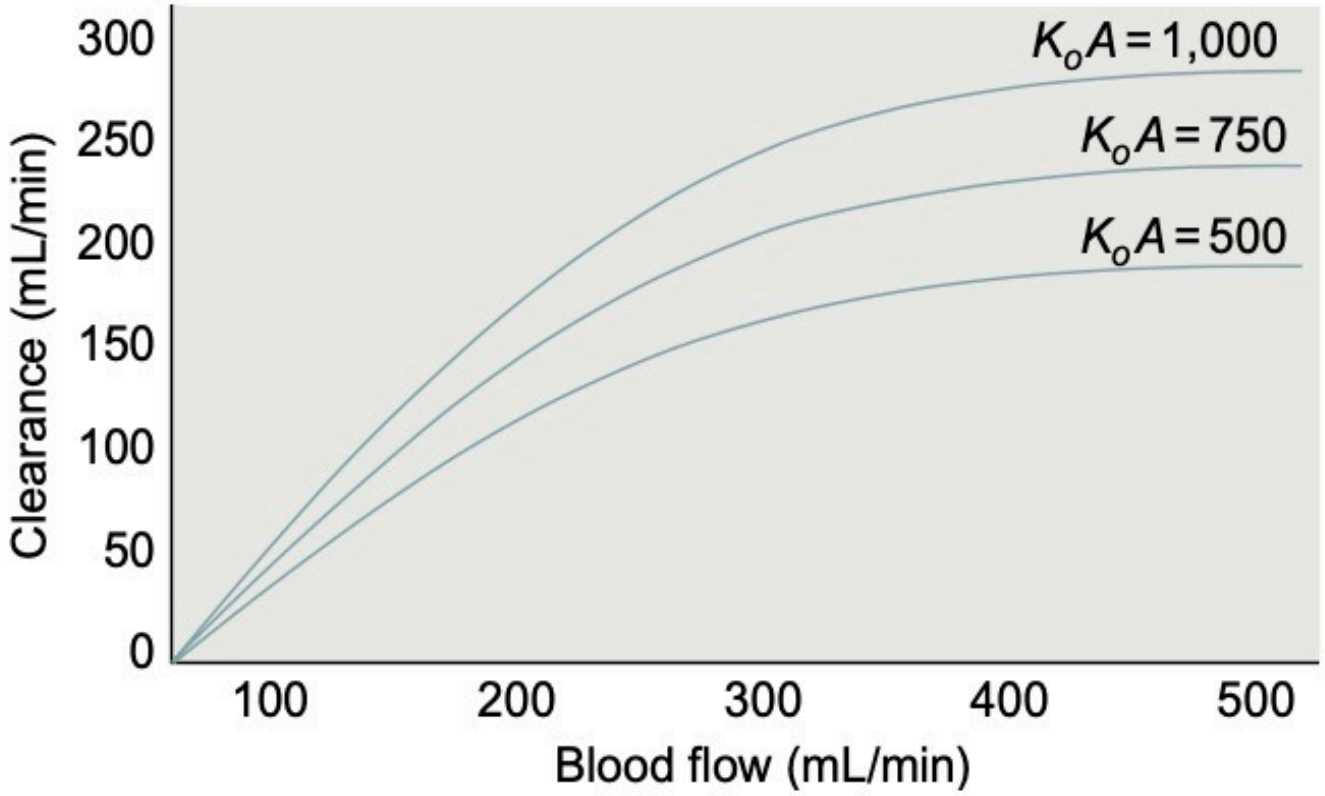
	Standard	High Efficiency	High Flux
Blood flow rate (mL/min)	250	≥350	≥350
Dialysate flow rate (mL/min)	500	≥500	≥500
K_0A urea	300–500	≥600	Variable
Urea clearance (mL/min)	<200	>210	Variable
Urea clearance/body weight (mL/min/kg)	< 3	>3	Variable
Vitamin B_{12} clearance (mL/min)	30–60	Variable	>100
Beta-2 microglobulin clearance (mL/min)	<10	Variable	>20
Ultrafiltration coefficient (mL/hr/mm Hg)	3.5–5.0	Variable	>20
Membrane	Cellulose	Variable	Variable

BRENNER & RECTOR'S THE KIDNEY 11th ed

DIALYZER

K_oA

- **Maximum theoretical clearance of dialyzer for a given solute at infinite blood and dialysis solution flow rate**
  - **Membrane porosity and thickness**
  - **Solute size**
  - **Flow rate of blood and dialysis solution**



Handbook of dialysis, 5th ed. 2015

DIALYZER

Ultrafiltration coefficient (K_{UF})

- **Volume of fluid (ml/h) that is transferred across the membrane per mmHg of pressure gradient**

Ultrafiltration (ml) = K_{uF} (ml/mmHg/h) x TMP (mmHg) x dialysate time (h)

Handbook of dialysis, 5th ed. 2015

DIALYZER

Blood volume capacity

- **Blood volume required to fill dialyzers 60-120 ml**
- **Lower volume : minimize the risk of hemodynamic compromise**

Surface area

- **Small surface**

Technical and In-vitro Performance Data

		Pro 13H			Pro 16H			Pro 19H		
Blood flow (Q_B) mL/min		**200**	**300**	**400**	**200**	**300**	**400**	**200**	**300**	**400**
Clearance Dialysate flow = 500mL/min Ultrafiltration flow (Q_F)=0mL/min	Urea	194	263	303	196	270	322	197	280	332
	Creatinine	185	236	269	189	248	284	194	260	305
	Phosphate	178	220	249	184	230	261	186	242	278
	Vitamin B_{12}	133	151	167	143	166	183	150	180	202
	Inulin	86	92	101	96	106	116	102	117	128
	Cytochrome C	65	73	75	72	81	86	80	90	95
SC, (Sieving Coefficient) Q_B = 300mL/min Q_F = 60mL/min	Inulin					1.0				
	ß$_2$-Microglobulin					0.7				
	Albumin					< 0.001				
Ultrafiltration coefficient mL/h/mmHg	Q_B = 300mL/min		70			85			97	
KoA Urea (Q_B = 300mL/min)			1010			1145			1415	
Volume of blood compartment (mL)			82			100			120	
Membrane material						α Polysulfone Pro				
Surface Area (m^2)			1.3			1.6			1.9	
Sterilization						Oxygen-free Gamma				
Recommended blood flow rate (mL/min)			200-500			200-500			200-500	
Max. dialysate flow (mL/min)			800			800			800	
Pressure drop blood (Q_B = 300mL/min) mmHg			101			82			72	
Article No.			720DH13			720DH16			720DH19	

Order for hemodialysis

Access				**Patient**
Dialyzer				**Machine**
Session length	h			
BFR	ml/min			
DFR	ml/min			
Net Ultrafiltration	L			
Dialysis solution				**Dialysis solution composition**
Na	mEq/l	K	mEq/l	
HCO_3	mEq/l	Ca	mEq/l	
Dialysis solution temperature	°C			
Anticoagulant				**Medication**
Medication				
Nutrition				

SESSION LENGTH

- **1st session : 2 h**
- **2nd session : 3 h**
- **3rd session : 4 h**

Handbook of dialysis, 5th ed. 2015

FLOW RATE

Blood flow rate

- 150-200 ml/min

Dialysis solution flow rate

- 300-500 ml/min

Handbook of dialysis, 5th ed. 2015

ULTRAFILTRATION

- **Target intravascular volume**
  - **Non-invasive monitoring : bio-impedance analysis, echocardiography**
  - **Invasive monitoring**

- **Volume status**
  - **Volume overload : UF 10 ml/kg/hour**
  - **1st session : UF < 2 l**

Handbook of dialysis, 5th ed. 2015

Order for hemodialysis

Access				**Patient**
Dialyzer				**Machine**
Session length	h			
BFR	ml/min			
DFR	ml/min			
Net Ultrafiltration	L			
Dialysis solution				**Dialysis solution composition**
Na	mEq/l	K	mEq/l	
HCO_3	mEq/l	Ca	mEq/l	
Dialysis solution temperature	^oC			
Anticoagulant				**Medication**
Medication				
Nutrition				

DIALYSIS SOLUTION : NA

Mild hyponatremia

- **Serum Na > 130 mEq/l**
- **Goal serum Na 140 mEq/l**
- **Dialysis solution Na as low as 135 mEq/l**
- **Brain edema or hypotension : < 10 mEq/l**

Moderate to severe hyponatremia

- **Serum Na < 130 mEq/l**
- **Dialysis solution Na as low as 135 mEq/l**
- **Slow blood flow rate (50-100 ml/min)**
- **Duration < 1 hour alternating with isolated UF**
- **Check serum Na after each dialysis 30-60 minutes of dialysis**

$$\text{Change in Na (mEq/L)} = \frac{\text{BFR} \times \text{session time (minutes)} \times (\text{dialysate Na} - \text{plama Na})}{\text{total body water}}$$

Handbook of dialysis, 5th ed. 2015

DIALYSIS SOLUTION: NA

Mild hypernatremia

- **Close to serum Na**
- **Lower than the serum value 3-5 mEq/l**
  - **Hypotension**
  - **Muscle cramps**
  - **Cerebral edema and disequilibrium syndrome**

Severe hypernatremia

- **Prefer CRRT**

Handbook of dialysis, 5th ed. 2015

DIALYSIS SOLUTION : NA PROFILE

1. **Decreasing Na profile**
   - **Linear : late dialytic hypotension**
   - **Stepwise : early dialytic and postdialytic hypotension**
   - **Exponential**
2. **Increasing Na profile : late muscle cramp**
3. **Alternating high-low Na profile**

Textbook of hemodialysis & renal replacement therapy : 2013

DIALYSIS SOLUTION : K

Serum K	Dialysate K
< 4.5 mEq/L	≥ 4 mEq/L
4.5 - < 5.5 mEq/L	3 mEq/L
K rebound within 1-2 hours after dialysis **No treat a postdialysis hypokalemia**	
	• patients have arrhymia risk • patients on digitalis
> 7 mEq/L	< 2 mEq/L + monitor ECG + monitor K every 30-60 minutes

Handbook of dialysis, 5th ed. 2015

DIALYSIS SOLUTION : GLUCOSE

Glucose 100 mg/dl

- **Severe hyperkalemia**

Glucose 200 mg/dl

- **Mild to moderate hyperkalemia**

Glucose free dialysis solution : risk of hypoglycemia

- Diabetes
- Sepsis
- Beta-blocker

UpToDate

DIALYSIS SOLUTION : CA

- **Hypocalcemia or normocalcemia**
  - **Ca 3-3.5 mEq/l**

- **Hypercalcemia**
  - **Ca 2.5-3.5 mEq/l**

- **Dialysis solution Ca < 3 mEq/L : intradialytic hypotension**

Handbook of dialysis, 5th ed. 2015

DIALYSIS SOLUTION : CA

- **serum Ca < 8 mg/dL**
  - **Ca 3-3.5 mEq/L**

- **serum Ca 8-12 mg/dL**
  - **Ca 2.5 mEq/L**

- **serum Ca > 12 mg/dL**
  - **Ca 2-2.5 mEq/L**

UpToDate

DIALYSIS SOLUTION : HCO_3

- **Evaluate acid-base status of patient**

- **Avoid alkalosis**
  - **Additional bicarbornate 4-8 mEq/l : citrate-based and acetate based**

Goal : normalize pH, not serum HCO_3

Handbook of dialysis, 5th ed. 2015

DIALYSIS SOLUTION : HCO_3

Mild to moderate acidosis

- **30-35 mEq/L**

Severe acidosis

- **35-40 mEq/L**

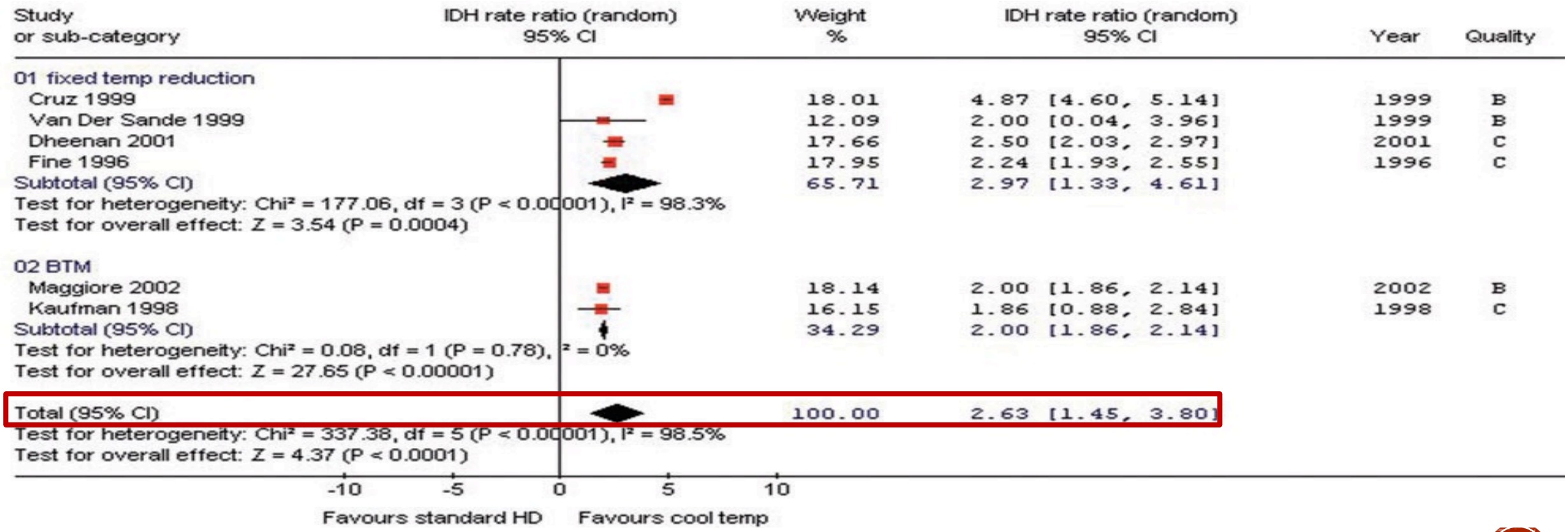
DIALYSIS SOLUTION : HCO_3

HCO_3 > 28 mEq/L

- **25-30 mEq/L**
- **plus NaCl**

DIALYSIS SOLUTION : TEMPERATURE

Review: Systematic review of the effects of adjusting thermal balance during haemodialysis
Comparison: 01 IDH
Outcome: 02 IDH rate



Nicholas M, et al. NDT (2006) 21 : 1883–1898

DIALYSIS SOLUTION : TEMPERATURE

- **Cool temperature**
  - **Hypothermia**
  - **Myocardial function**
  - **End-organ perfusion**
  - **Blood clotting**
  - **Possibly renal recovery**

UpToDate®

Order for hemodialysis

Access — **Patient**

Dialyzer

Session length h

BFR ml/min

DFR ml/min

Net Ultrafiltration L

— **Machine**

Dialysis solution

Na mEq/l K mEq/l

HCO_3 mEq/l Ca mEq/l

Dialysis solution temperature °C

— **Dialysis solution composition**

Anticoagulant

Medication

Nutrition

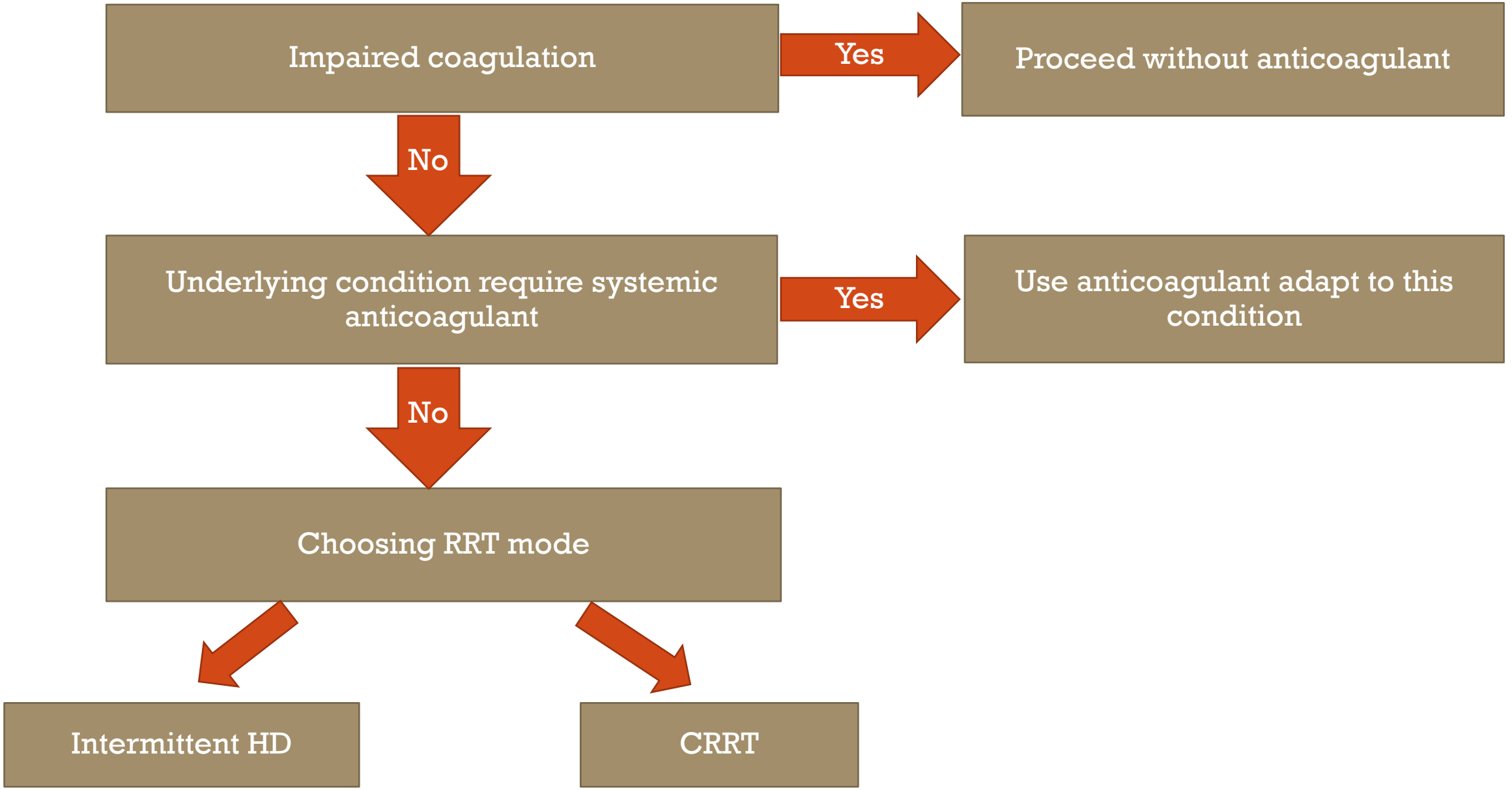
— **Medication**

ANTICOAGULATION

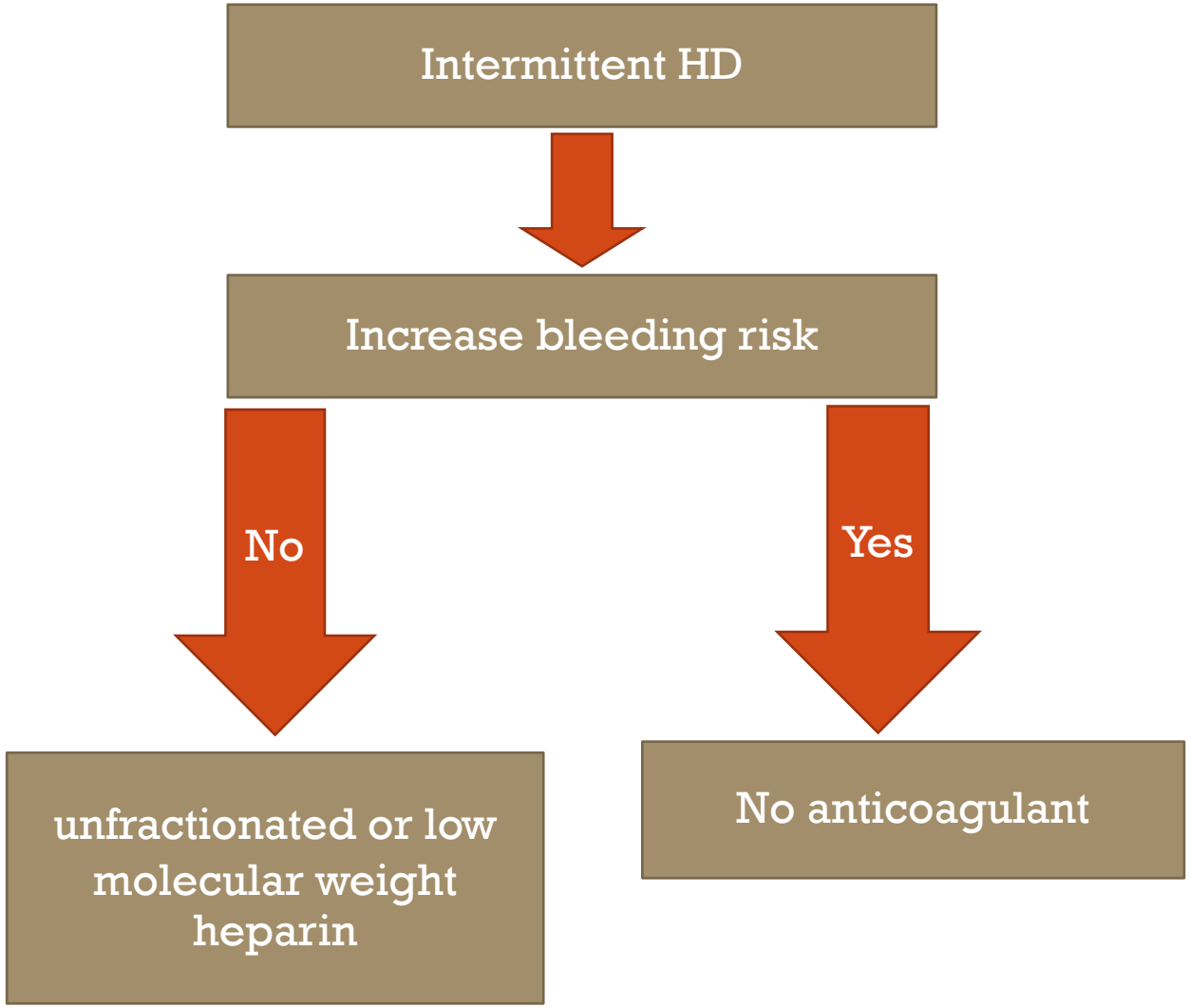
- **Use anticoagulation for RRT on assessment of the patient's potential risks and benefits from anticoagulation**

- **For anticoagulation in intermittent RRT, recommend using either unfractionated or low-molecular-weight heparin, rather than other anticoagulants**

KDIGO 2012 Clinical practice guideline for Acute kidney injury



KDIGO 2012 Clinical practice guideline for Acute kidney injury



KDIGO 2012 Clinical practice guideline for Acute kidney injury

Anticoagulation for Hemodialysis	Clinical Condition
No anticoagulation or regional anticoagulation	Actively bleeding
	Significant risk for bleeding
	Major thrombostatic defect
	Major surgery within 7 days
	Intracranial surgery within 14 days
	Biopsy of visceral organ within 72 hours
	Pericarditis
Low-dose heparin	Major surgery beyond 7 days
	Biopsy of visceral organ beyond 72 hours
	Minor surgery 8 hours prior
	Minor surgery within 72 hours
Low-dose heparin or no anticoagulation	Major surgery 8 hours prior

BRENNER & RECTOR'S THE KIDNEY 11th ed

ANTICOAGULATION

Unfractionated heparin

- **Constant-infusion method : 2000–5000 U or 50 U/kg bolus followed by a 1000–1500 U/h until 15 to 60 minutes before the end of dialysis**

- **Repeated-bolus method : 4000 U bolus followed by 1000-2000 U after 2 h**

- **Low dose regimen : 500–1000 U bolus followed by 500–750 U/h**

BRENNER & RECTOR'S THE KIDNEY 11th Ed

ANTICOAGULATION

Low molecular weight heparin

- **Enoxaparin 0.7-1 mg/kg single bolus**

Test	Baseline value	Routine heparin Desired range		Tight heparin Desired range	
		During dialysis	At end of dialysis	During dialysis	At end of dialysis
Activated partial thromboplastin time	1	2-2.5	1.5-2.0	1.5-2.0	1.5-2.0
Whole-blood partial thromboplastin time	60-85 sec	120-140	85-105	85-105	85-105
Activated clotting time	120-150 sec	200-250	170-190	170-190	170-190
Lee-white clotting time	4-8 min	20-30	9-16	9-16	9-16

Handbook of dialysis, 5th ed. 2015

Anticoagulation	Advantage	Disadvantage
Unfractionated heparin	▪ **Wide availability** ▪ **Large experience** ▪ **Short half life** ▪ **Antagonist available** ▪ **monitoring with routine test** ▪ **Low costs**	▪ **Narrow therapeutic index-risk of bleeding** ▪ **Unpredictable kinetics-monitoring required** ▪ **HIT** ▪ **Heparin resistance**
Low molecular weight heparin	▪ **More predictable kinetics** ▪ **No monitoring required** ▪ **Single predialysis dose** ▪ **Reduced risk of HIT**	▪ **Risk of accumulation in kidney failure** ▪ **Monitoring require non-routine test** ▪ **Incomplete irreversible by protamine** ▪ **More expensive**

ANTICOAGULATION

- **Anticoagulation-free dialysis**
  - **Rinse the circuit before dialysis with heparinized saline**
  - **Use a less thrombogenic dialyzer**
  - **Flush the circuit with 100 to 200 mL of 0.9% NaCl q 15-30 min**
  - **Avoid blood or platelet transfusions through the circuit**
  - **Maintain a high blood flow rate**
  - **Limit ultrafiltration as feasible because hemoconcentration**

BRENNER & RECTOR'S THE KIDNEY 11th Ed

MEDICATION

Drug	HEMODIALYSIS		Peritoneal Dialysis
	Conventional	High Permeability	
Abacavir	U	No (40)	ND
Abatacept	U	U	U
Abciximab	U	ND	U
Abiraterone	No (NS)	No (NS)	U
Acamprosate	ND	ND	ND
Acarbose	ND	ND	ND
Acebutolol (diacetolol)	Yes (NS)	L	ND
Acenocoumarol	U	U	U
Acetaminophen (paracetamol)	Yes (NS)	L	No
Acetazolamide	U	ND	No
Acetohexamide	U	ND	U

Dialysis of drugs 2013

PATIENT MONITORING AND COMPLICATION

- **Intradialytic hypotension**
- **Muscle cramps**
- **Nausea and vomiting**
- **Headache**
- **Chest pain and back pain**
- **Disequilibrium syndrome**
- **Dialyzer reaction**
- **Hemolysis**
- **Air embolism**
- **Arrhythmia**

Handbook of dialysis, 5th ed. 2015

PATIENT MONITORING AND COMPLICATION

- **Intradialysis hypotension**
  - **increasing frequency and duration**
  - **Soidum and UF profiling**
  - **Cool temperature dialysate**
  - **higher dialysate Ca**
  - **vasopressor**
  - **Bolus NSS or albumin**

PATIENT MONITORING AND COMPLICATION

- **CRBSI**
  - **Universal precaution**
  - **Site of vascular access**
  - **Duration**
  - **Antibiotics : topical and lock**

POSTDIALYSIS EVALUATION

- **Weight loss**
- **Postdialysis blood values**
  - **20-30 sec to 2 minutes after dialysis**
    - **BUN**
    - **Na**
    - **Ca**
  - **1-2 hour after dialysis**
    - **K**

Handbook of dialysis, 5th ed. 2015

DIALYSIS DOSAGE AND FREQUENCY

- **Urea reduction < 40%**

DIALYSIS DOSAGE AND FREQUENCY

Dosage

- **Kt/V ≥ 1.3/session**
- **Weekly Kt/V 3.9**

Frequency

- **3 times/week**

KDIGO 2012 Clinical practice guideline for Acute kidney injury

DISCONTINUATION OF THERAPY

- **Indication of extracorporeal therapies**

- **If Urine output > 30 ml/hour**
  - **CrCl < 12 ml/min : continuation of RRT**
  - **CrCl 12-20 mL/min : clinician's judgment**
  - **CrCl > 20 ml/min : discontinuation of RRT**

Palevsky PM, et al. NEJM, 2008 ; 359 : 7-20

The End