Abbinamento emoadsorbimento + emodialisi (HA-HD): una nuova opportunità da esplorare? In quali pazienti?

Marita Marengo,
SC Nefrologia e Dialisi,
ASL CN1, Cuneo

Chronic kidney disease and cardiovascular risk: epidemiology, mechanisms, and prevention

Ron T Gansevoort, Ricardo Correa-Rotter, Brenda R Hemmelgarn, Tazeen H Jafar, Hiddo J Lambers Heerspink, Johannes F Mann, Kunihiro Matsushita, Chi Pang Wen

www.thelancet.com Vol 382 July 27, 2013

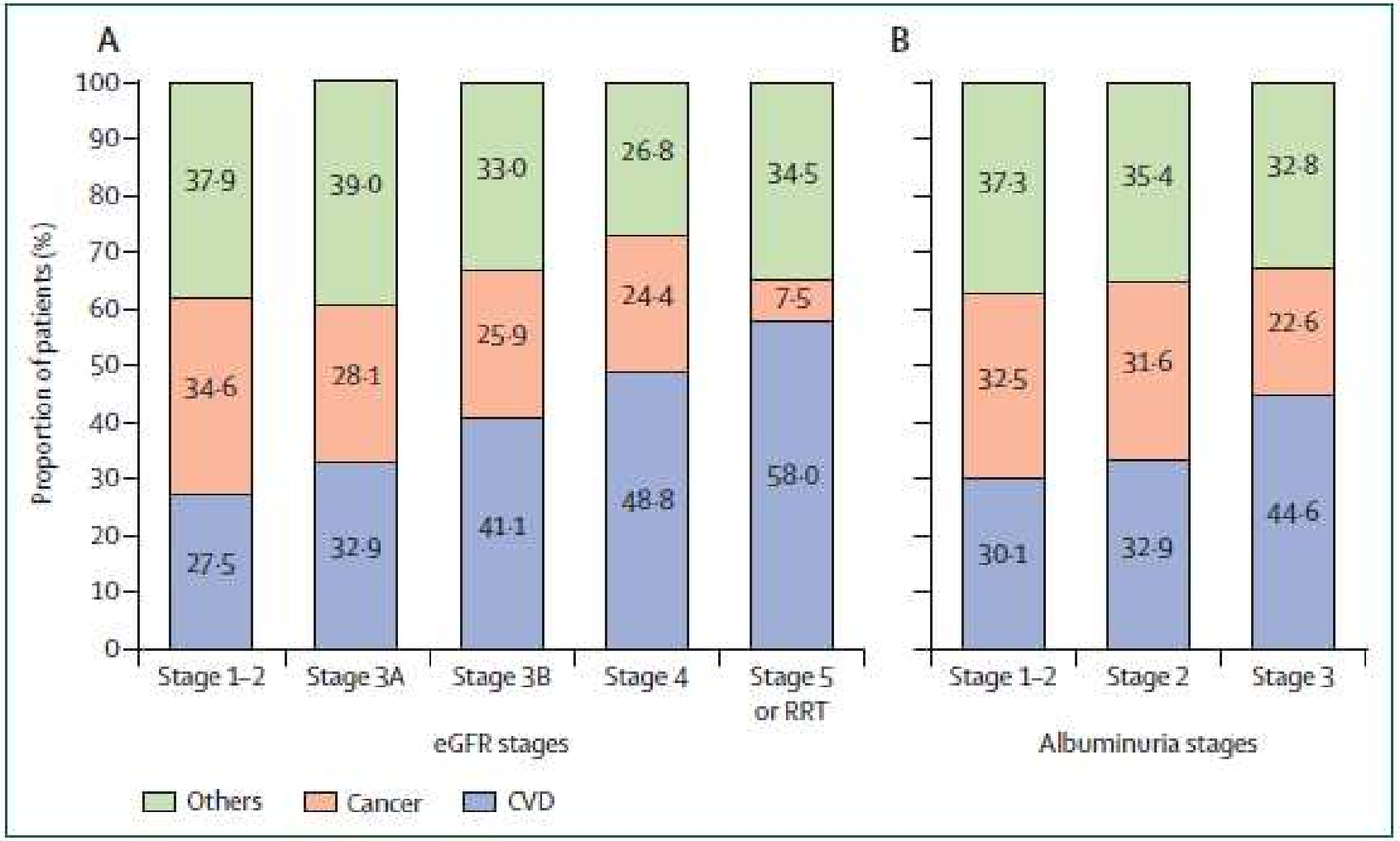
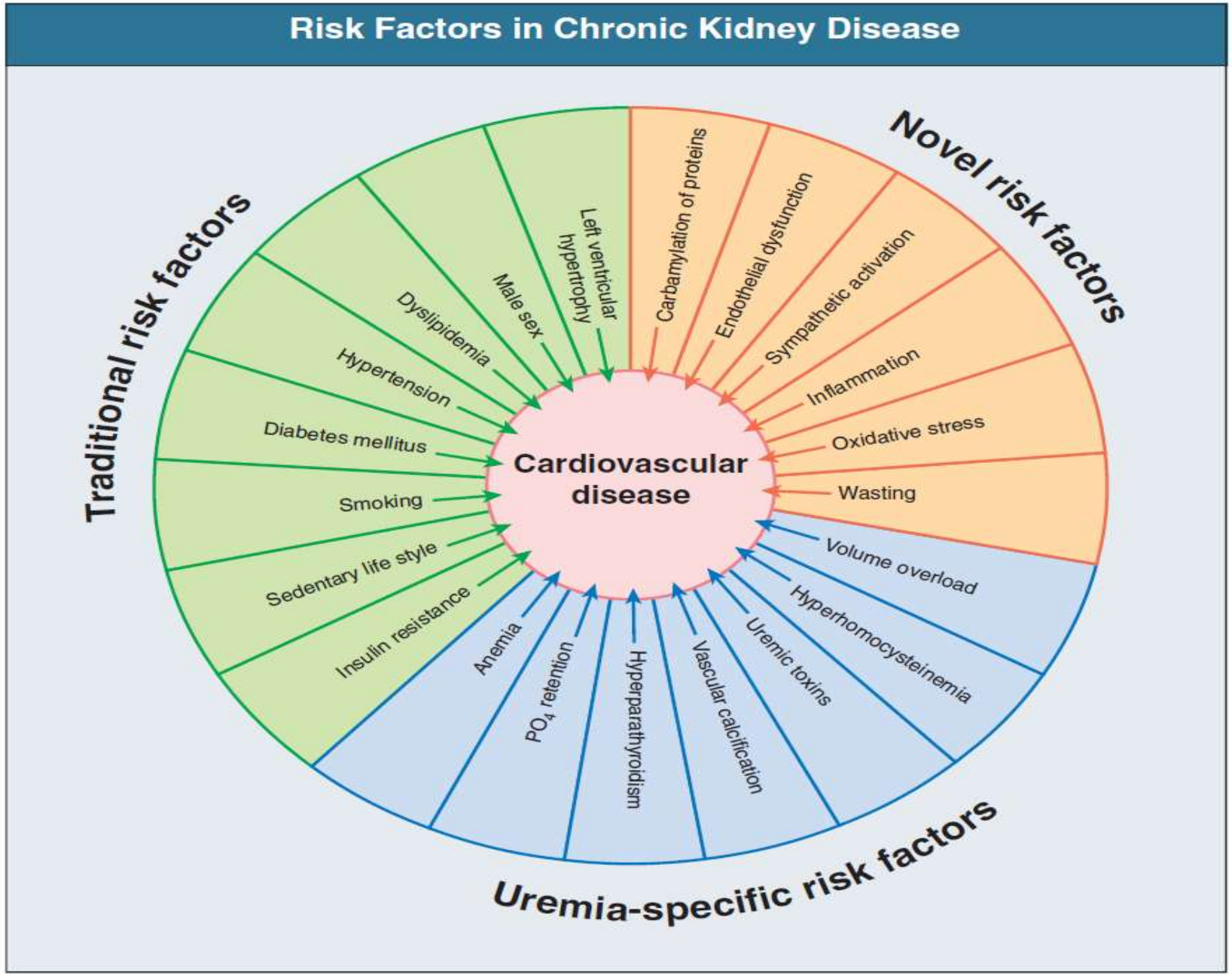
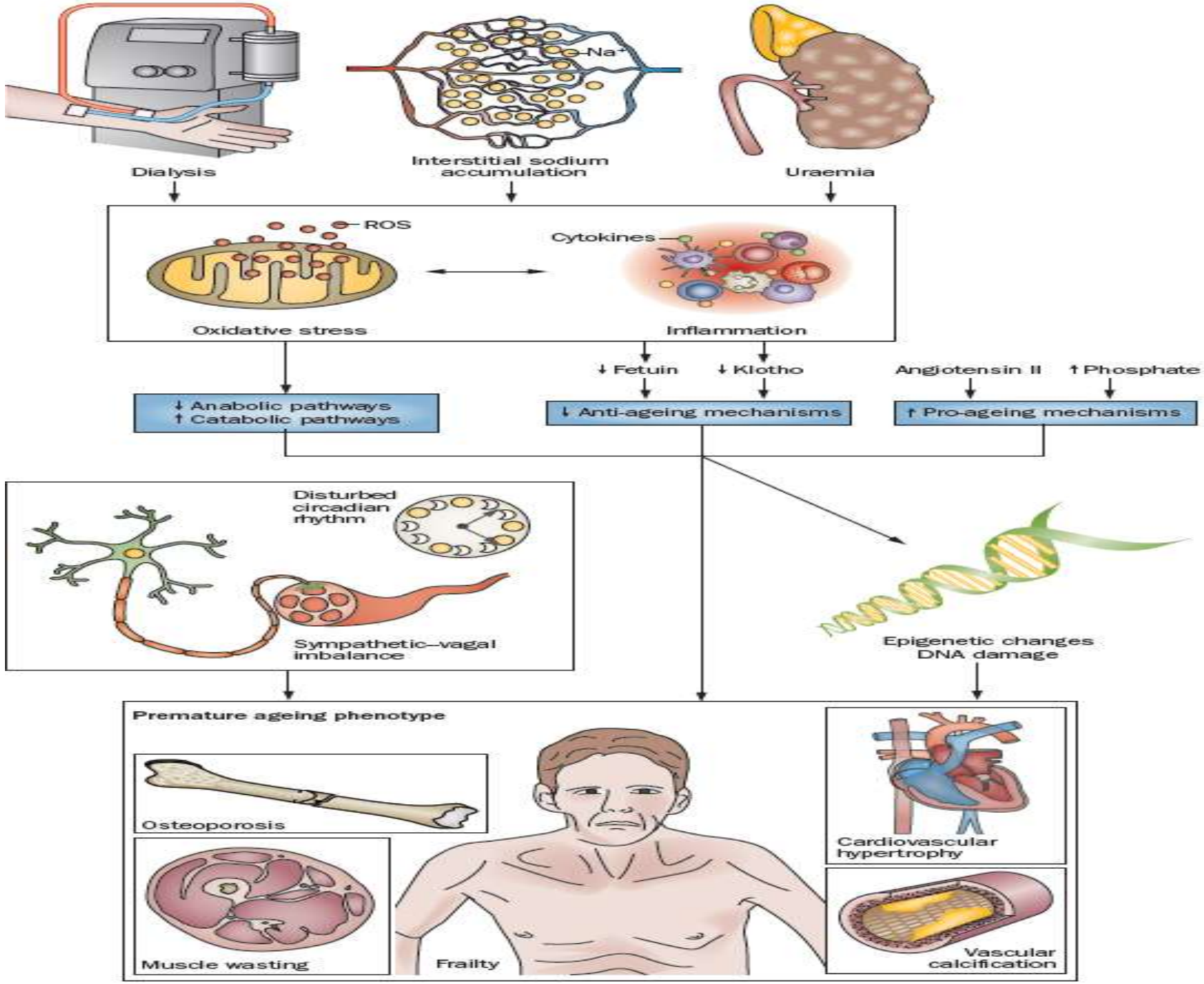


Figure 3: **Causes of death per chronic kidney disease stage (Canadian data)**



Cardiovascular Disease in Chronic Kidney Disease

Peter Stenvinkel, Charles A. Herzog



Box 1 | Aetiologies of uraemic ageing

Increased allostatic load
- Persistent inflammation
- Oxidative stress
- Increased carbonylation and glycation of proteins
- Sympathetic–vagal imbalance

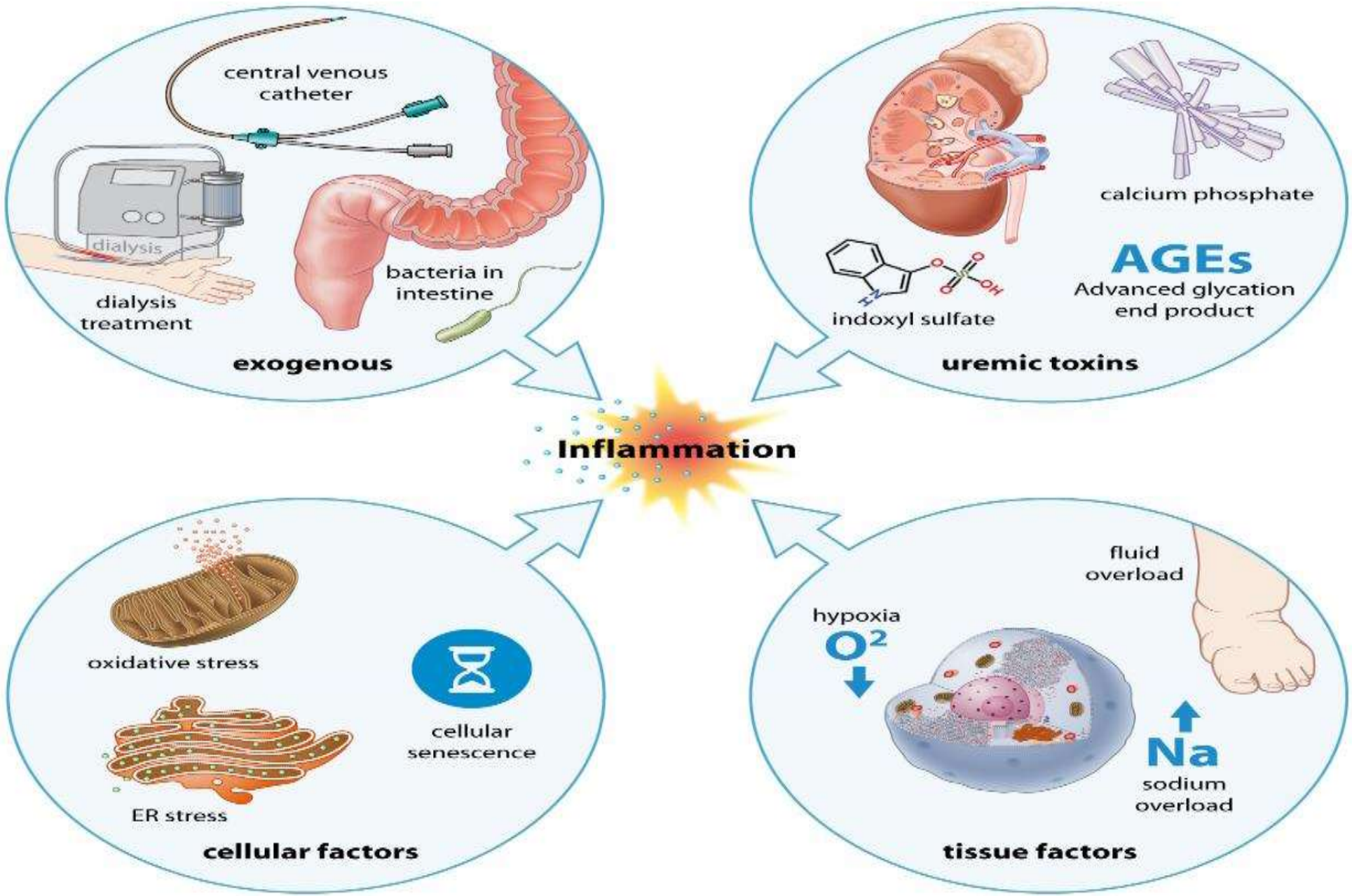
Pro-ageing factors
- Hyperphosphataemia
- Angiotensin II activation
- Sodium accumulation

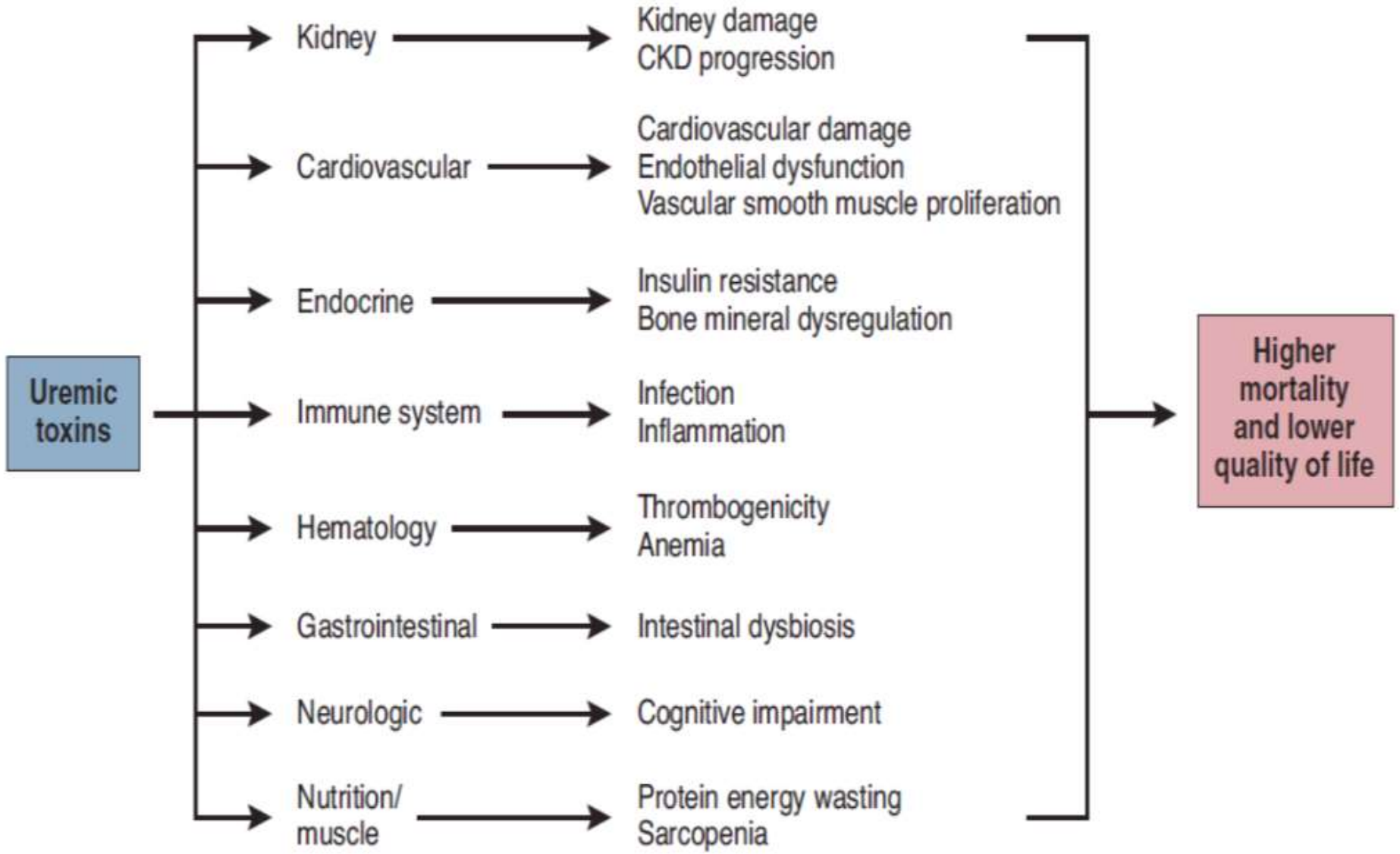
Defective anti-ageing mechanisms
- Klotho deficiency
- Vitamin D deficiency
- Hypogonadism
- Nuclear lamina defects

Use of drugs such as steroids

Chronic kidney disease and premature ageing

Jeroen P. Kooman, Peter Kotanko, Annemie M. W. J. Schols, Paul G. Shiels and Peter Stenvinkel


central venous catheter
dialysis
dialysis treatment
bacteria in intestine
exogenous
calcium phosphate
AGEs
Advanced glycation end product
indoxyl sulfate
uremic toxins
Inflammation
oxidative stress
cellular senescence
ER stress
cellular factors
fluid overload
hypoxia
O2
Na
sodium overload
tissue factors

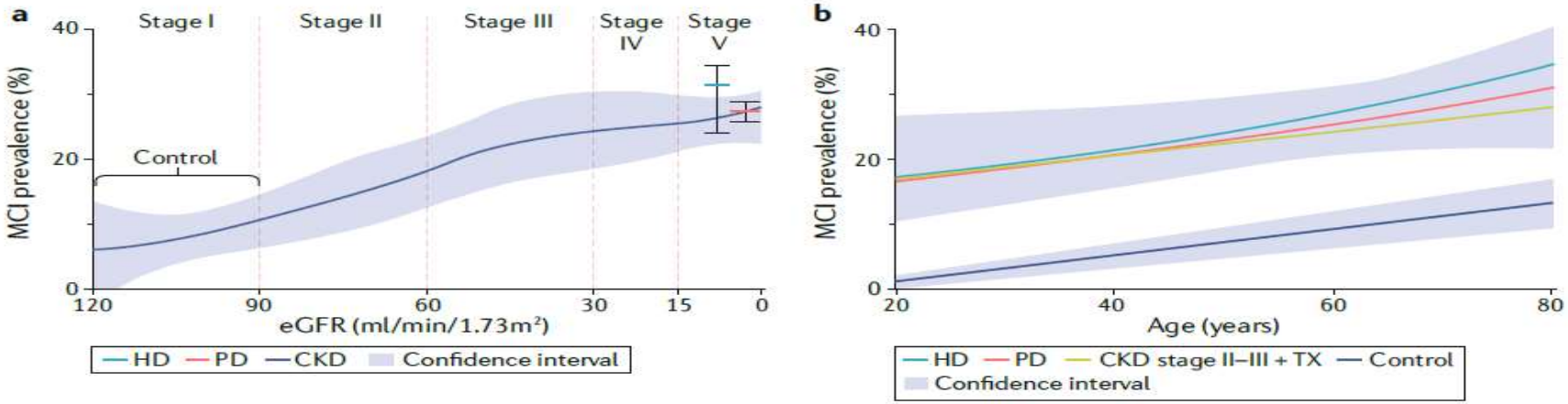


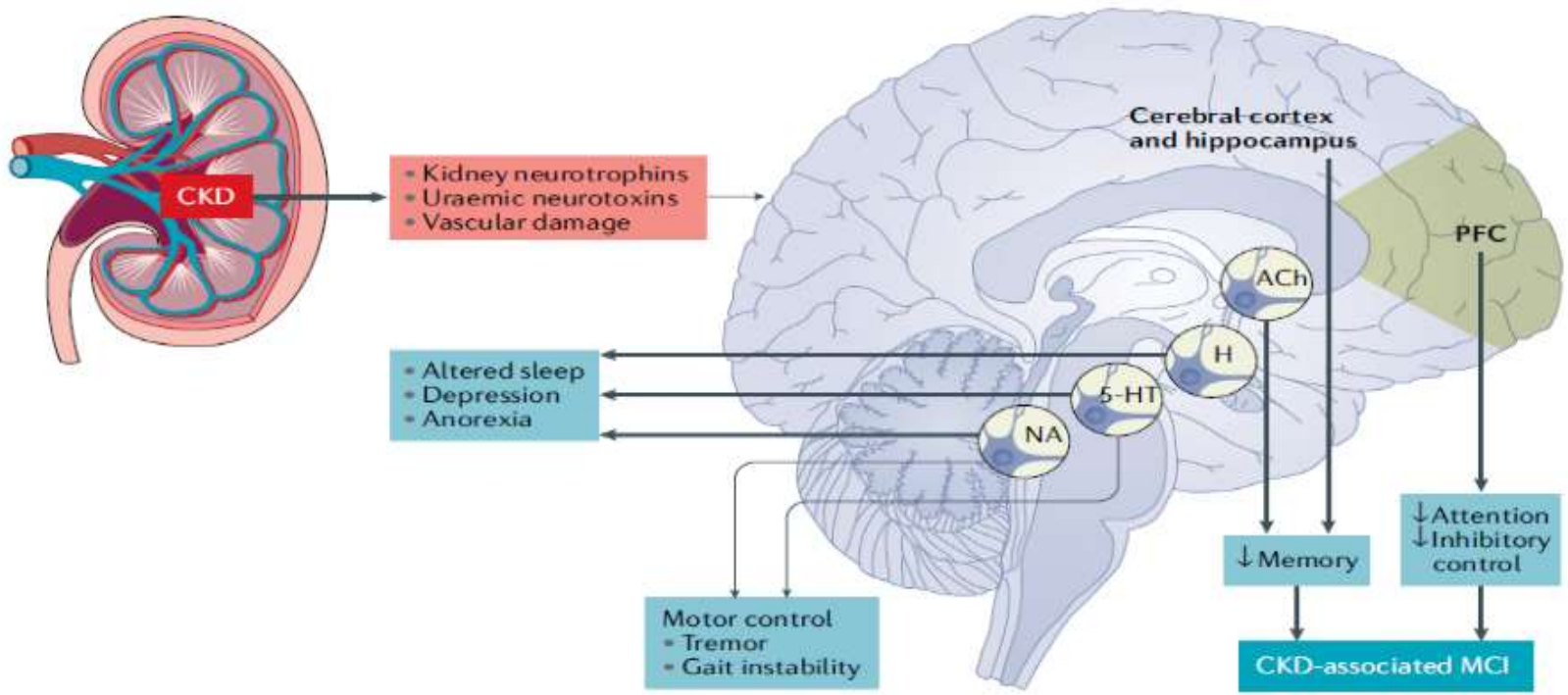
Classification of Uremic Toxins and Their Role in Kidney Failure

CJASN 16: 1918–1928, 2021.

Mechanisms of cognitive dysfunction in CKD

Davide Viggiano[1,2,9], Carsten A. Wagner[3,9], Gianvito Martino[4]*, Maiken Nedergaard[5], Carmine Zoccali[6], Robert Unwin[7,8,9] and Giovambattista Capasso[1,2,9]



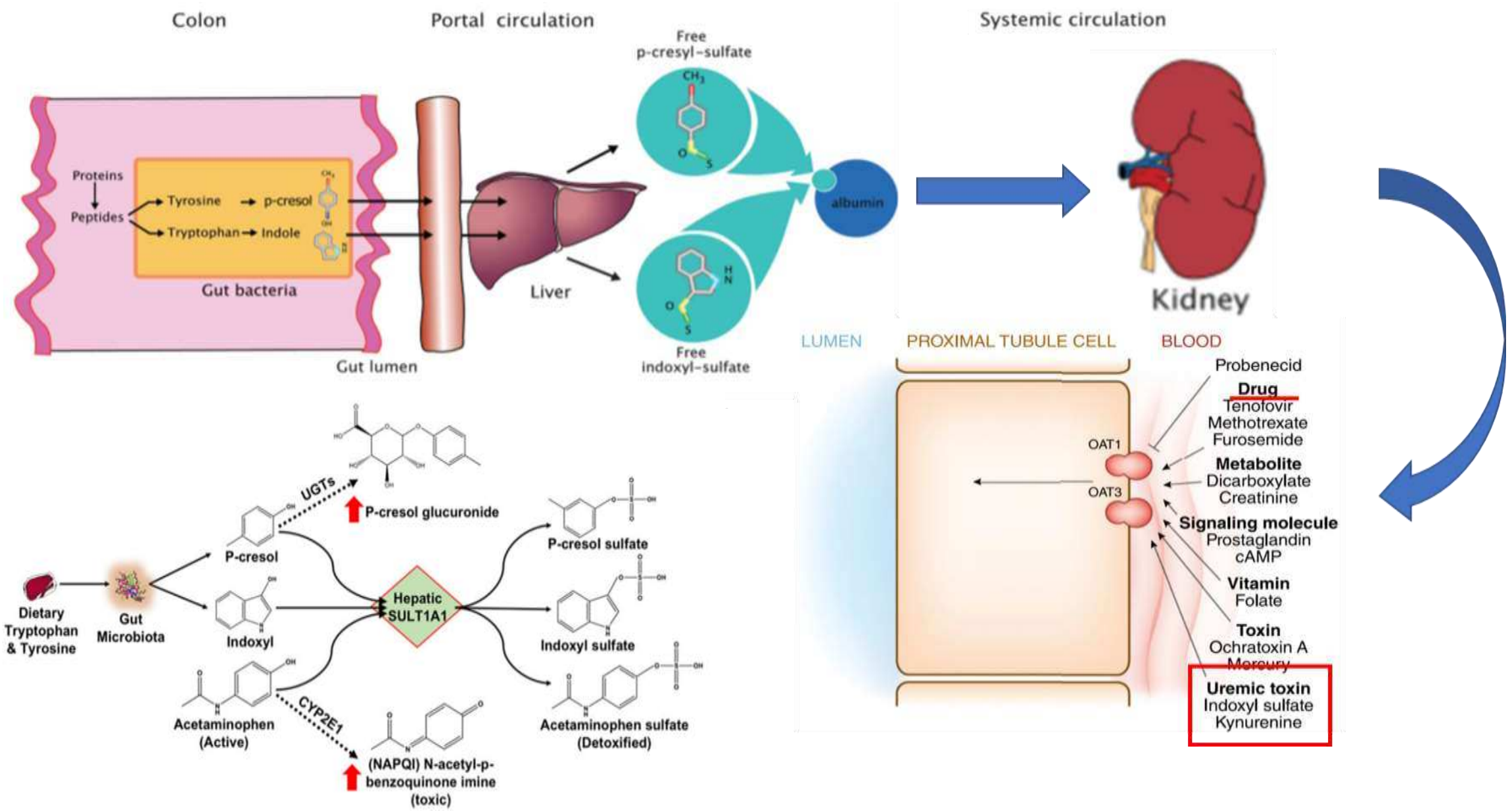


Review on uremic toxins: Classification, concentration, and interindividual variability

Kidney International, Vol. 63 (2003), pp. 1934–1943

RAYMOND VANHOLDER, RITA DE SMET, GRIET GLORIEUX, ANGEL ARGILÉS, ULRICH BAURMEISTER, PHILIPPE BRUNET, WILLIAM CLARK, GERALD COHEN, PETER PAUL DE DEYN, REINHOLD DEPPISCH, BEATRICE DESCAMPS-LATSCHA, THOMAS HENLE, ACHIM JÖRRES, HORST DIETER LEMKE, ZIAD A. MASSY, JUTTA PASSLICK-DEETJEN, MARIANO RODRIGUEZ, BERND STEGMAYR, PETER STENVINKEL, CIRO TETTA, CHRISTOPH WANNER, and WALTER ZIDEK, For the EUROPEAN UREMIC TOXIN WORK GROUP (EUTox)

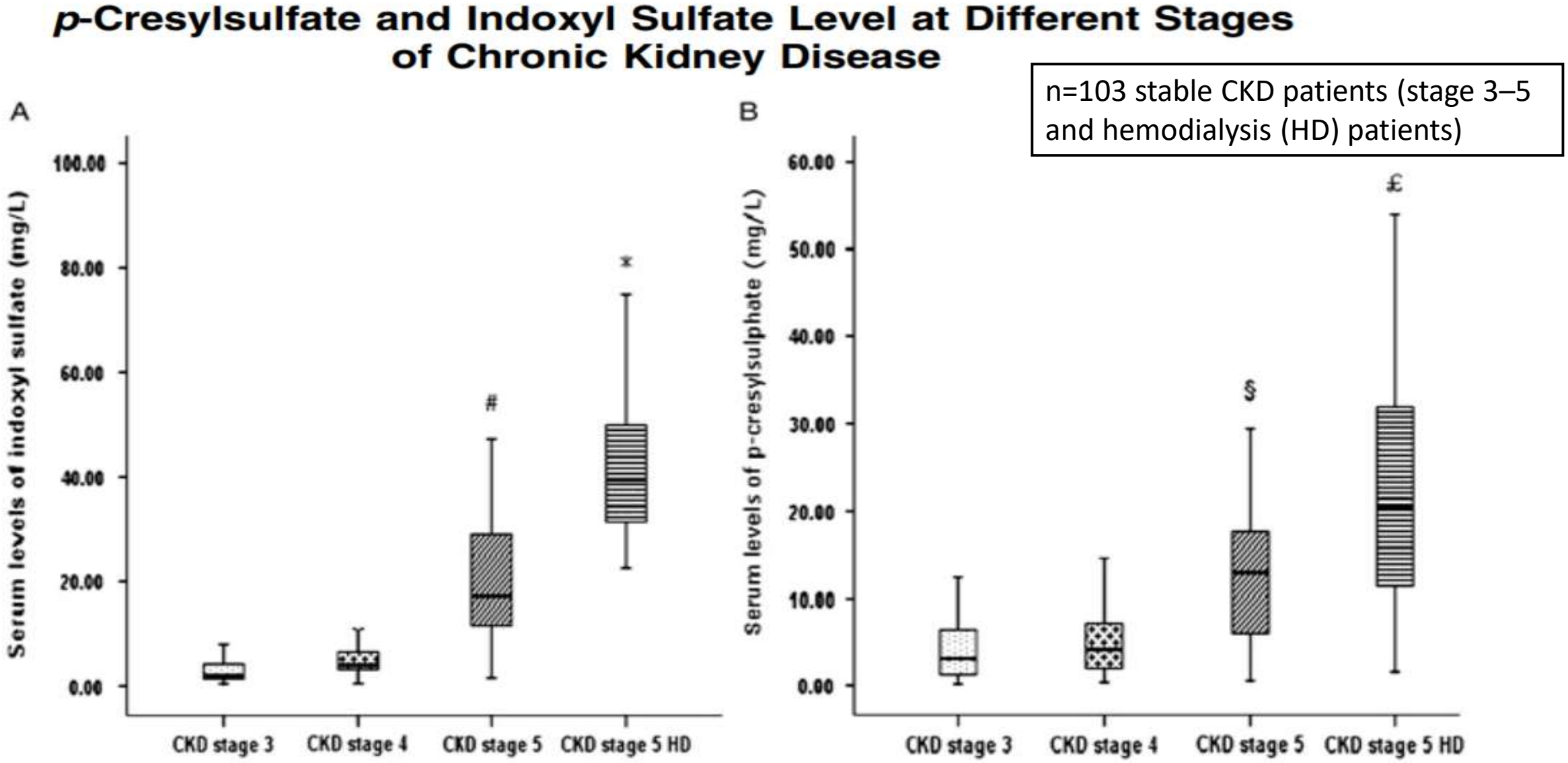
Small water-soluble solutes < 500 Da	*Protein-bound solutes* variabile	*Middle molecules* 500–15000 Da
asymmetric dimethylarginine	3-deoxyglucosone	β_2-microglobulin
benzylalcohol	CMPF	β-endorphin
creatinine	fructoselysine	clara cell protein
guanidine	glyoxal	complement factor D
guanidinoacetic acid	hippuric acid	cystatin C
guanidinosuccinic acid	homocysteine	degranulation inhibiting protein I
hypoxanthine	indole-3-acetic acid	endothelin
methylguanidine	indoxyl sulfate	hyaluronic acid
myoinositol	methylglyoxal	interleukin 1β
orotic acid	N-carboxymethyllysine	interleukin 6
orotidine	p-cresol	κ-Ig light chain
oxalate	pentosidine	λ-Ig light chain
pseudouridine	phenol	leptin
symmetric dimethylarginine	p-OH-hippuric acid	methionine-enkephalin
urea	quinolinic acid	parathyroid hormone
uric acid	spermidine	retinol binding protein
xanthine	spermine	tumor necrosis factor α



Microbiota-Derived Uremic Retention Solutes: Perpetrators of Altered Nonrenal Drug Clearance in Kidney Disease

Expert Rev Clin Pharmacol. 2018 January ; 11(1): 71–82.

PBUTs levels and CKD

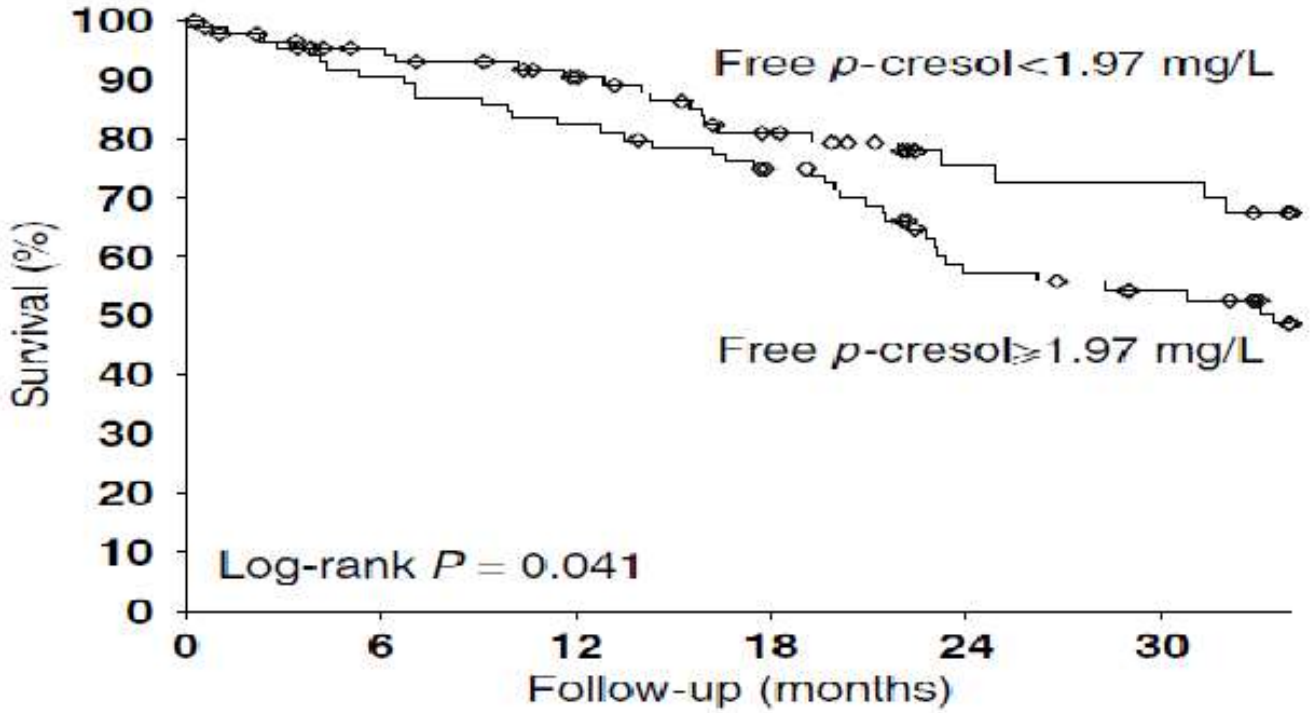


n=103 stable CKD patients (stage 3–5 and hemodialysis (HD) patients)

Lin et al. J. Clin. Lab. Anal. 25:191-197 (2011)

PBUTs: why so dangerous?

…because they are associated mortality…



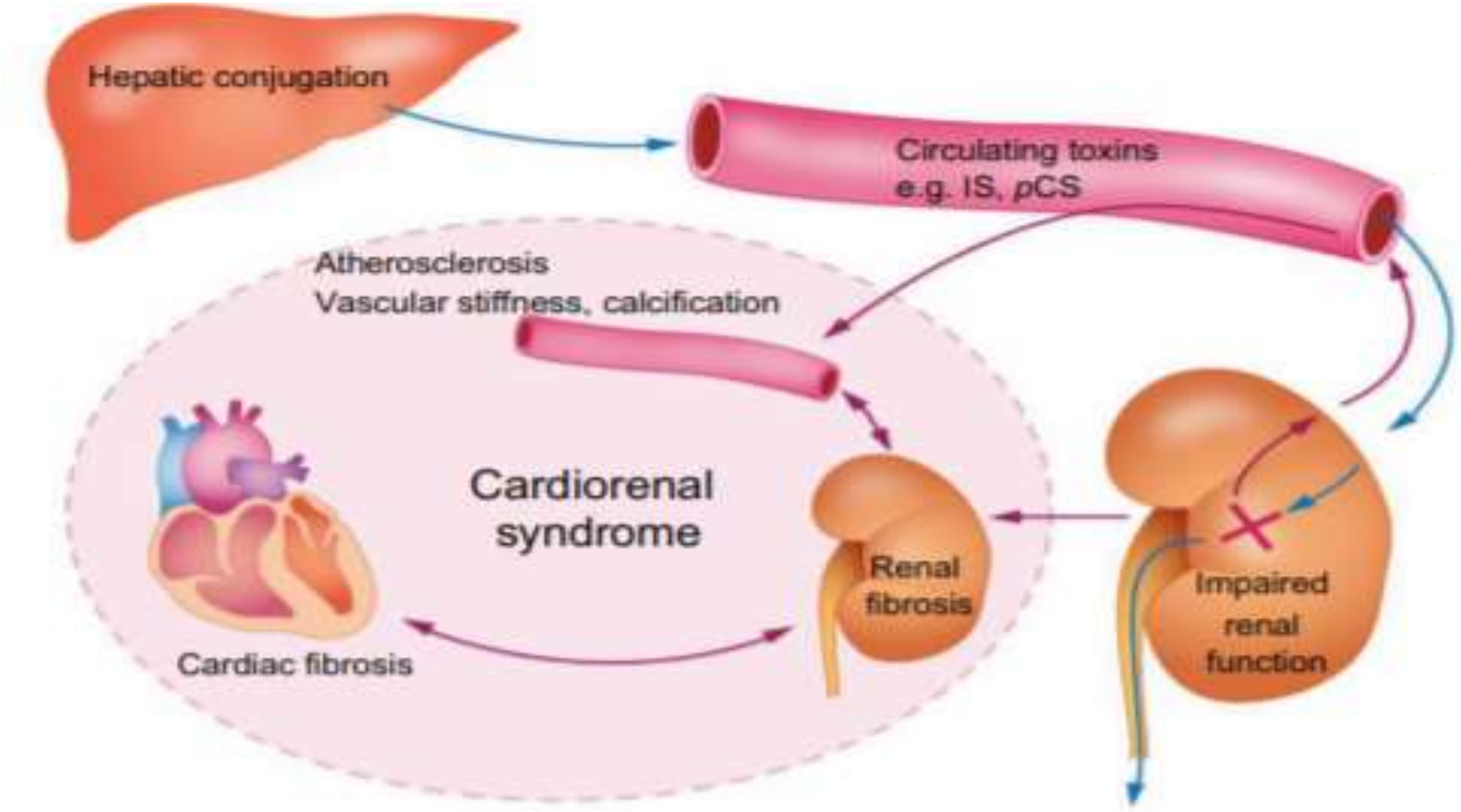
In conclusion, our data suggest for the first time that free serum levels of the protein-bound uremic retention solute *p*-cresol are associated with mortality in patients treated with HD.

n=175 patients with stage 5D chronic kidney
Follow-up: 36 months
Two Belgian HD center

Bammens B. et al Kidney International 2006

PBUTs: why so dangerous?

…because they are the "missing link" with cardiorenal syndrome…



Lekawanvijit S. et al. Am J Physiol Renal Physiol 311: F52–F62, 2016

PBUTs: why so dangerous?

… because they are associated mortality…..

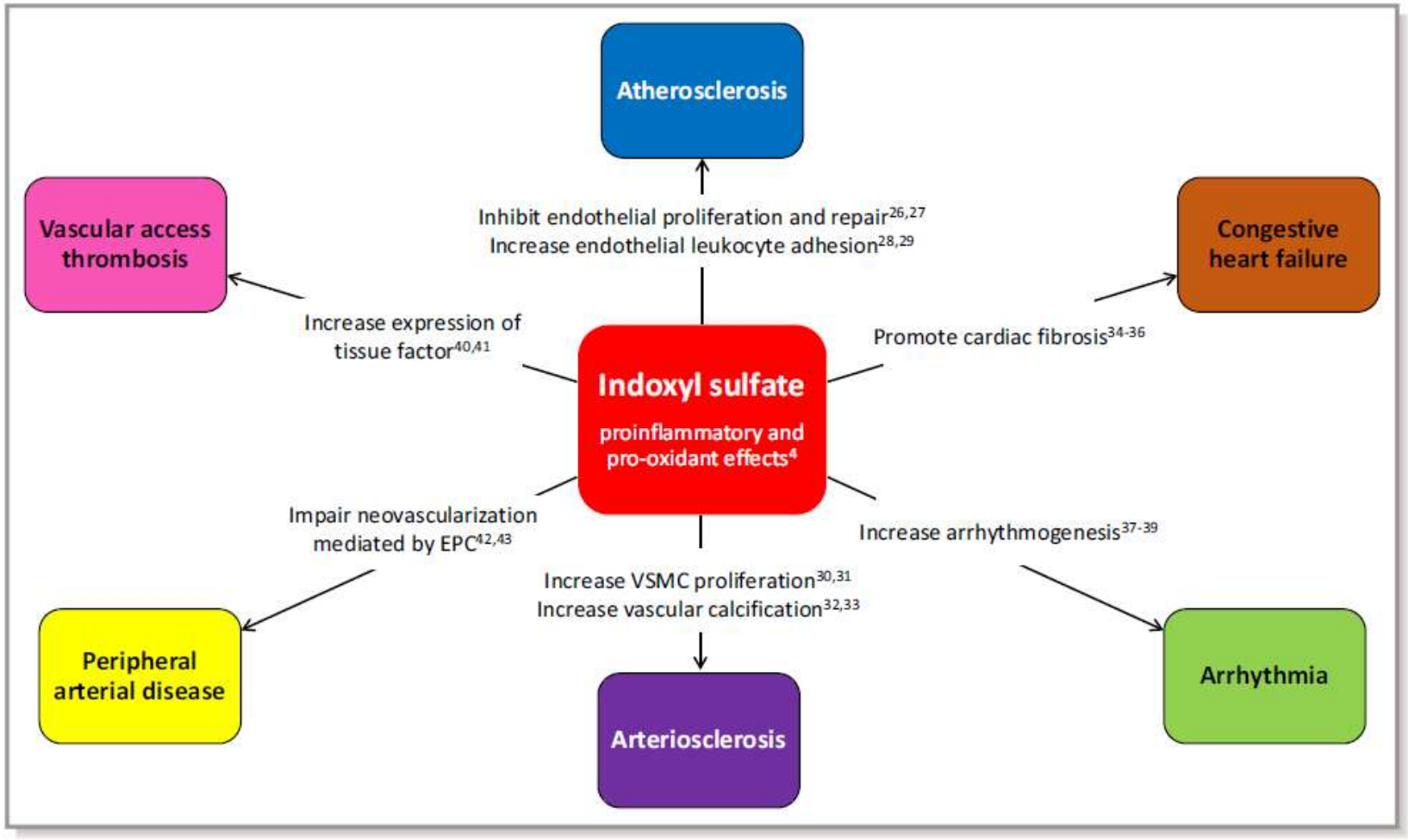


Figure 1. Role of indoxyl sulfate in the pathogenesis of various forms of cardiovascular disease in chronic kidney disease. EPC indicates endothelial progenitor cell; VSMC, vascular smooth muscle cell.

PBUTs: why so dangerous?

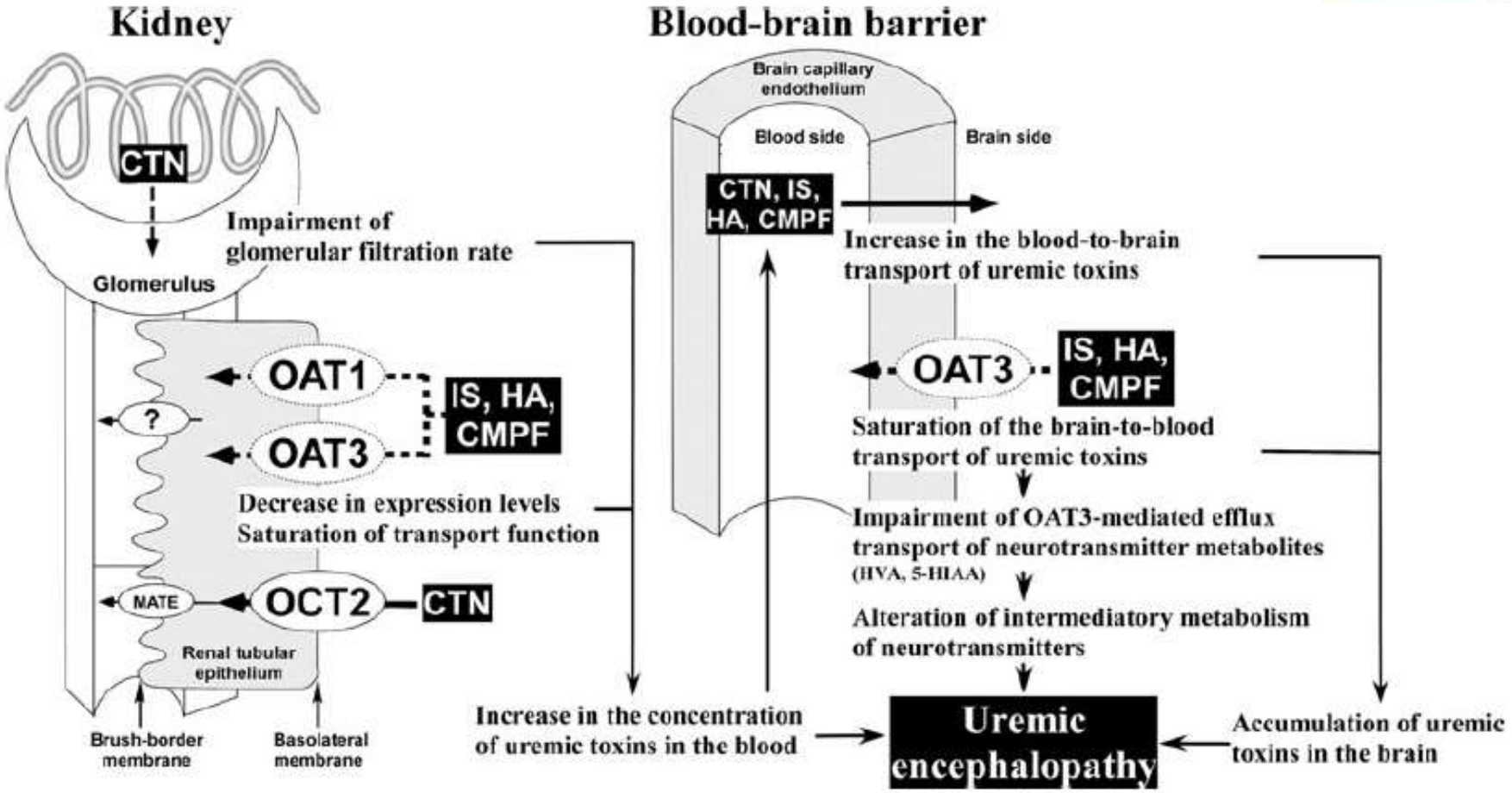


Fig. 5 Putative mechanisms of uremic encephalopathy with regard to dysfunction of organic anion transporters (OATs) caused by uremic toxins.

Roles of organic anion/cation transporters at the blood–brain and blood–cerebrospinal fluid barriers involving uremic toxins

Ken-ichi Hosoya · Masanori Tachikawa

Clin Exp Nephrol (2011) 15:478–485

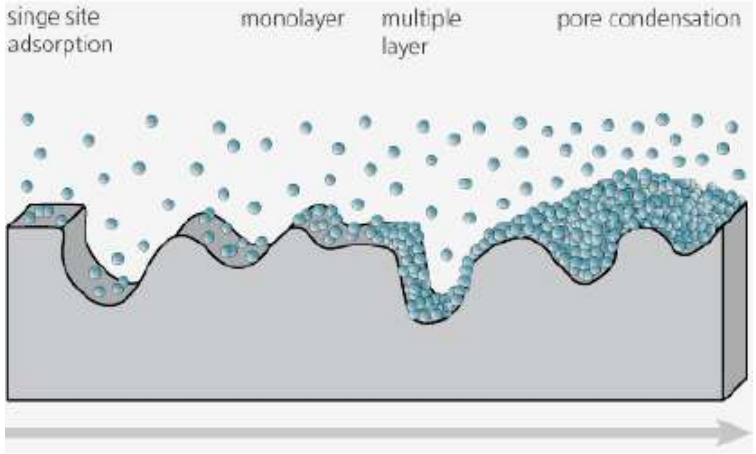
PBUTs: why so dangerous?

…because they are poorly filtrated by dialysis membranes …


Classification of Uremic Toxins and Their Role in Kidney Failure
CJASN 16: 1918–1928, 2021.

L’adsorbimento è un fenomeno di superficie

Processo chimico per cui un elemento (soluto) aderisce ad un altro elemento (adsorbente) con una struttura molecolare adeguata ad essere complementare al soluto.



La specificità dell’adsorbimento è il risultato di diversi gradi di affinità tra le molecole ed il materiale sorbente.

L’adsorbimento è un fenomeno di superficie

Blood–Membrane Interactions During Dialysis

Zhongping Huang,* Dayong Gao,† Jeffrey J. Letteri,† and William R. Clark†§
*Department of Mechanical Engineering, Widener University, Chester, Pennsylvania, †Department of Biomedical Engineering, University of Washington, Seattle, Washington, †Gambro Renal Products, Lakewood, Colorado, and §Nephrology Division, Indiana University School of Medicine, Indianapolis, Indiana

Seminars in Dialysis—Vol 22, No 6 (November–December) 2009 pp. 623–628

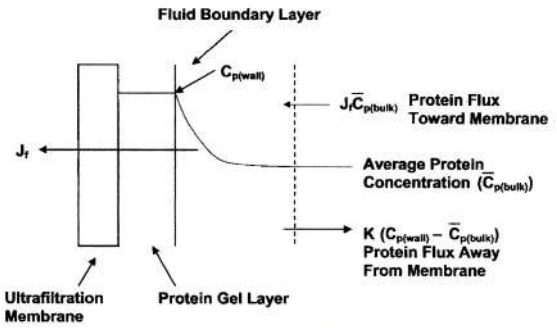
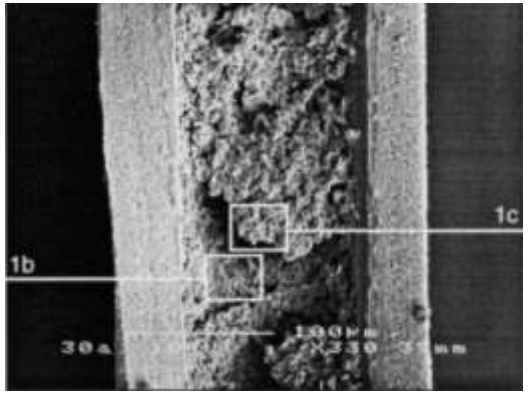
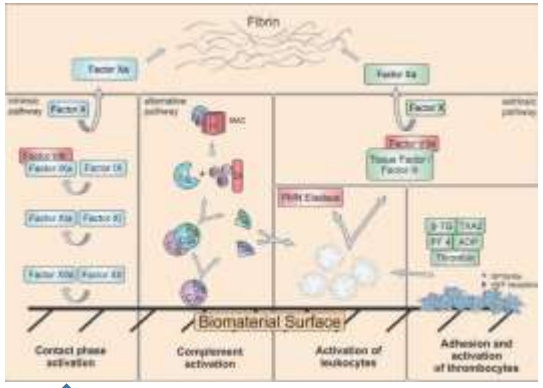


FIG. 3. Depiction of the phenomena of secondary membrane formation and concentration polarization during hemofiltration. In the figure, J represents fluid flux while C represents protein concentration. Reprinted with permission from Clark et al. (47).

Protein layer

Exposure of blood to artificial membrane surfaces almost immediatly leads to the adsorption of plasma proteins.
The initial adsorption influences all subsequent events and determines the thrombogenicity and biocompatibility of the material.





membrane permeability

thrombogenicity

Time-dependent loss of efficiency

L’adsorbimento è un fenomeno di superficie

…..si dice che una membrana è adsorbente quando le sue proprietà di adsorbimento possono essere considerate come un reale metodo di depurazione…

There are two steps of plasma protein membrane adsorption:

1) the first occurs **on the membrane surface** as a result of preferential competitive adsorption of **high molecular weight proteins**, such as albumin, fibrinogen/fibrin, immunoglobulins. **This process has no relevant effect on their plasma concentrations.**

2) the second adsorption is **in the body of the membrane** of proteins with **low- and medium-molecular weights** (such as β2microglobulin). This is slower, depends on membrane structure and thickness, and **can be quantitatively important, contributing to relevant decreases in plasma concentrations.**

L’adsorbimento in emodialisi

MEMBRANE

HFR

DEVICES

Blood Purification

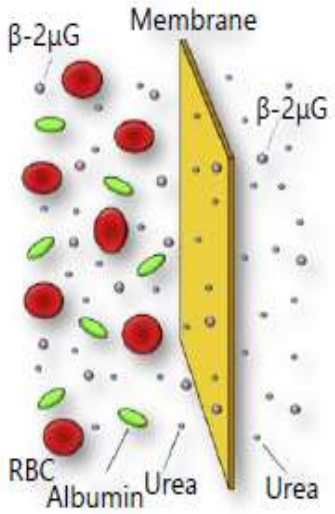
Focus: ESKD – Editorial

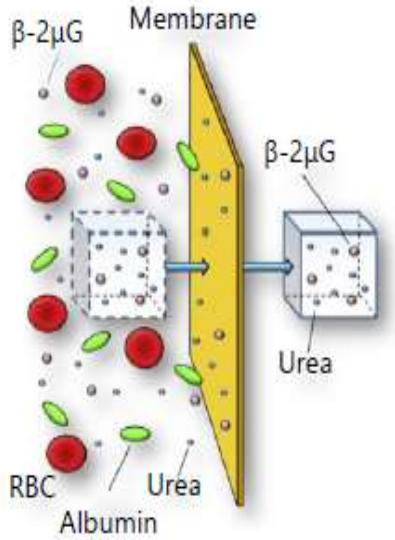
Blood Purif 2022;51:799–802
DOI: 10.1159/000525953

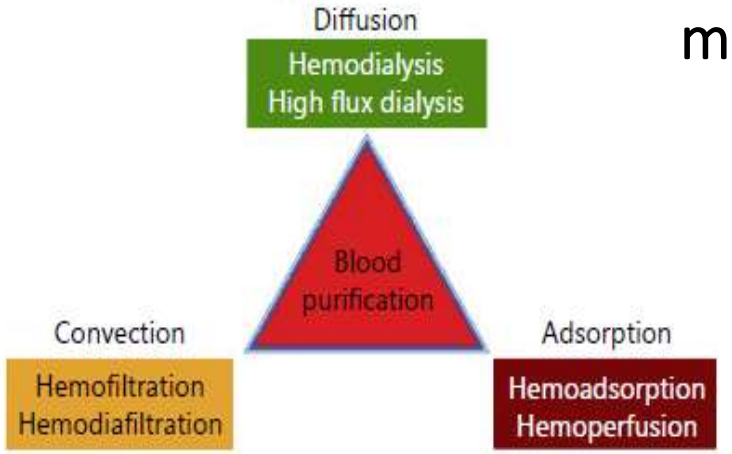
The Promise of Adsorption for Chronic Dialysis Patients

Claudio Ronco[a, b]

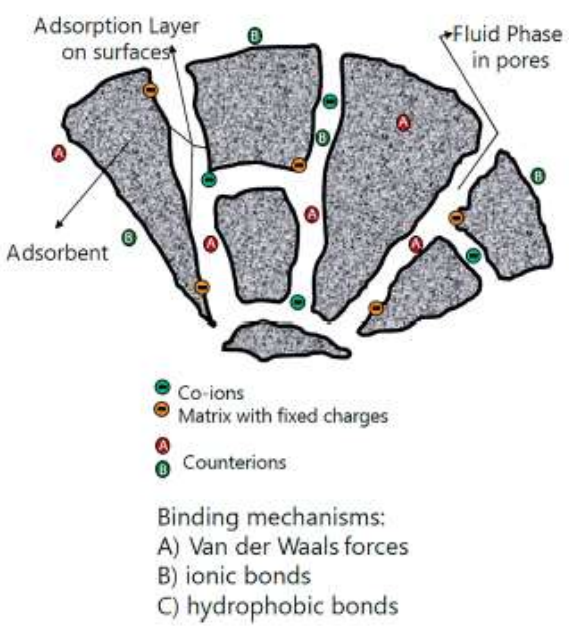
[a]Director of International Renal Research Institute of Vicenza and IRRIV Foundation at San Bortolo Hospital, Vicenza, Italy; [b]Department of Medicine, University of Padova, Padova, Italy

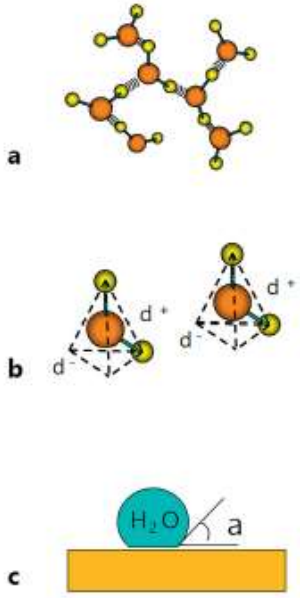






Adsorption is a mass separation process by a solid agent, it differs significantly from the classic mechanisms of convection and diffusion based on separation by a barrier (dialysis membrane). **This modality of solute removal goes beyond membrane characteristics and permeability**.





L’adsorbimento è un fenomeno di superficie

	Example	Sorption principle	Substances bound
Activated charcoal		Van der Waals	Creatinine
		Hydrophobic	Beta2 microglobulin
		Interactions	PBUT
Non-ionic organic polymer	Resins	Van der Waals	PBUT
		Hydrophobic	Cytokines
Organic ion exchanger	Resins	Ionic bonds	Ions
Crystalline ion exchanger	Zirconium	Ionic bonds	Ions
	FeOOH		
Specific binders	Ninhydrin	Covalent bonds	Urea

Pores are divided based on their inlet size:

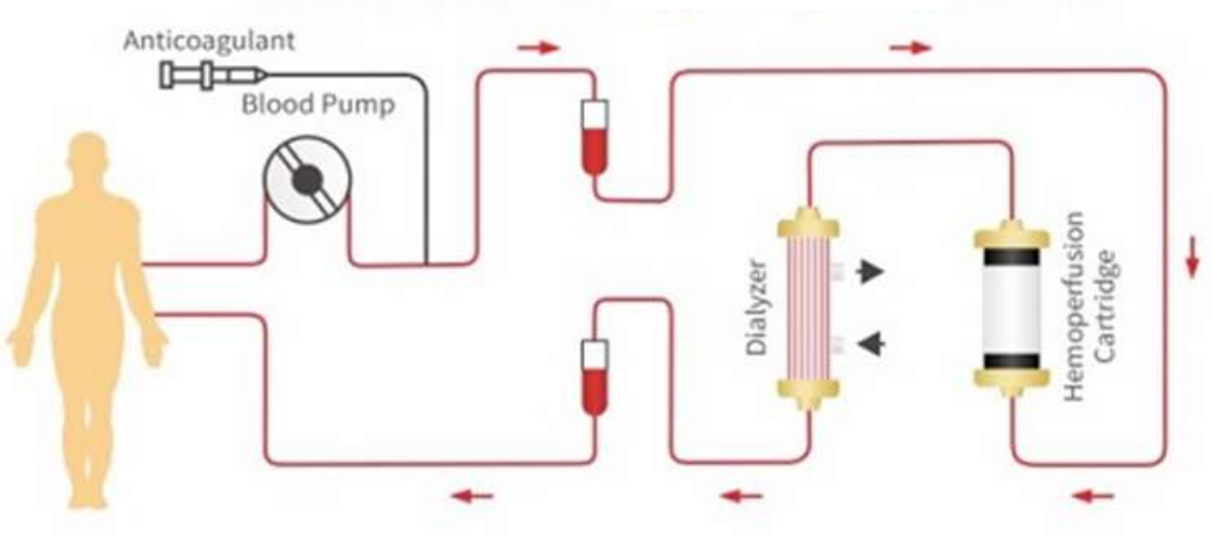
- micropores (< 2 nm)
- mesopores (2-50 nm)
- macropores (> 50 nm)

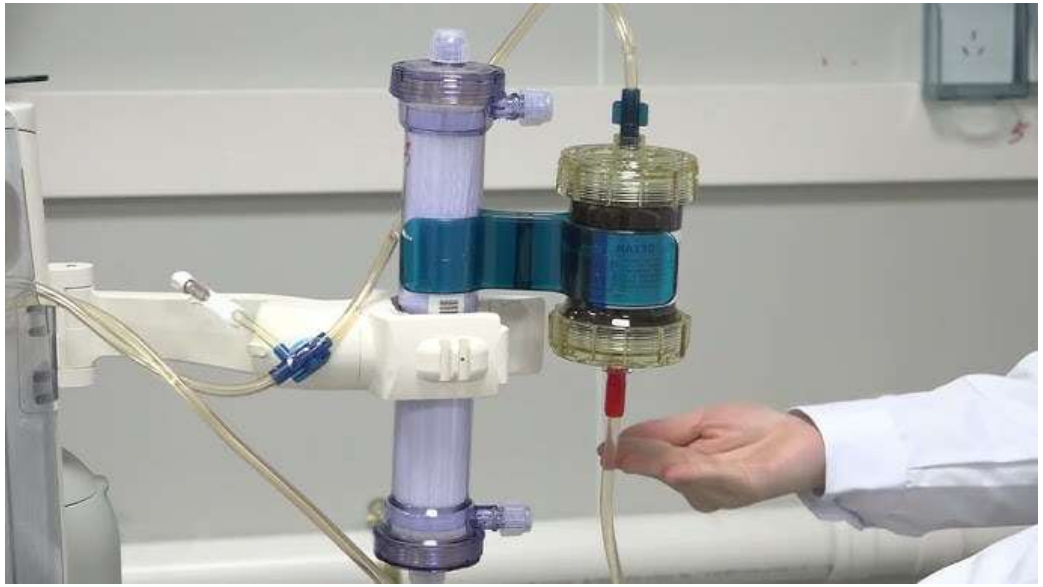
For removal of uremic toxins without albumin removal, mesopores appear the most relevant

Adsorption is limited by saturation of the sorbents.

The Revival of Sorbents in Chronic Dialysis Treatment
[author block]
Seminars in Dialysis, 2024; 0:1–8
https://doi.org/10.1111/sdi.13203

Emoadsorbimento + Emodialisi (HA-HD)





The *"new"* concept of sorbent in hemodialysis….

LA STAMPA

DOPO 110 PAESI, A 110 ANNI DALL'UNITÀ

Divorzio anche in Italia

La Camera ha approvato la legge con 319 sì e 286 no - Per il decretone-bis 359 favorevoli e 246 contrari
Per respingere gli emendamenti della dc e del msi, lo scarto dei voti a favore dei divorzisti è stato più alto del previsto - Quattro deputati colti da malore - Il decretone-bis passa all'esame del Senato

La frontiera
tra legge e dogma

Ore 5,40: legge di Stato

1970

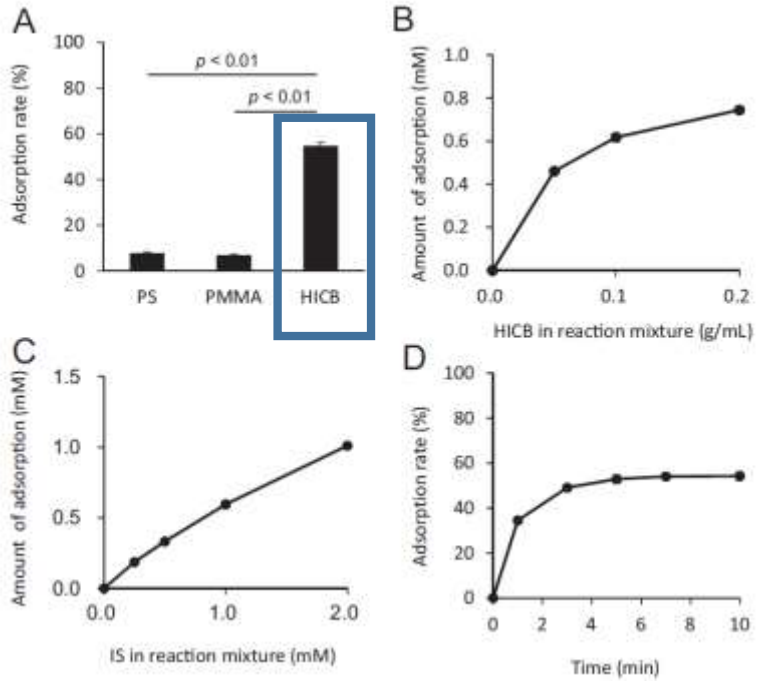
The *"new"* concept of sorbent in hemodialysis….

Adsorption of Protein-Bound Uremic Toxins Through Direct Hemoperfusion With Hexadecyl-Immobilized Cellulose Beads in Patients Undergoing Hemodialysis

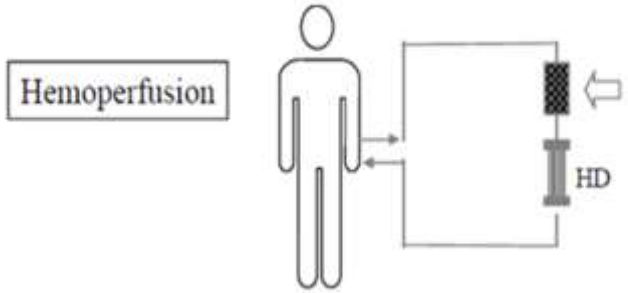
Artificial Organs 2018, 42(1):88–93

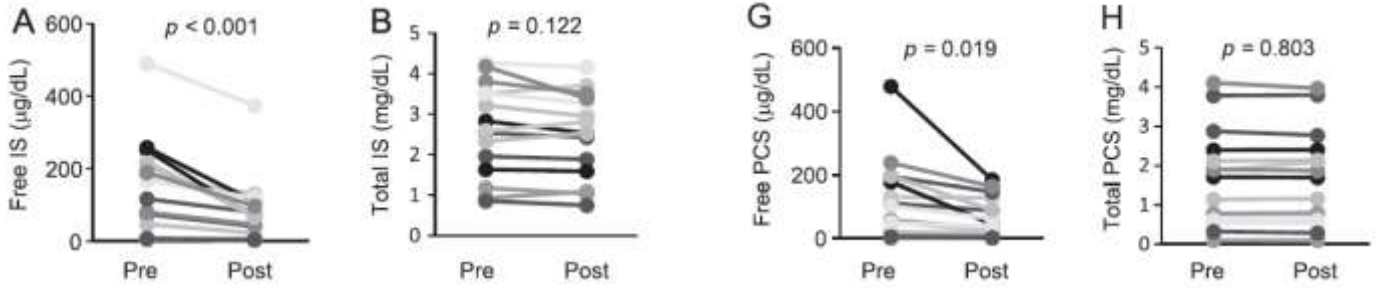
*†Suguru Yamamoto, *Mami Sato, *Yoko Sato, *Takuya Wakamatsu, *Yoshimitsu Takahashi, ‡Akira Iguchi, §Kentaro Omori, ‡Yasushi Suzuki, ¶Isei Ei, *Yoshikatsu Kaneko, *Shin Goto, ||Junichiro J. Kazama, *#Fumitake Gejyo, and *Ichiei Narita

Adsorption of IS in vitro



Adsorption of PBUTs in vivo





In clinical studies, passing the adsorber column decreased the serum level of free IS and PCS significantly, but not protein-bound IS and PCS.

The *"new"* concept of sorbent in hemodialysis….

Article

Efficacy of Divinylbenzenic Resin in Removing Indoxyl Sulfate and P-cresol Sulfate in Hemodialysis Patients: Results from an In Vitro Study and an In Vivo Pilot Trial (xuanro4-Nature 3.2)

Maria Teresa Rocchetti [1,†,*], Carmela Cosola [1,†], Ighli di Bari [1], Stefania Magnani [2], Vanessa Galleggiante [2], Letizia Scandiffio [2], Giuseppe Dalfino [1], Giuseppe Stefano Netti [3], Mauro Atti [2], Roberto Corciulo [1] and Loreto Gesualdo [1,*]

Toxins 2020, *12*, 170; doi:10.3390/toxins12030170

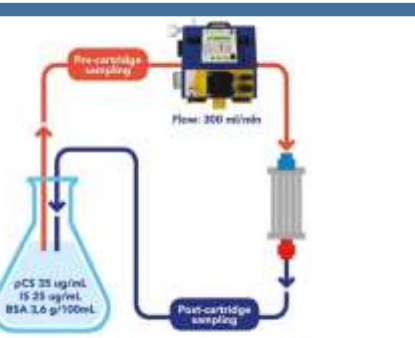
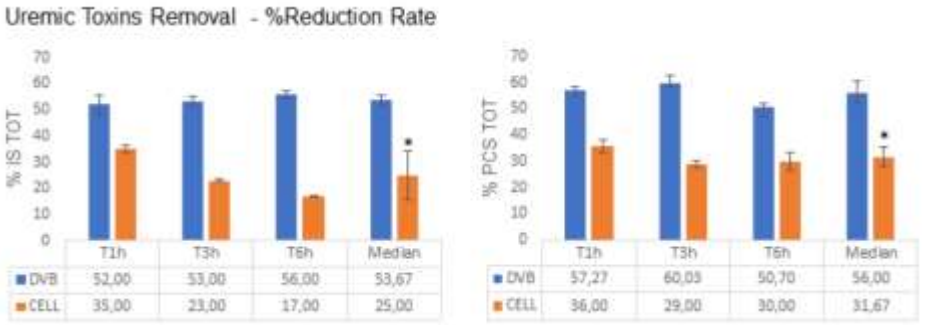


Figure 1. In vitro experiment. Recirculation of an experimental solution in a closed circuit containing the resin sorbent to be tested. Solution samples to be tested were collected after passing through the resin after 1, 3, and 6 hours.



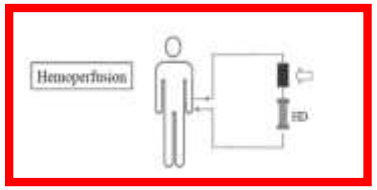
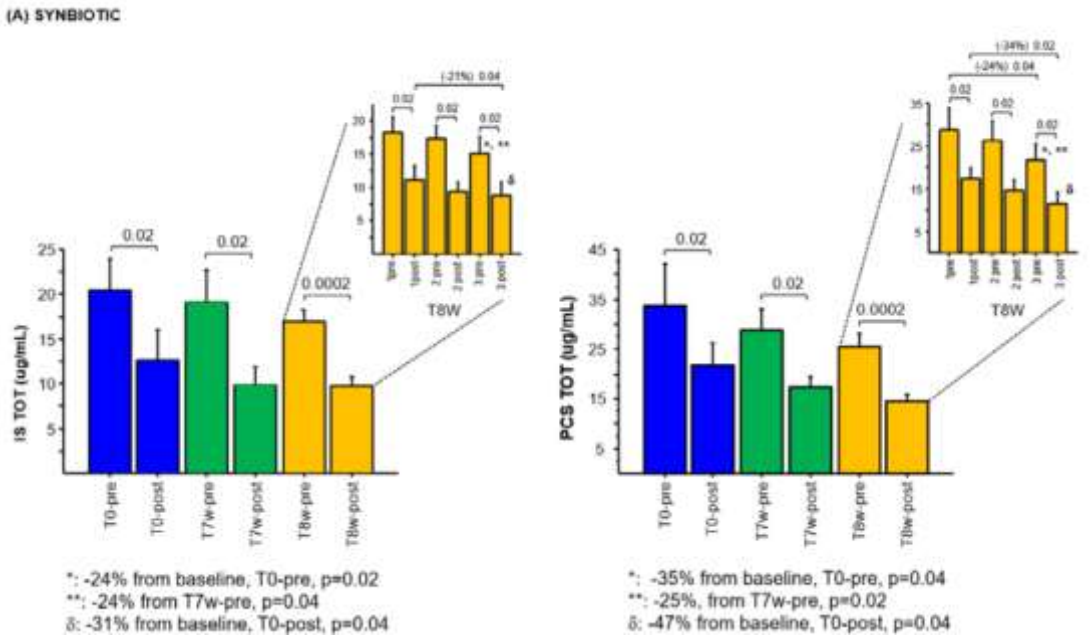


Figure 3. Study Design.



The *"new"* concept of sorbent in hemodialysis….

The Effect of Combination Use of Hemodialysis and Hemoperfusion on Microinflammation in Elderly Patients with Maintenance Hemodialysis

Jun Li[a] Hui Li[b] Wenjiao Deng[a] Lixin Meng[a] Wenya Gong[a] Huitian Yao[a]

Blood Purification

Aim of the study was to investigate the effects of hemodialysis (HD) combined with hemoperfusion (HP) on microinflammatory state in elderly patients with MHD.

150 elderly patients with MHD were randomly divided into the control group and the observation group.

Groups	CRP, mg/L	Hcy, μmol/L	IL-6, ng/L	TNF-α, ng/L
Control group ($n = 75$)				
Difference before and after treatment	0.96±1.14	0.52±2.35	2.45±3.83	1.80±0.97
CV, %	134	129	154	183
Observation group ($n = 75$)				
Difference before and after treatment	9.61±3.48	30.82±9.62	38.26±10.89	22.85±6.41
CV, %	21.12	27.84	30.37	36.70
t	12.33	14.67	16.29	19.81
p value	0.035	0.023	0.041	0.029

Comparison of the differences of inflammatory levels between the 2 groups before and after treatment

Clinical effect of HD combined with HP in elderly patients is significant, which can effectively reduce the incidence of adverse reactions and inflammation in the patients and improve the quality of life and nutritional indicators of the patients.

ORIGINAL ARTICLE

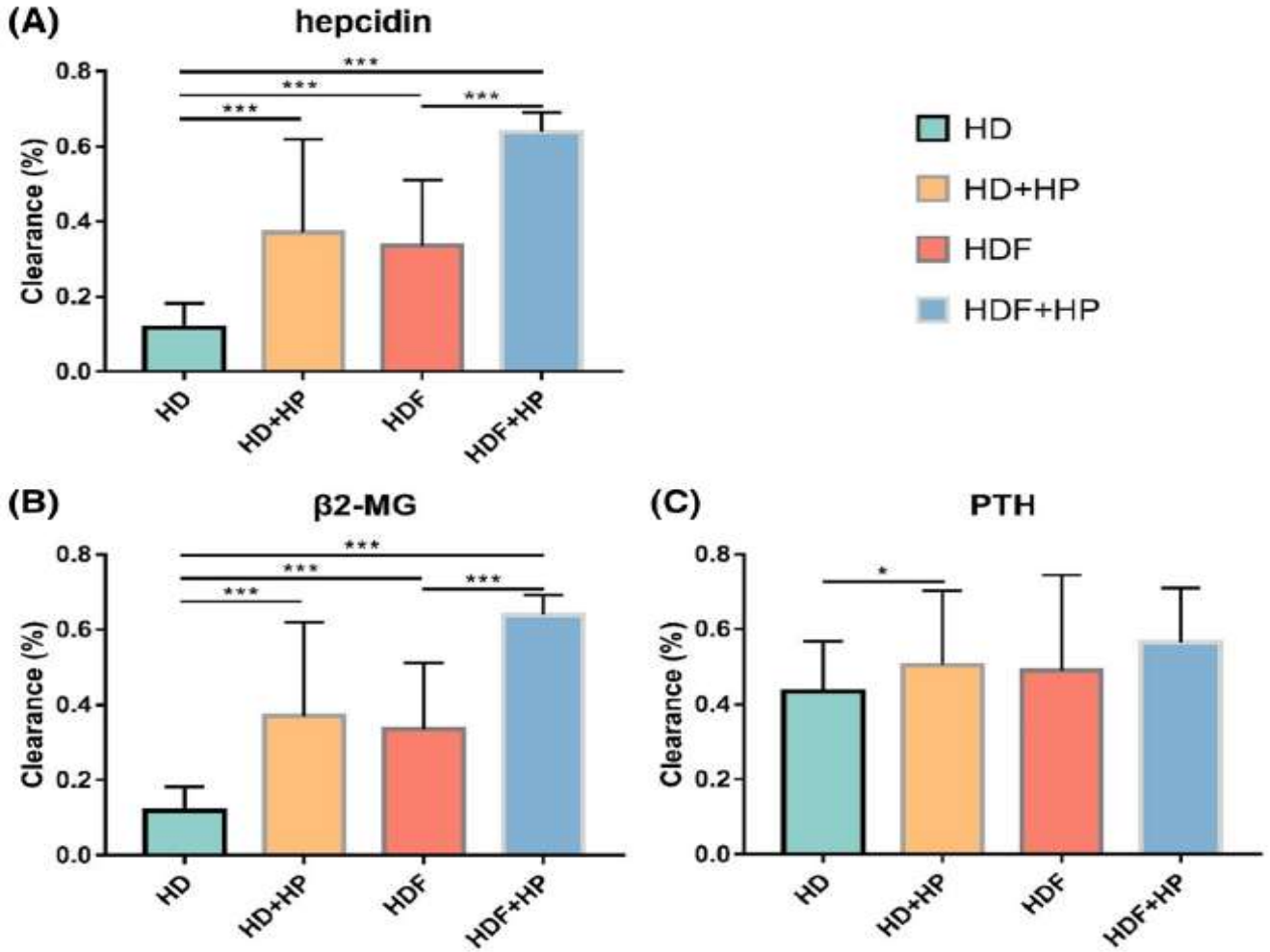
Seminars in Dialysis WILEY

Semin Dial. 2023;36:240–246.

Effect of different hemodialysis modalities on hepcidin clearance in patients undergoing maintenance hemodialysis

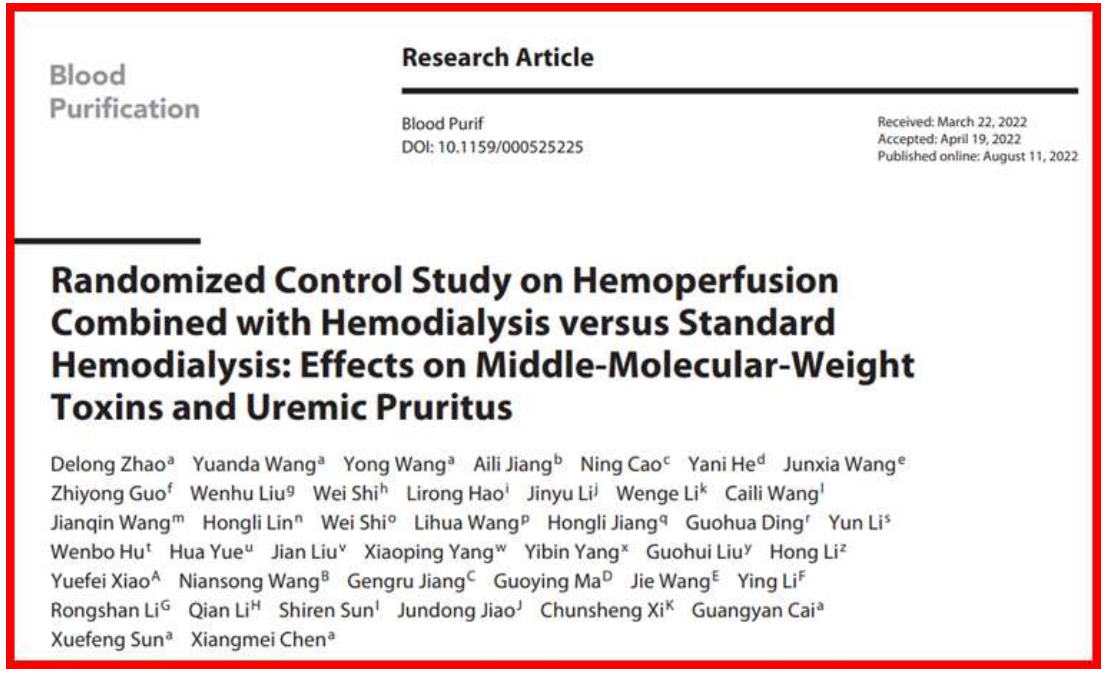
Ling Sun[1] | Rui-Xue Hua[2] | Yu Wu[2] | Lu-Xi Zou[2]

Materials and Methods: In a longitudinal interventional study of 26 stable MHD patients, the serum hepcidin, β2-microglobulin (β2-MG), and intact parathyroid hormone (iPTH) were measured before and after one treatment session of hemodialysis (HD), hemodiafiltration (HDF), HD + HP, and HDF + HP, separately. One-way analysis of variance (ANOVA) was used to identify the effect of dialysis modalities on the intra-dialysis clearance ratios.



The combined dialysis modalities of regular HD/HDF plus HP could achieve better clearance ratios of hepcidin than HD/HDF alone during one treatment session, thereby, the combined dialysis modalities might improve iron utilization, and benefit anemia management in MHD patients.

The *"new"* concept of sorbent in hemodialysis….



Blood Purification

Research Article

Blood Purif
DOI: 10.1159/000525225

Received: March 22, 2022
Accepted: April 19, 2022
Published online: August 11, 2022

Randomized Control Study on Hemoperfusion Combined with Hemodialysis versus Standard Hemodialysis: Effects on Middle-Molecular-Weight Toxins and Uremic Pruritus

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438 MHD patients from 37 HD centers in China with end-stage kidney disease (63.9% males, mean age 51 years) suffering from chronic intractable pruritus were enrolled in the study.

Eligible patients were randomized into four groups:

1. low-flux hemodialysis (LFHD)
2. high-flux hemodialysis (HFHD)
3. HP + LFHD
4. HP + HFHD

Beta-2 microglobulin (β2M) and parathyroid hormone (PTH) were measured at baseline, 3-6, and 12 months. At the same time points, the pruritus score was evaluated.

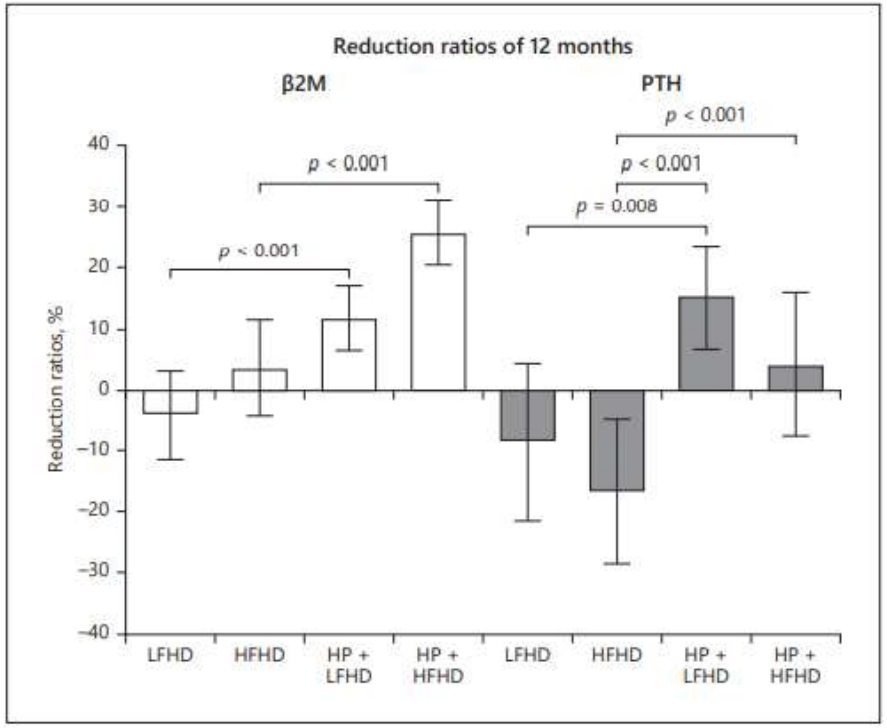


Fig. 3. Reduction ratios of β2M and PTH: intergroups analysis. LFHD, low-flux hemodialysis; HFHD, high-flux hemodialysis; HP, hemoperfusion; β2M, β2-microglobulin; PTH, parathyroid hormone.

In the two groups HP + LFHD and HP + HFHD, there was a significant decrease of β2M and PTH levels after 12 months compared to the control groups. No significant differences were noted between HP + LFHD and HP + HFHD.

Pruritus score reduction was 63% in the HP + LFHD group and 51% in the HP + HFHD group, respectively.

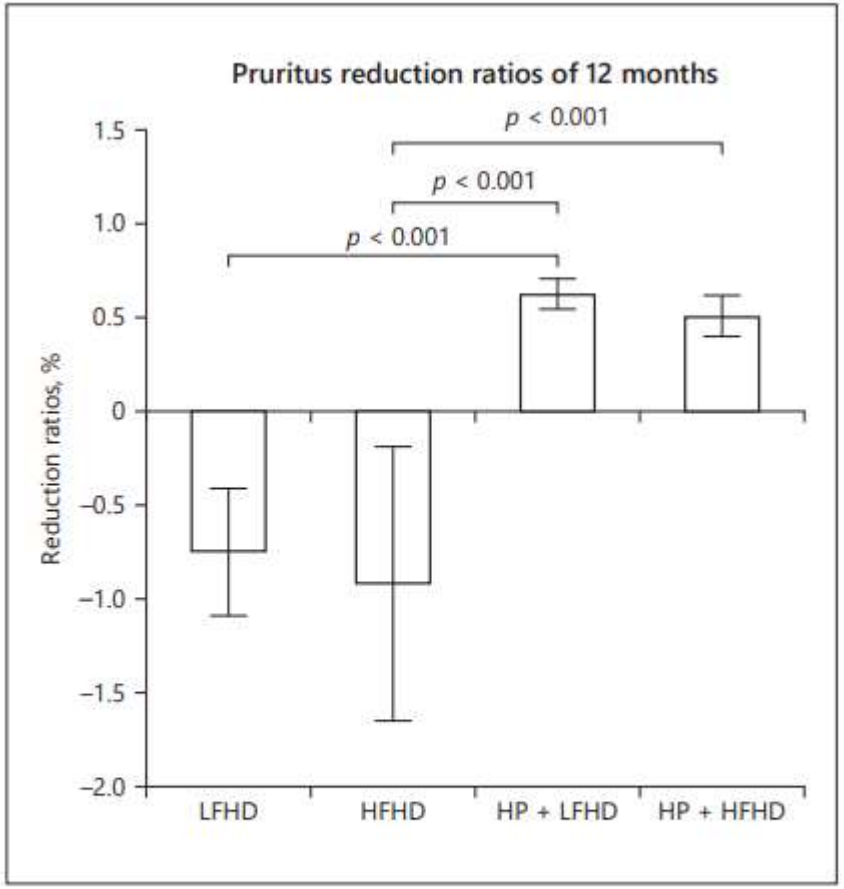


Fig. 5. Reduction ratios of pruritus: intergroups analysis. LFHD, low-flux hemodialysis; HFHD, high-flux hemodialysis; HP, hemoperfusion.

Conclusion: The long-term HP + HD can reduce β2M and PTH levels and improve pruritus in MHD patients independently on the use of high- or low-flux dialyzers, showing that the results are linked to the effect of adsorption.

Original Research Article

Additional hemoperfusion is associated with improved overall survival and self-reported sleep disturbance in patients on hemodialysis

Yan Hong Gu[1,*], Xiu Hong Yang[1,*], Li Hua Pan[1,*], Xiao Li Zhan[1], Li Li Guo[2] and Hui Min Jin[1]

Improving Pruritus & Sleep

158 patients who underwent routine hemodialysis divided into two groups:

1. 80 patients => HD
2. 78 patients => HD+HP

Hemoperfusion was performed 1-2 times biweekly, with each session lasting 2 h.

Self-reported sleep disturbance was evaluated before and after the observational time (2-year period).

Sleep quality was measured using the Pittsburgh Sleep Quality Index.

	Baseline		P	End of treatment		P
	HD	HD + HP		HD	HD + HP	
Patients (n)	80	78		68	75	
Age (years)	62.5 ± 11.5	63.9 ± 12.8	NS	64.1 ± 10.6	65.6 ± 11.8	NS
Male (%)	41.25	43.56	NS	42.65	41.33	NS
Diabetes (%)	40	39.74	NS	41.18	40.0	NS
HD duration (years)	4.4 ± 0.5	4.8 ± 0.6	NS	6.3 ± 0.7	6.5 ± 0.8	NS
Low-incomes (%)	28.75	14.10	<0.05	25.0	12.0	<0.05
Pruritus score	7.3 ± 1.5	7.2 ± 1.4	NS	7.2 ± 0.9	5.9 ± 1.1	<0.01
Sleep medication	37	34	NS	28	19	<0.05
Laboratory parameters						
CRP (mg/L)	13.1±0.7	12.7±0.8	NS	12.7±0.5	9.6 ± 0.4	<0.01
Albumin (g/dL)	31.1±1.5	31.0±1.6	NS	30.0±2.1	31.4±1.5	NS
Hemoglobin (g/dL)	9.8 ± 2.3	9.2 ± 2.7	NS	10.6±0.6	10.8±0.7	NS
Hypercalcemia (%)	8.75	8.97	NS	8.82	1.33	<0.05
Hyperphosphatemia (%)	75.0	76.9	NS	63.2	42.7	<0.05
iPTH (pg/mL)	601 ± 23.9	607 ± 23.5	NS	618 ± 29.4	449 ± 27.3	<0.01
Sleep parameters						
Sleep duration (min)	360 ± 16.6	370 ± 15.1	NS	368 ± 25.2	418 ± 22.7	<0.05
Sleep efficiency (%)	76 ± 5.5	78 ± 6.9	NS	78.5±5.4	88.2±3.5	<0.01

Tab. 1 Characteristics of the HD versus HD + HP groups at baseline and at the 2-year follow-up.

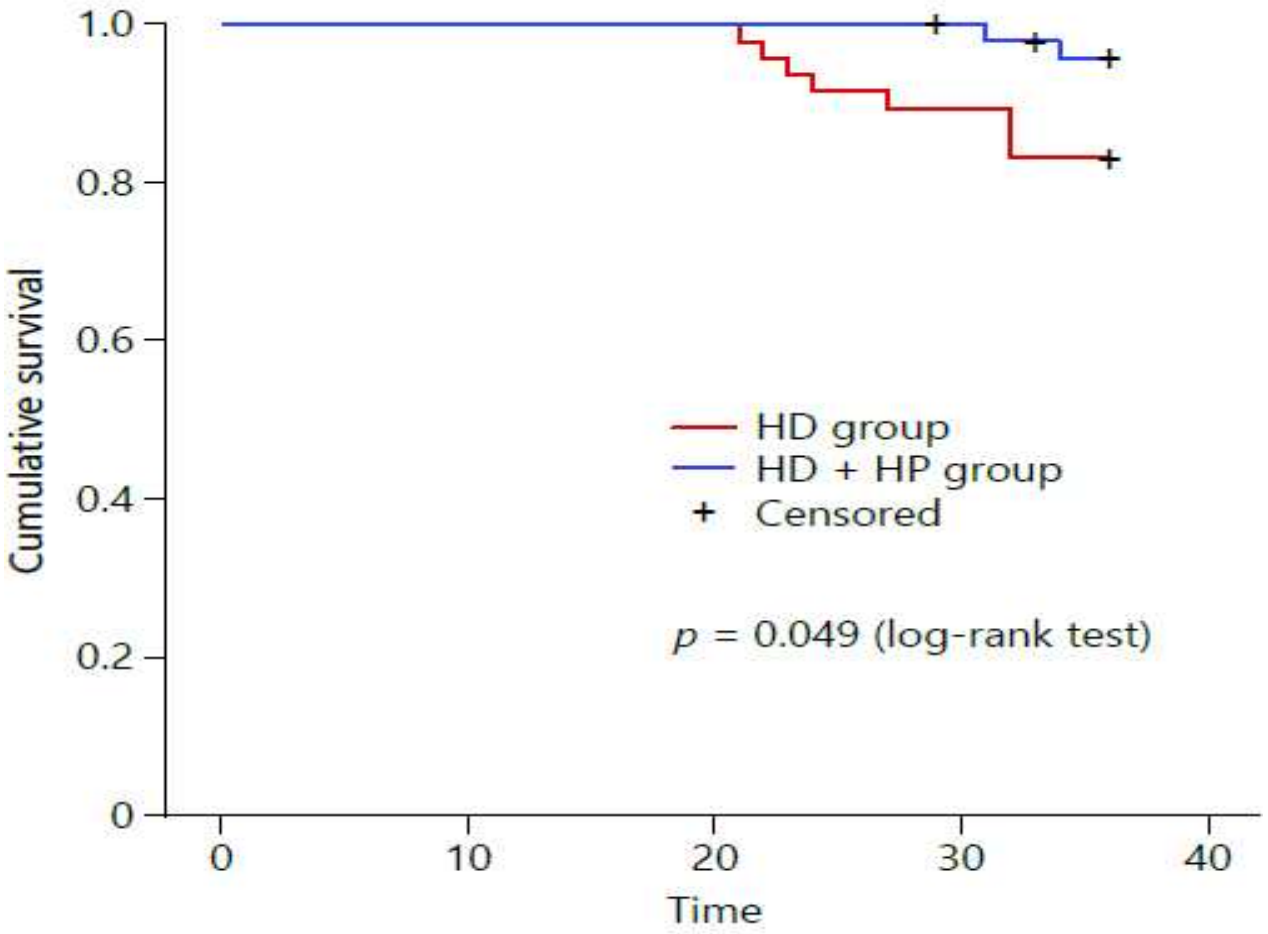
A Combination of Hemodialysis with Hemoperfusion Helped to Reduce the Cardiovascular-Related Mortality Rate after a 3-Year Follow-Up: A Pilot Study in Vietnam

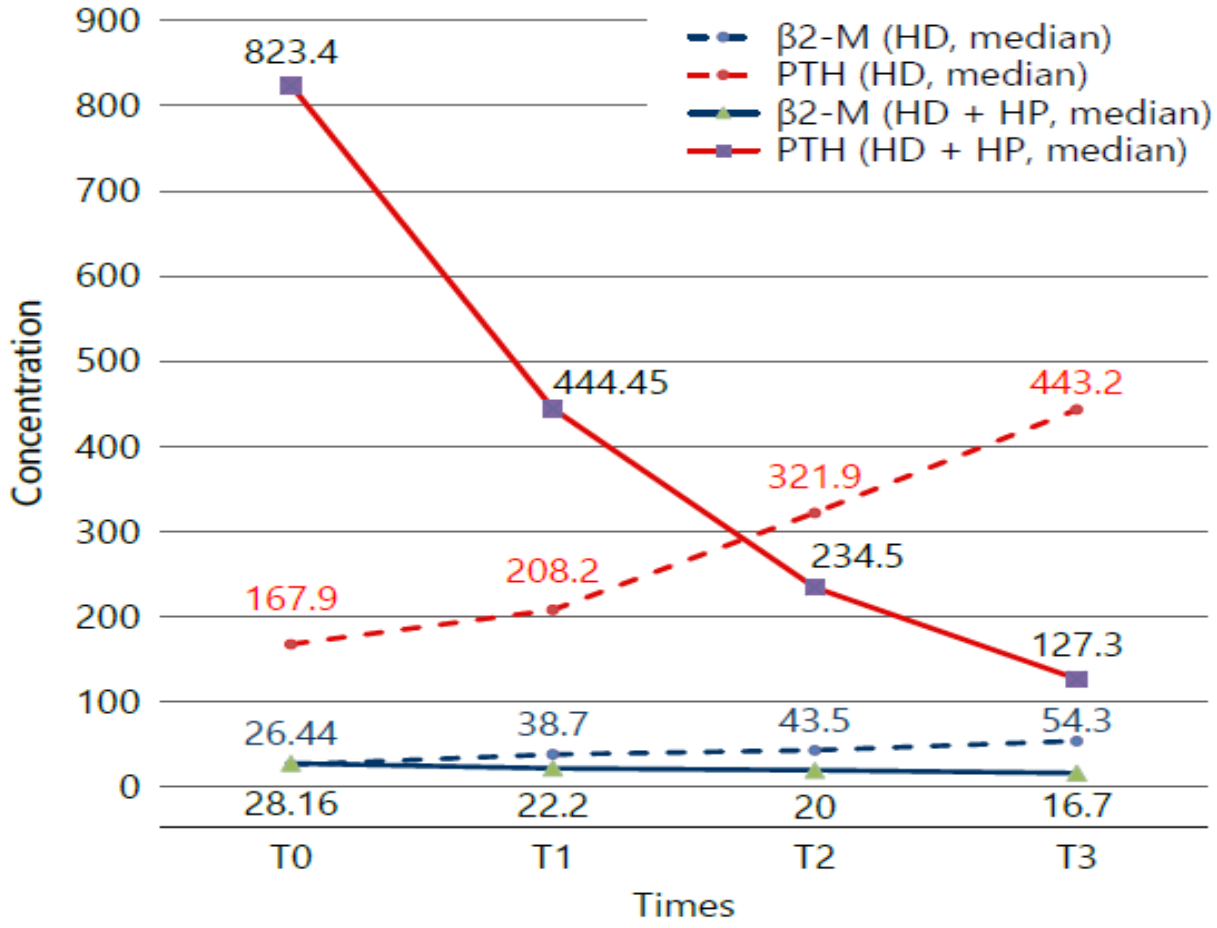
Dung Nguyen Huu[a] Quyen Dao Bui Quy[b] Hai Nguyen Thi Thu[a]

Blood Purif (2021) 50 (1): 65–72.

93 maintenance hemodialysis patients with PTH ≥ 600 pg/ml were divided into 2 groups:

1. 46 patients => HD + HP for consecutive 3 years
2. 47 patients => HD for consecutive 3 years





Blood Purification

Review

Blood Purif
DOI: 10.1159/000525952

Received: April 24, 2022
Accepted: June 27, 2022
Published online: August 11, 2022

Hemoperfusion in Maintenance Hemodialysis Patients

Wei Lu[a] Gengru Jiang[a, b, c] on behalf of Shanghai HP-HD Consensus Group

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1. **Patients**
2. Treatment frequency
3. Treatment methods
4. Adverse reactions

- severe uremic pruritus
- severe uremia-related sleep disorders
- protein-energy wasting
- microinflammatory state
- severe secondary hyperparathyroidism
- severe hyperβ_2-microglobulin
- refractory hypertension
- restless legs syndrome
- uremic peripheral neuropathy

1. Patients
2. **Treatment frequency**
3. Treatment methods
4. Adverse reactions

Individualized HP treatment frequency should be determined according to patients' complications and severity

Once a week or once every 2 weeks

1. Patients
2. Treatment frequency
3. Treatment methods
4. Adverse reactions

Treatment Mode

HP can be combined with three blood purification methods, i.e., LF-HD, HF-HD, and HDF.

Each HP Treatment Duration

The recommended HP treatment duration is 2.0–2.5 h each time. In practice, it should be the treatment duration recommended in the product manual of each brand of perfusion device.

Blood Flow during HP Treatment

When HP is combined with HD or HDF, the blood flow should be controlled at 150–250 mL/min.

Hemoperfusor Connection with Dialyzer or Filter in Group Treatment

It is recommended that the hemoperfurors be connected in series, in front of a dialyzer or filter.

Start Time of HP Treatment in the Treatment Group

For group treatment, HD and HP devices should be combined in series. After 2.0–2.5 h of the first group treatment, the HP device should be removed, but HD treatment should continue; alternatively, 2.0 h–2.5 h before the end of HD treatment (the second group treatment), the HP device should be installed, and the group treatment should be performed again.

1. Patients
2. Treatment frequency
3. Treatment methods
4. **Adverse reactions**

- Abnormal biocompatibility
- Adsorbent particle embolization
- Air embolism
- Blood coagulation dysfunction
- Hypotension

HP Is Not Recommended, or HP Treatment Should Be Suspended, in the following Circumstances

(1) Platelet count $<60 \times 10^9$/L; (2) white blood cell count $<4 \times 10^9$/L; (3) hypotension (predialysis blood pressure <90/60 mm Hg); (4) active hemorrhage; and (5) unstable hemodynamics or vital signs.

Effects of Sequential therapy with Hemoperfusion (HP) and Hemodialysis (HD) on uremic toxin removal

Study Design: Multicenter, prospective and observational study aimed to evaluate the efficacy of a coupled hemoperfusion (HP)-hemodialysis (HD) system aimed to enhance the removal of small-medium-large size molecules and protein-bound uremic toxins (PBUT).

Population: 18 patients undergoing high-flux hemodialysis (HF-HD) were enrolled in the study. Patients in on-line hemodiafiltration (OL-HDF) were enrolled as control group.

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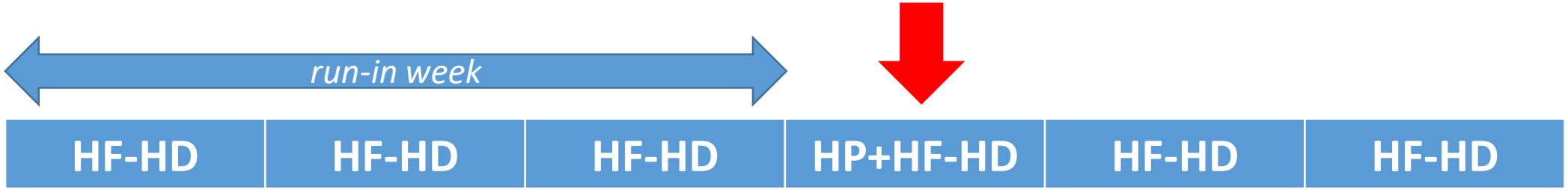
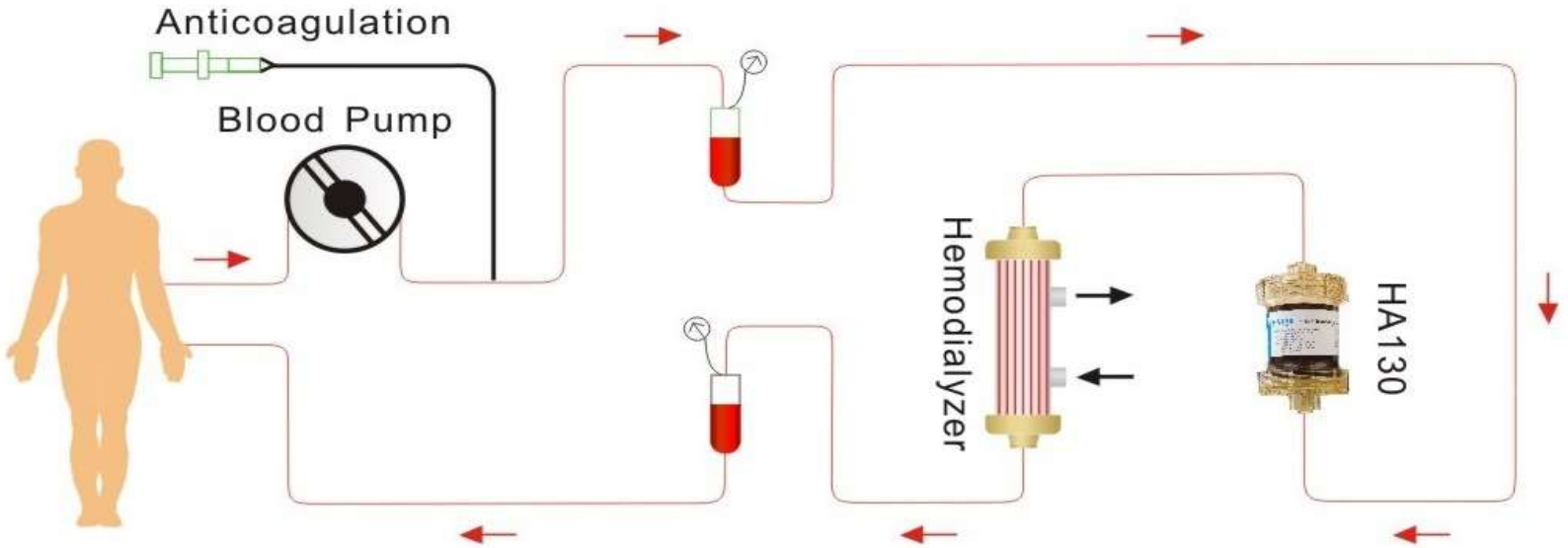
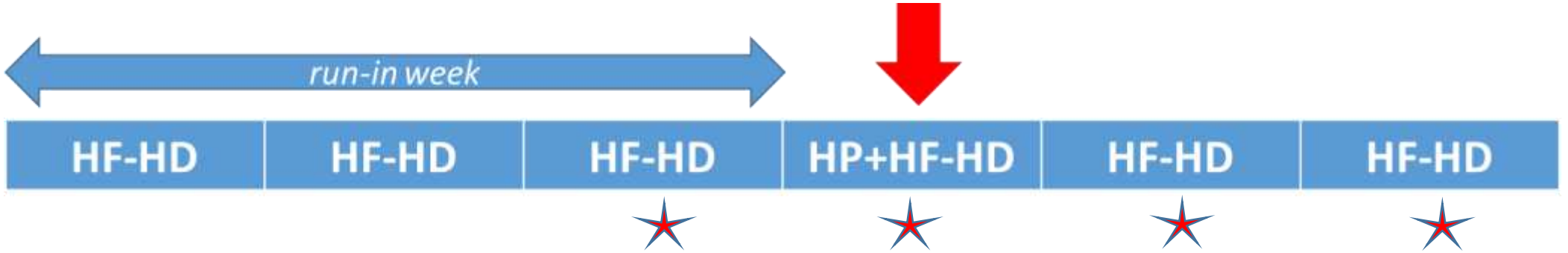
Method: Run-in phase of 3 HD sessions (1 week) performed with HF-HD (polysulfone membrane). After the run-in week, only at the first dialysis of the following week (HP-HD week), HP device will be added to standard HF-HD, maintaining the usual prescription of dialytic parameters. The same variables will be also applied to the second and third dialysis of the HP-HD week, but without addition of the HP device.





4 hr HF-HD + HP
Qb 300 ml/min
Qd 500 ml/min



the following parameters have been collected: real duration of dialysis (min), dialyzer, Qb, Qd, recirculation index, arterial and venous pressure, transmembrane pressure (TMP), initial and final hematocrit, initial and final body weight, volume of blood processed, Kt/V, circuit clotting, heparin dose.
At the start and at the end of all the above-reported HD sessions, the following lab tests have been performed: creatinine, red/white blood cell count, sodium, potassium, calcium, phosphate, uric acid, albumin, total proteins, cholesterol, HDL, LDL, triglycerides, albumin, CRP, β2-microglobulin, myoglobin, kappa and lambda FLCs.

Samples

Before and after each dialysis session, analysis of serum levels of the following uremic toxins (UTs): 1-methyladenosine, trimethylamine-N-oxide (TMAO), indoxyl sulfate, p-cresyl sulfate, phenyl sulfate and 4-ethylphenyl sulfate.
Mass Removal (MR) of the above-mentioned UTs has been evaluated using the following formula:
MR= [Body Volume before HD (ml) x UTs before HD (ng/ml)] - [Body Volume after HD (ml) x UTs after HD (ng/ml)]
where:
- Body Volume before HD (ml) = 1000 x Body Weight before HD (Kg) x (1/13)
- Body Volume after HD (ml) = 1000 x Body Weight before HD (Kg) x (1/13) x [Hct before HD (%)/Hct after HD (%)]

Take home points

Dialysis adequacy should not be based only on Kt/V urea, but consider the kinetics of other retention solutes that are associated with adverse clinical outcomes.

Relevance of PBUT (IS, pCS) in CKD progression and ESRD-associated cardiovascular and neurological alterations.

PBUT are not removed (if not the unbound free fraction) by conventional diffusive and convective strategies.

Adsorption (HP + HD) can be a good therapeutic option for ESRD: promising results from first clinical trials aimed to evaluate HD complications.