ERKNet/ESPN Workshop
fundamentals of pediatric dialysis
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Dialysis in AKI

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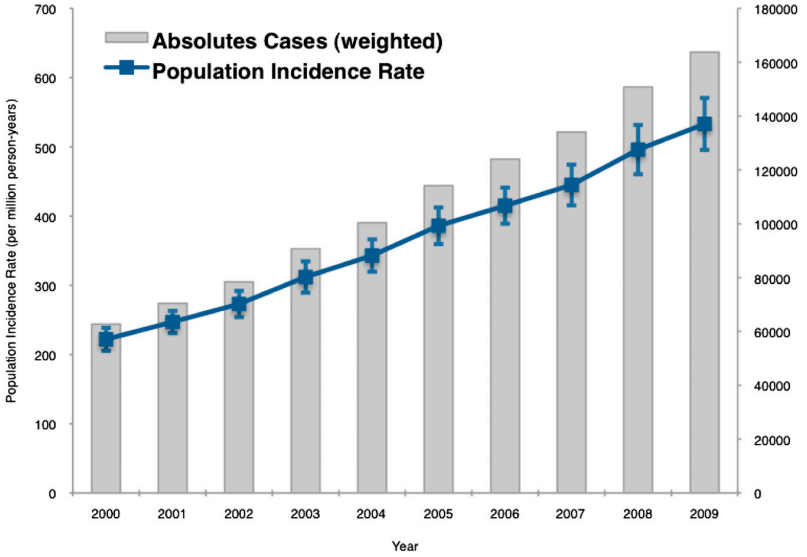
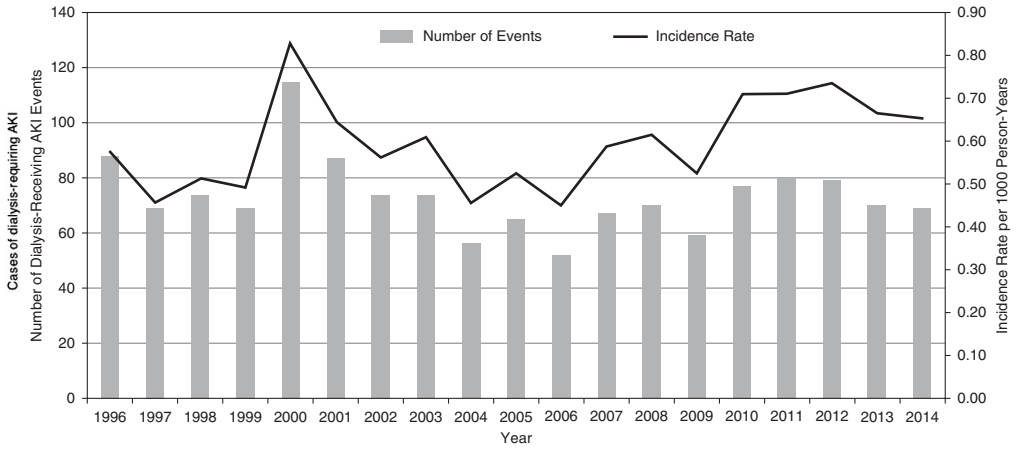
Dialysis in AKI

- When to start dialysis
- Which modality of dialysis
- How to prescribe dialysis in AKI

Trend in incidence in dialysis receiving AKI





- From 2000 to 2009, the incidence of dialysis-requiring AKI increased of 10% per year
- The increase in incidence was evident in all age groups examined and in children the increase was 7% per year

- There was a significant change in the incidence of dialysis-receiving AKI among children from 1996 (**0.58 per 1000 person-years**) to 2015 (**0.65 per 1000 person-years**) (Cochran–Armitage test for trend, P=0.01)

Hsu RK et al. J Am Soc Nephrol 24: 37–42, 2013

Chanchlani R. CJASN 14: 1288–1296, 2019

Author	Year of publication	Type of study	N of patients	Country	Age	Male sex	Primary disease	Dialysis modality	Setting	Outcome Survival
Bunchman TE[10]	2001	Single center Retrospective	226	USA	Newborn-216 mo Mean 74±11.7 mo	51%	Congenital heart disease 21% ATN 20% Sepsis 17% BMT 11% Liver Tx 10% TLS 7% HUS 7% Cardiac Tx 6%	CKRT 47% HD 27% PD 26%	PICU	Overall 54% CKRT 40% PD 49% HD 81%
Symons JM[24] ppCRRT Registry	2007	Multicenter Prospective Observational	344	USA	Newborn-25 yrs	58%	Sepsis 23% BMT 16% Cardiac disease 12% Renal disease 9%	CKRT	PICU	58%
Fleming GM[32] ppCRRT Registry	2012	Multicenter Prospective Observational	50	USA	Median 5.5 yrs (IQR 0.25-14 yrs)	Not indicated	IEM 42% Drug toxicity 36% TLS 22%	CKRT HD prior to CKRT 9	PICU	78%
Kaddourah A[4] AWARE	2017	Multicenter Prospective Observational	4984 AKI 1261 AKI stage 2-3 543 KRT 73 (2%)	Asia Australia Europe USA	Median 66 mo (IQR 18.8-151.1)	55%	Respiratory 38% Surgical or trauma 30% Shock 24%	Not indicated	PICU	Overall 97% AKI 93% AKI stage 2-3 89% KRT 67%
Jetton JG[43] AWAKEN	2017	Multicenter Retrospective Observational	2022 AKI 605 AKI stage 2-3 324 KRT 25	Australia Canada India USA	Gestational age: 22 0/7->36 weeks	Overall 56% AKI 57%	Reasons for NICU admission: Prematurity 52% Sepsis 50% Respiratory failure 46%	PD 9 pts CKRT 4 pts CKRT + ECMO 11 pts PD + CKRT 1 pt	NICU	Overall 96% No AKI 99% AKI 90% AKI stage 2-3 90% KRT 76%
Chanchlani R[9]	2019	Retrospective Population-based cohort	1394 dialysis-receiving AKI	Canada	29 days-18 yrs Median 1996-2001 13 yrs 2002-2005 3 yrs 2006-2009 5 yrs 2010-2015 3 yrs	1996-2001 50% 2002-2005 51% 2006-2009 53% 2010-2015 57%	Not indicated	HD 25% PD 47% CKRT 28%	Hospital	Overall 81% 1996-2001 86% 2002-2005 76% 2006-2009 75% 2010-2015 81%

Indications to KRT

- Hyperkaliemia
  - serum potassium >6 mE
  - serum potassium >5.5 mEq/
- Acidosis
  - pH<7.15 in a conte
  - pH<7.15 in a context o
    possibility of increasing a
- Oligo-anuria
- Acute pulmonary edema due to fluid
- Severe symptomatic uremia
- Drug toxicities
- Hyperammonemia/inborn errors of metabol

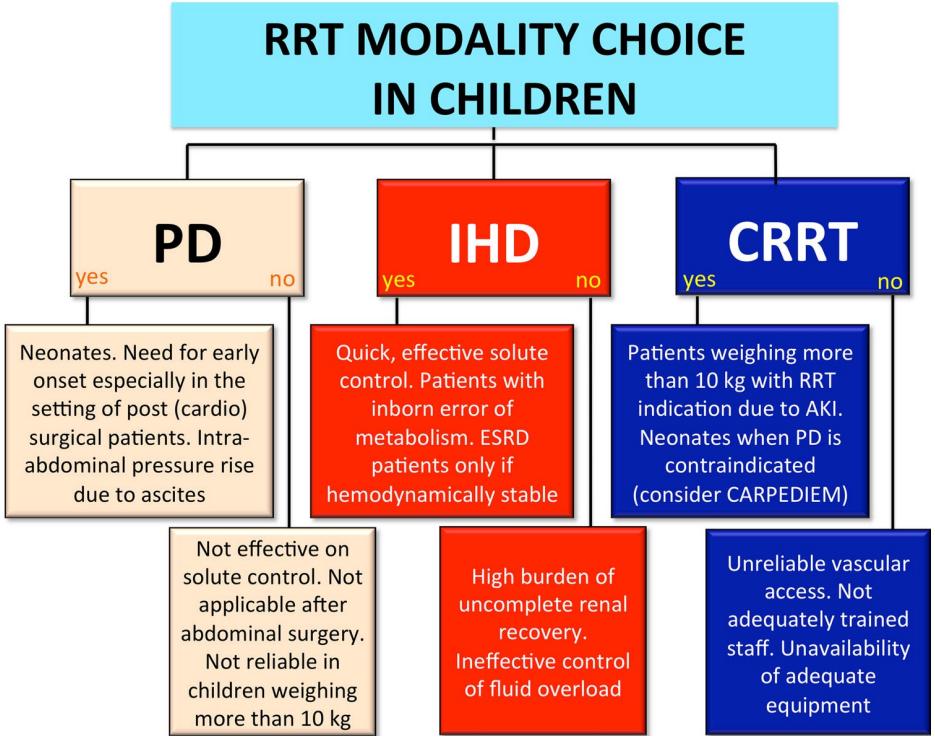
KDIGO Guidelines

- Initiate KRT emergently when life-threatening changes in fluid, electrolyte, and acid-base balance exist
- Consider the broader clinical context, the presence of conditions that can be modified with KRT, and trends of laboratory tests

For those patients with AKI but without indications for urgent dialysis should KRT be initiated early or should it be delayed?

Study	Design (year)	Sample size	Early KRT	Delayed KRT	Type of patients	Type of KRT	Dose of RRT	Outcome
ELAIN	Single center RCT (2016)	231	Within 8 hours of KDIGO 2	Within 12 hours of KDIGO 3 *or* Specific indication	Medical ICU 6 % Surgical ICU 94%	CKRT	30 mL/Kg/h	90 Day Mortality: Early 39.3% Delayed 54.7% (p=0.03)
AKIKI	Multicenter RCT (2016)	620	Within 6 hours of KDIGO 3	Specific indicaion	Medical ICU 80% Surgical ICU 20%	IHD/CKRT	Not standardized	60 Day Mortality: Early 48.5% Delayed 49.7% (p=0.79)
IDEAL-ICU	Multicenter RCT (2018)	488	Within 12 hours of RIFLE-F	After 48 hours	Septic shock	IHD/CKRT	IHD 300-500 ml/min CRRT 25 mL/kg/h	90 Day Mortality Early 58% Delayed 54% (p=0.38)
STARRT-AKI	Multicenter RCT (2020)	2927	Within 12 hours of KDIGO 2-3	After 72 hours of KDIGO 2-3 *or* Specific indication	Medical ICU 67% Surgical ICU 33%	IHD/CKRT /SLED	CRRT 23-33 mL/kg/h	90 DAY Mortality: Accelerated 43.9% Standard 43.7% (p=0-92)
AKIKI 2	Multicenter RCT (2021)	278	**Delayed RRT** Oliguria for more than 72 h *or* BUN> 112 mg/dl	**More-delayed RRT** Mandatory indication *or* BUN >140 m g/dl	Mixed medical/surgical ICU Septic shock 46%	IHD/CKRT	Not standardized	RRT-free days Delayed 12 days More-delayed 10 days 60 Day Mortality Delayed 44% More-delayed 55% (p=0.071)

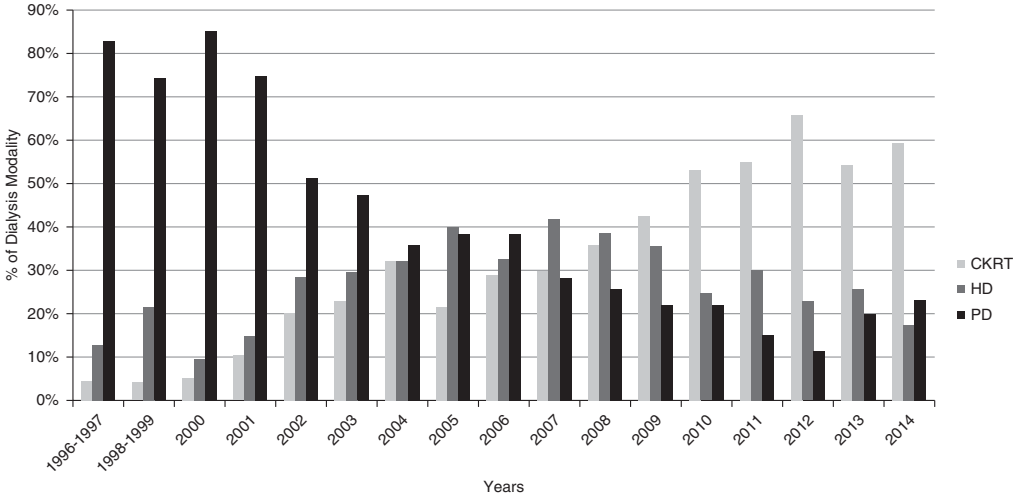
AKI and KRT modality choice

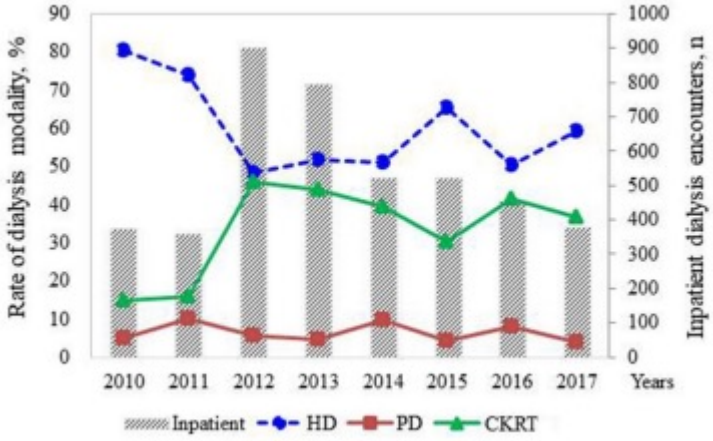


Consider:

- Age/patient size
- Primary disease
- Comorbidities
- Hemodynamic stability
- Local expertise
- Availability of dedicated devices

Dialysis modality

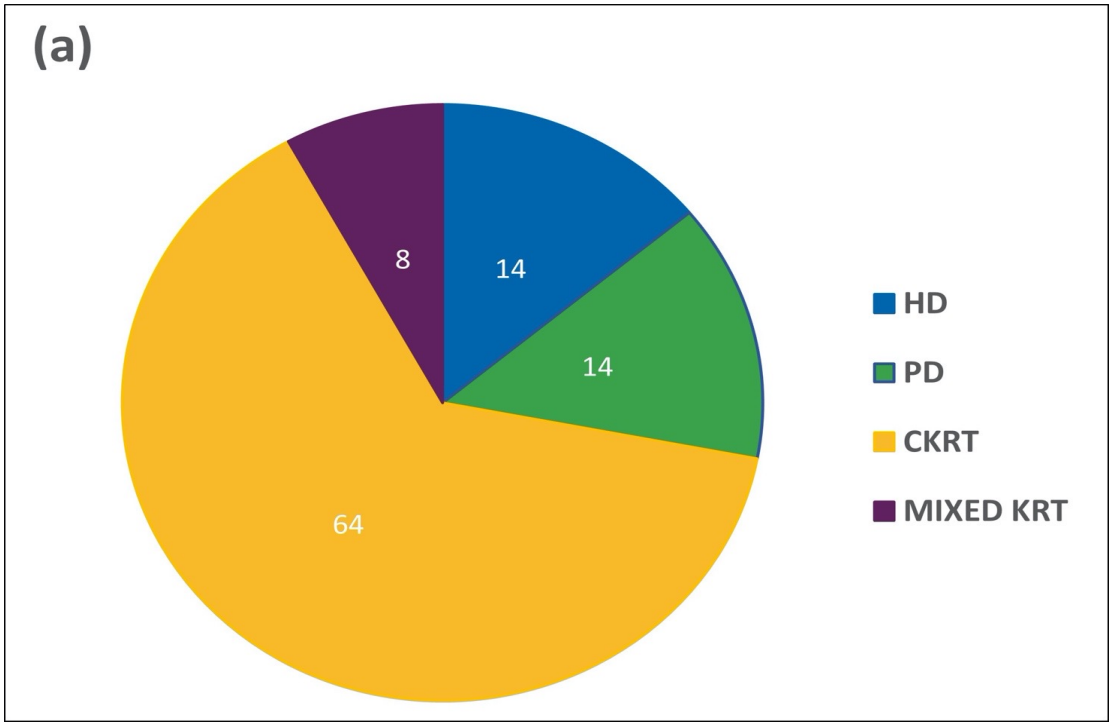




Chanchlani R. CJASN 14: 1288–1296, 2019

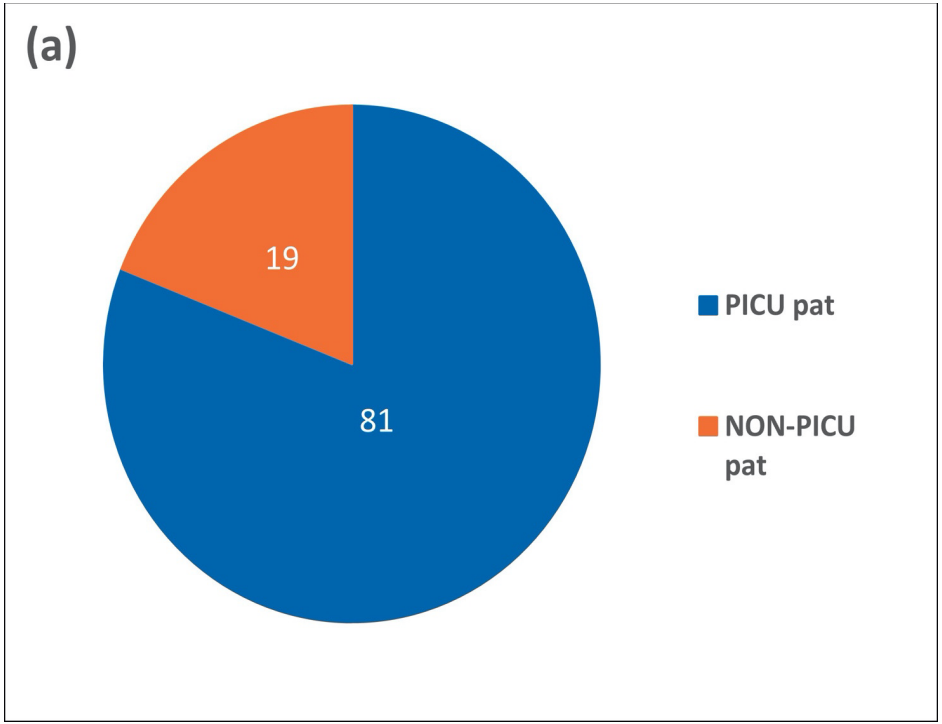
Tain YL. Scientific reports 2021;11: 11887

AKI – Dialysis modality



Guzzo I. NDT 2021; doi: 10.1093/ndt/gfab280

AKI – Dialysis setting



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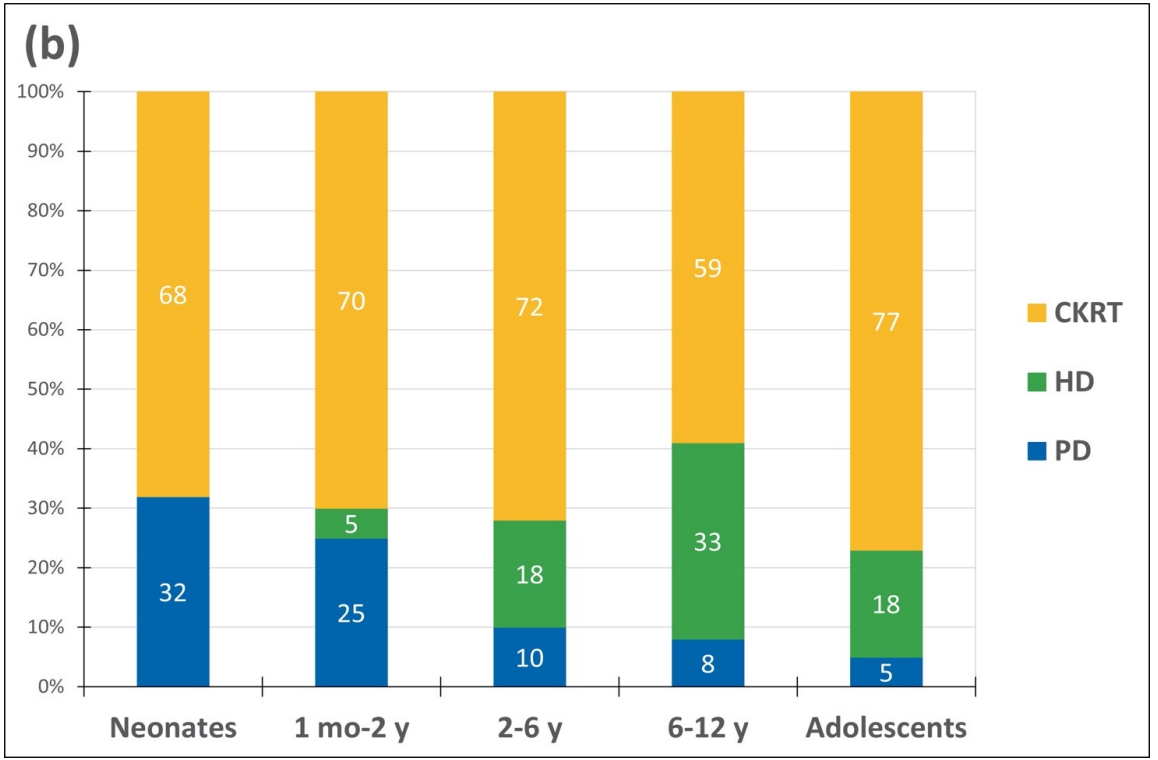
AKI - dialysis modality according to age

Awaken
25 KRT
PD 9 pts
CKRT 4 pts
CKRT + ECMO 11 pts
PD + CKRT 1 pt

62%



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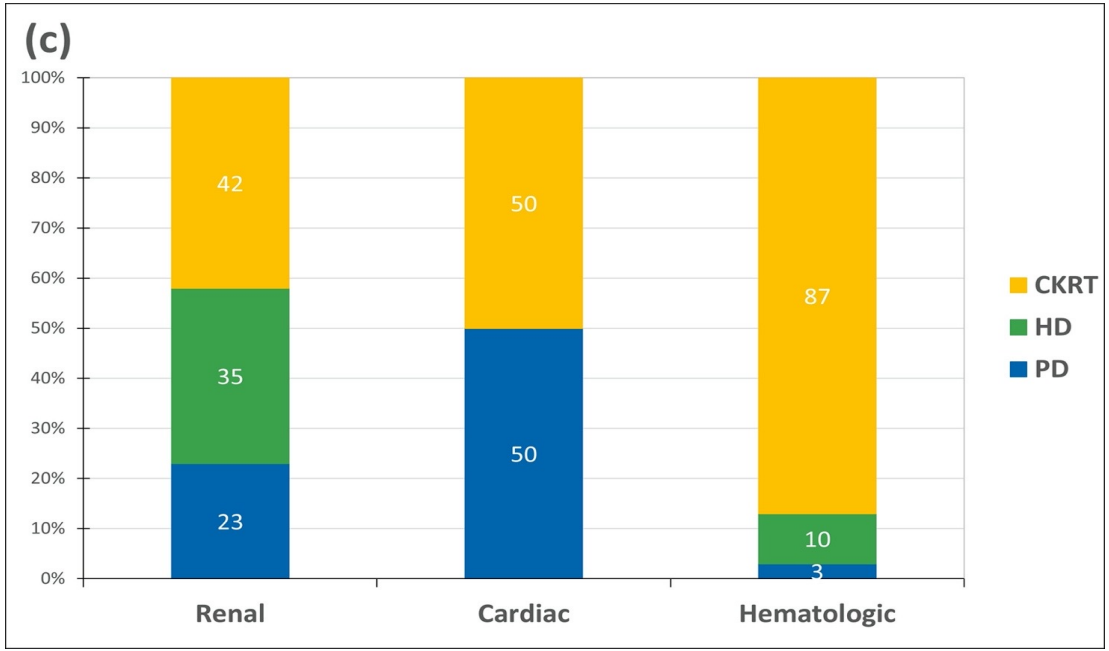
AKI - dialysis modality according to primary disease



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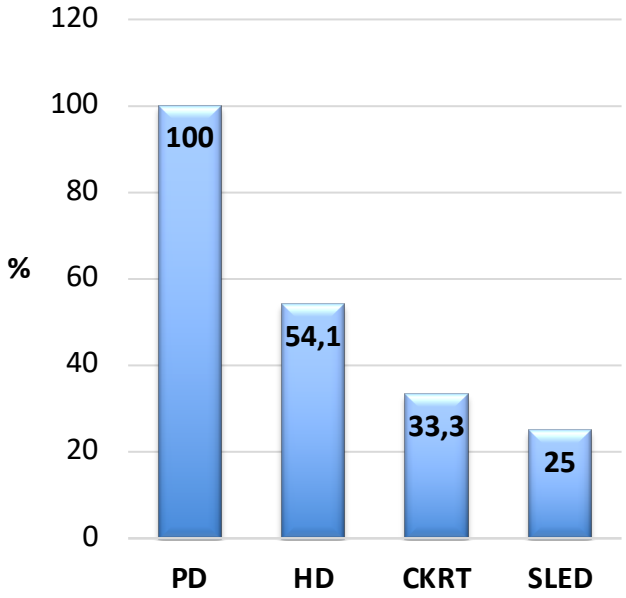
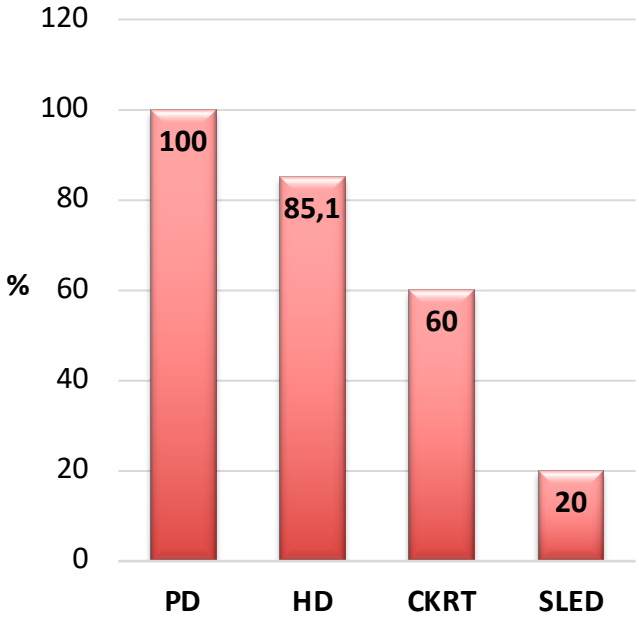
Availability of KRT in AKI

Developing Countries



Developed Countries



Peritoneal dialysis in AKI

Advantages

- Less pro-inflammatory and more physiological than EC treatments
- Safe in case of hemodynamic instability
- No need for vascular access
- No need for anticoagulation
- No need for PICU environment
- Glucose containing PD solutions are a source of glucose/calories
- Easy, no particular technical skill required
- Inexpensive

Peritoneal dialysis in AKI

Disadvantages

- Unpredictable UF
- Less effective in solutes removal than HD or CKRT
- Possible development of hyperglycemia
- Intact peritoneal cavity required
- Consider the possible worsening of respiratory failure
- High nursing workload

PD favourite modality

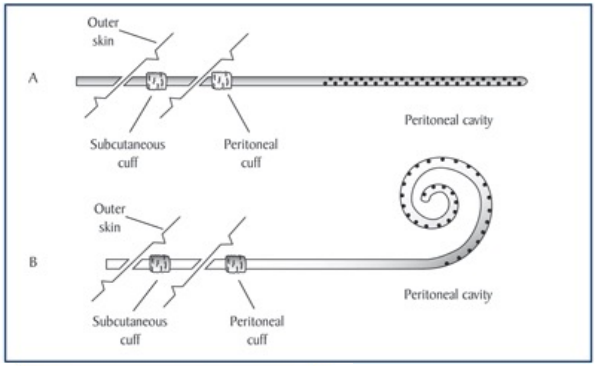
- In low birth-weight babies to avoid difficulties with the vascular access
- Post cardiac surgery in small babies
- Presence of bleeding diatheses which contraindicate the placement of large central venous catheters
- Cardiovascular instability in small babies where specialized paediatric CKRT equipment is not readily available to allow for low extracorporeal blood volumes

PD catheters

- Surgically placed catheters
  - Laparoscopic or open technique
- Catheters placed by Seldinger technique
  - With a guidewire and a peel-away sheath, under local anesthesia at the bedside
- Interventional radiological placement
  - Combining ultrasound and fluoroscopy
- Rigid stylet insertion PD catheters
  - Not advised to be used beyond 2-3 days

PD catheters

Tenckhoff catheter size 15 Fr approx. guide	Age
31–32 cm	<6 months
37–38 cm	6 months to 5 years
40–42 cm	Older than 5 years



Cook Multipurpose Drainage catheter

Catheter size	Age	Pigtail catheters less likely to obstruct
5 Fr	Premature infant	Obstructs easily as small drainage holes
6 Fr	Neonate	Obstructs easily as small drainage holes
8.5 Fr	1 month to 1 year	Most frequently used, even in neonates
10.2 Fr	6 months to 2 years	
12 Fr	1 year to 5 years	


MONTARE IL SET

PD Prescription

- Low fill volume 10-20 ml/kg (300-600 ml/m^2), gradually increased to 30-40 ml/kg (800-1100 ml/m^2)
- Dwell times 30-60 min (shorter in neonates and infants)
- Total cycle 60-90 min. Fill 5-10 min, dwell 30-60 min, drain 10-20 min
- Start with PD solution with dextrose concentration of 2.5%, increase it if more efficient ultrafiltration is required
- Add heparin to PD solution 500IU/l
- Check daily for electrolytes and add sodium and potassium to PD fluid if required
- Perform leukocyte count daily for peritonitis surveillance

Itermittent hemodialysis

Advantages

- Rapid rate of solute removal
- Rapid rate of ultrafiltration
- In selected cases may be performed without anticoagulation
- No need for PICU environment
- Allows down-times for diagnostic and therapeutic procedures

Itermittent hemodialysis

Disadvantages

- Hemodynamic stability required
- Need for a well-functioning vascular access
- Need for anticoagulation
- Fluid restriction required, limiting the amount of daily nutrition
- Need for experienced and trained nurses

Vascular access

Patient size	Catheter size	Site of insertion
Neonate	Double-lumen 7F	Femoral artery or vein
3–6 kg	Double- or triple-lumen 7F	Jugular, subclavian, or femoral
6–30 kg	Double-lumen 8F	Jugular, subclavian, or femoral
> 15 kg	Double-lumen 9F	Jugular, subclavian, or femoral
> 30 kg	Double-lumen 10F or triple-lumen 12F	Jugular, subclavian, or femoral

IHD prescription

- The dialyzer surface area should be between 75 and 100% of the patient's total body surface area
- Consider bloodline priming when the EC circuit volume exceeds 10% of the child's blood volume
- Blood flow 5-8 ml/Kg/min
- Dialysate flow 300-500 ml/min
- Length of the session tailored in order to obtain urea reduction rate of 30% for the first session (up to 70% in the following days)
- Weight loss should not exceed 5% of the patient's body weight
- Heparin initial bolus 20-30 UI/kg followed by continuous infusion of 10-20 UI/kg/h

CKRT in AKI

Advantages

- Safe in case of hemodynamic instability
- Allows the correction of electrolytes imbalance and acidosis
- Efficient in solute removal
- Allows for gradual fluid removal
- Treatment can be individualized to the specific clinical condition

CKRT in AKI

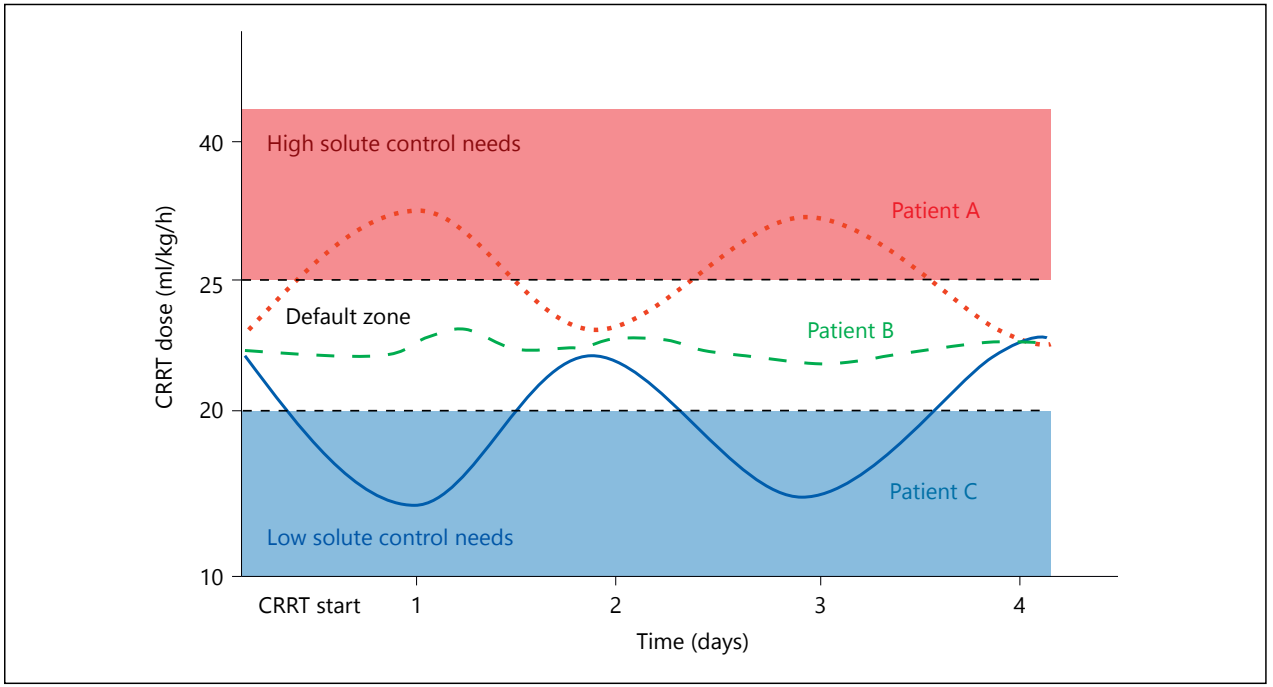
Disadvantages

- PICU environment required
- Need for well-functioning vascular access
- Need for anticoagulation
- Experienced and trained nurses are required
- Technically challenging in neonates and small infants
- Costs

CKRT Prescription

- Consider bloodline priming when the EC circuit volume exceeds 10% of the child's blood volume
- Blood flow 3-10 ml/Kg/min in neonates, 5 ml/kg/min in infants and 100-150 ml/min in older children and adolescents
- Dialysate and/or replacement flow to deliver the recommended dose of 2 l/h/1.73 m^2
- Add ultrafiltration when the patient is stable, 1-2 ml/kg/h
- Prefer citrate anticoagulation

Prescription dynamic and individualized

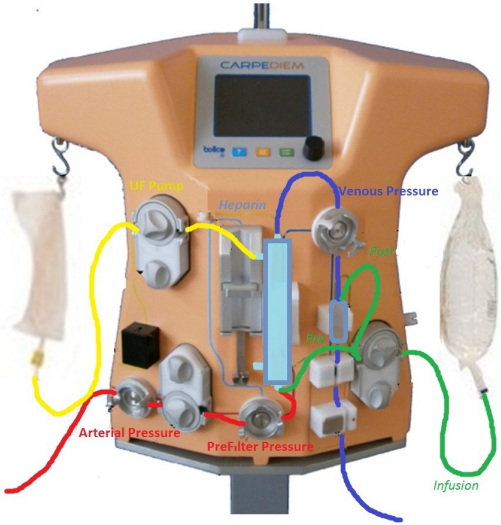


CKRT in infants

CKRT in neonates and infants

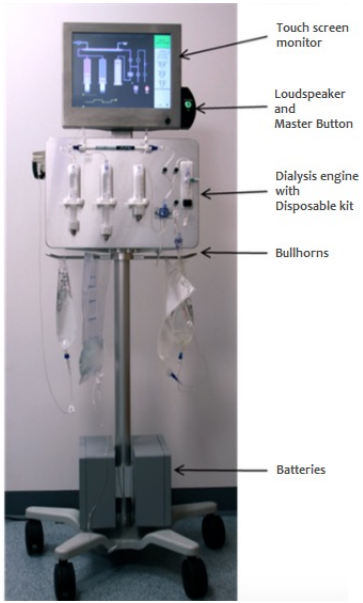
CARPEDIEM

CArdio Renal PEDIatric Emergency Machine



NIDUS

Newcastle Infant Dialysis and Ultrafiltration System



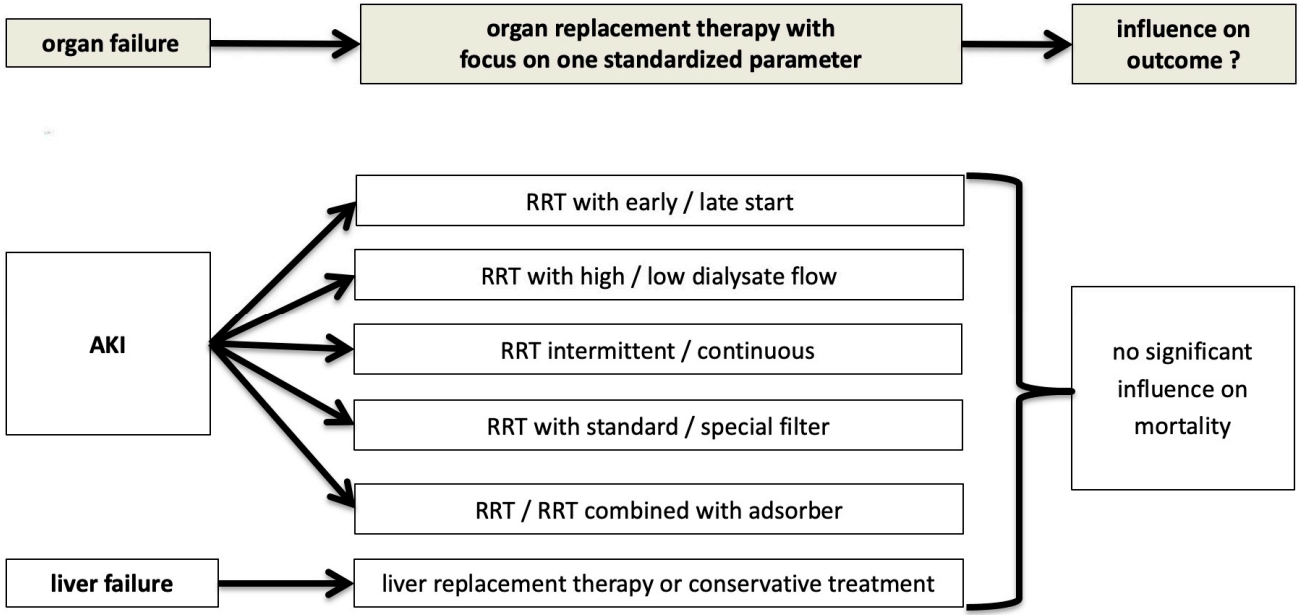
AQUADEX

Hemofilters

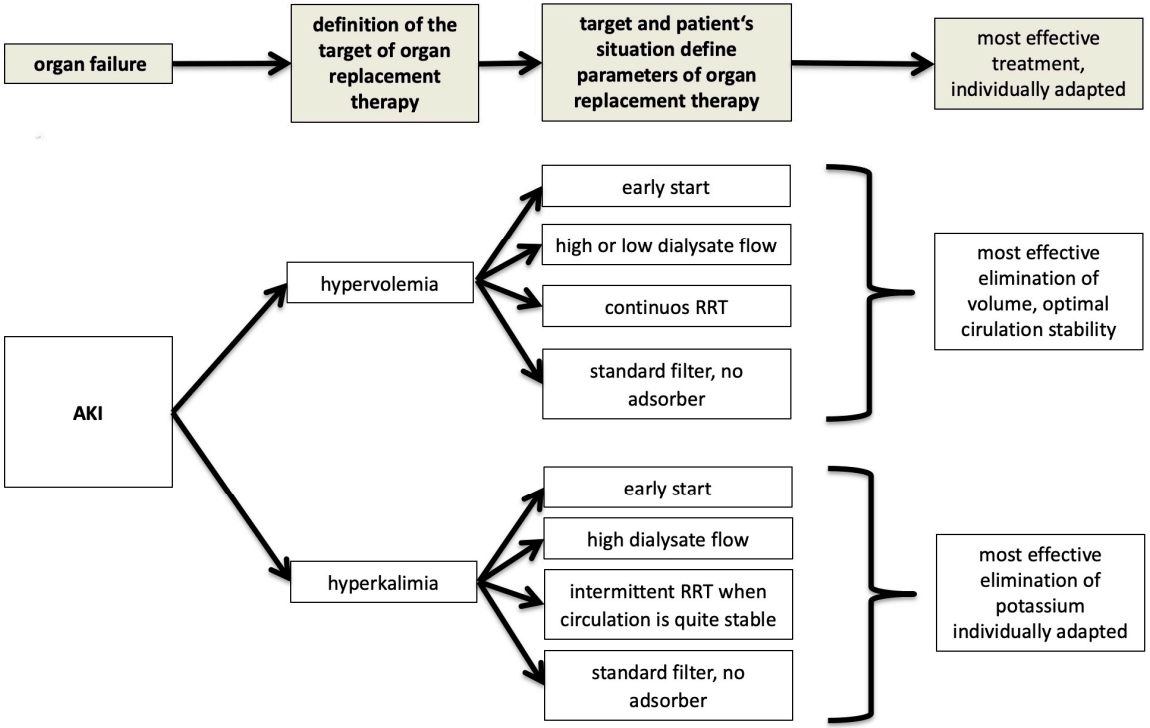
Hemofilter	Priming volume (ml)	Surface area (m^2)	Membrane	Manufacturer	System
Prismaflex HF20	60	0.2	Polyarylethersulfone	Baxter	Prismaflex
Prismaflex ST60 set	93	0.6	AN69 ST	Baxter	Prismaflex
Prismaflex ST100 set	152	1	AN69 ST	Baxter	Prismaflex
Ultraflux AVpaed	18 + luer-lock dialysate and filtrate ports + lines	0.2	Polysulfone	Fresenius	Multifiltrate
Ultraflux AV400S	52 + lines	0.75	Polysulfone	Fresenius	Multifiltrate
HCD 0075	27	0.075	Polysulfone	Medtronic	CARPEDIEM
HCD 015	33	0.15	Polyethersulfone	Medtronic	CARPEDIEM
HCD 025	41	0.25	Polyethersulfone	Medtronic	CARPEDIEM

Treatment option in AKI patients can only result in a benefit if the right patient is chosen for an appropriate indication and appropriate treatment

AKI and KRT: classic approach



AKI and KRT: individualized approach



Grazie!