Network physiology aspects of kidney-brain-heart interactions and function

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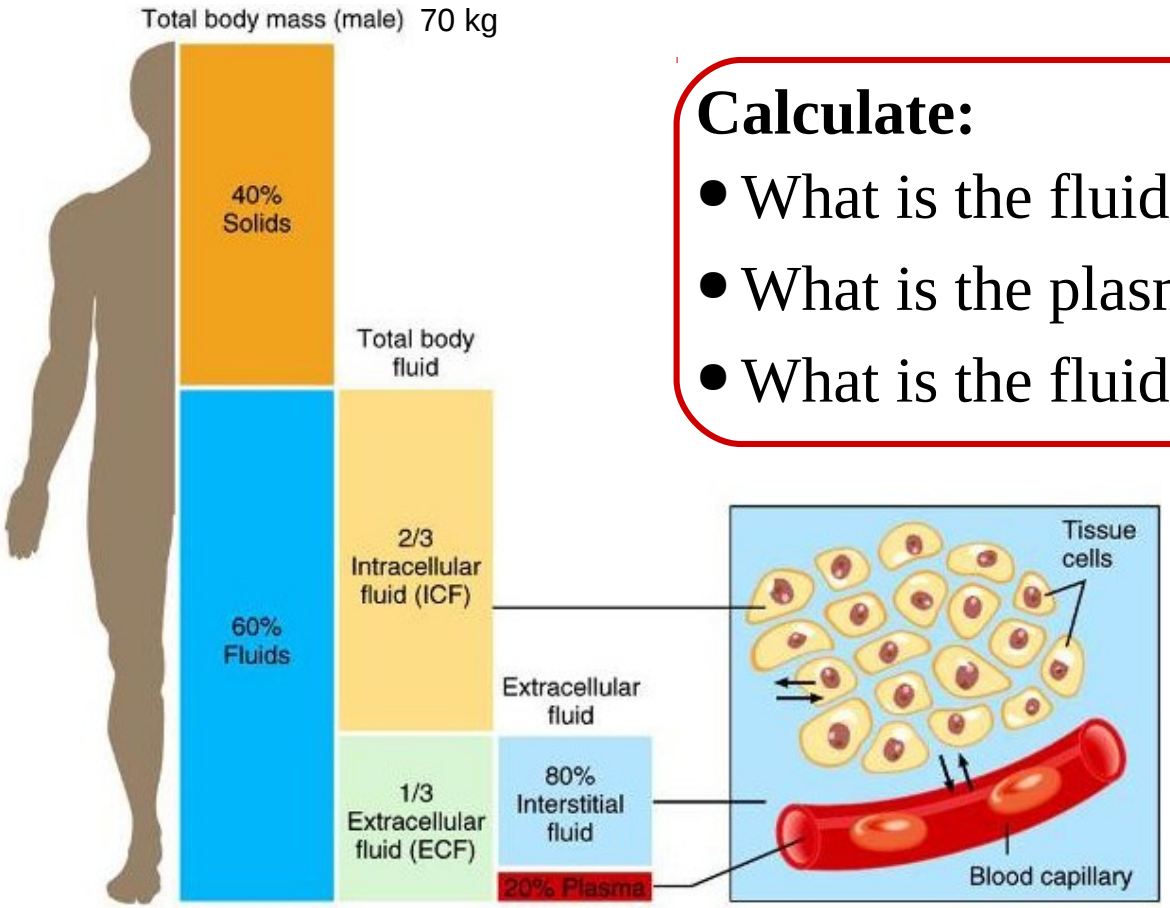
Kidney function

- Regulation of water and electrolyte balance
- Excretion of metabolic products
- Secretion of hormones
- Regulation of arterial pressure

Nearly 500 million people globally (which nearly 10% of global adult population) suffer from some kind of kidney problem/damage.

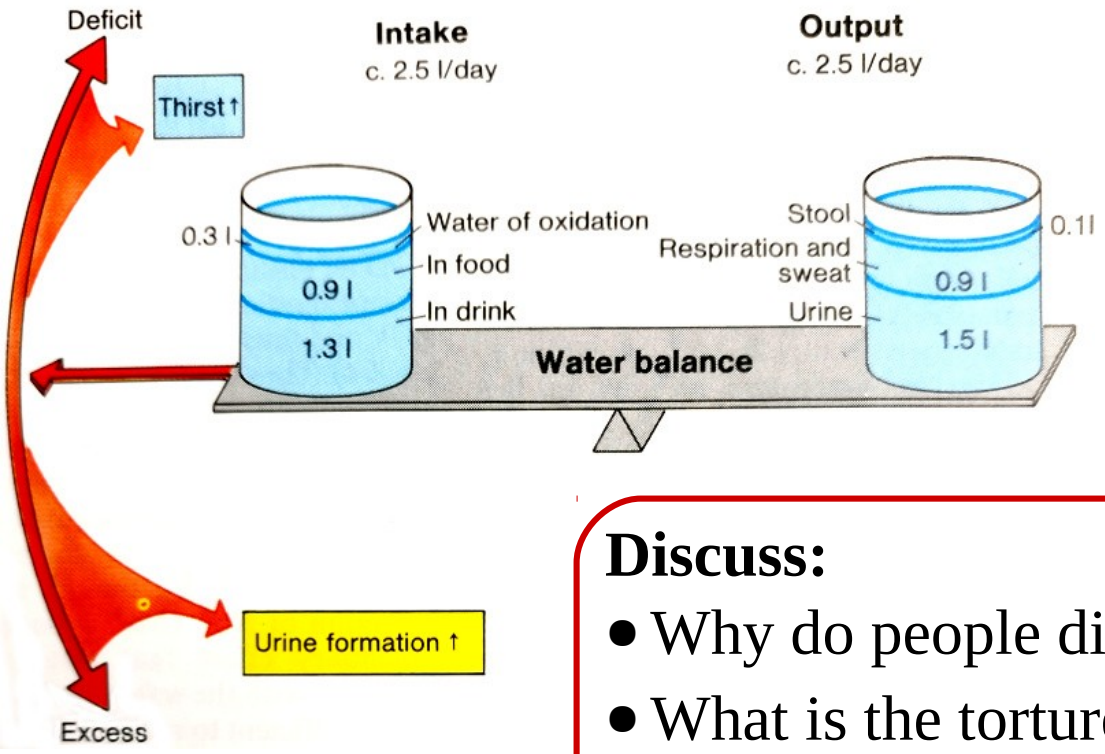
Body in numbers



Calculate:

- What is the fluid volume in the body?
- What is the plasma volume in the body?
- What is the fluid volume inside the cells?

Drink or not drink

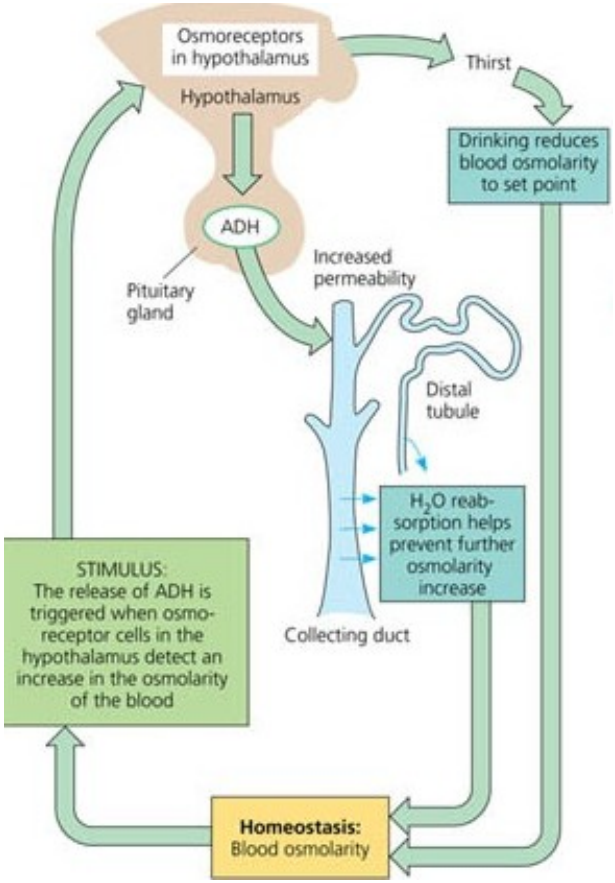


Discuss:

- Why do people die during marathon?
- What is the torture called "Water cure"?
- Why does alcohol/coffee make you pee?

Color atlas of physiology, Thieme, 1991

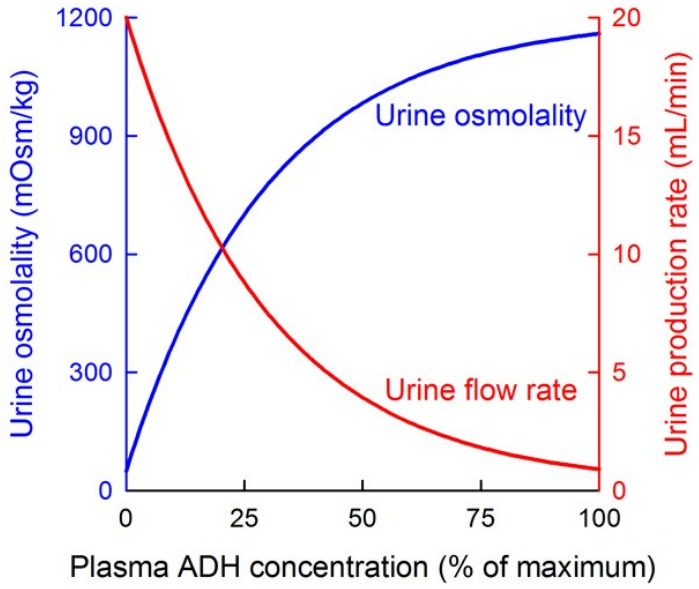
Anti-diuretic hormone

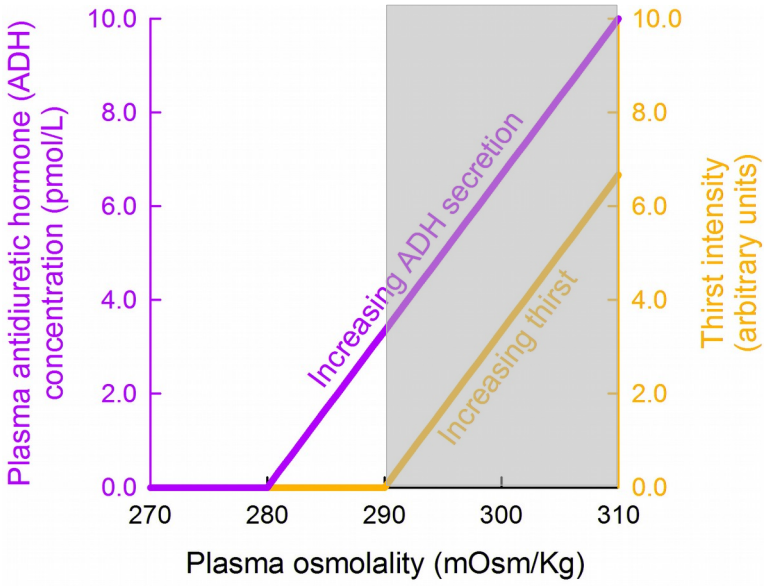


- The most important variable regulating anti-diuretic hormone secretion is plasma osmolarity (the concentration of solutes in blood);
- Osmolarity is sensed in the hypothalamus by neurons (osmoreceptors);
- Those neurons, in turn, stimulate secretion from the neurons that produce anti-diuretic hormone;
- Anti-diuretic hormone is delivered to the kidney and opens aquapores to reabsorb the water.

http://cikgurozaini.blogspot.com/2011/05/one-of-most-important-aspects-of.html

Drink or not drink

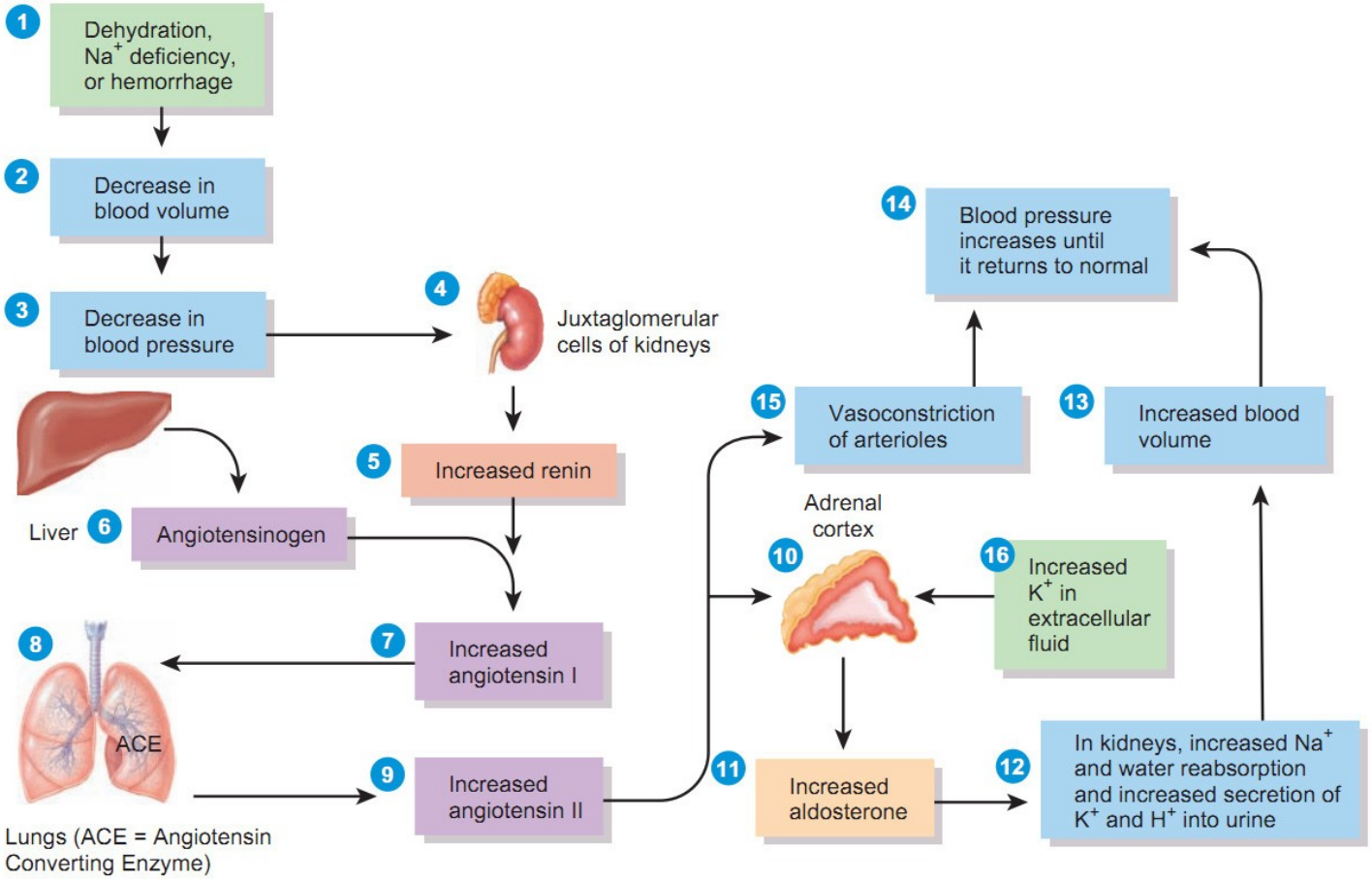




The osmotic threshold for anti-diuretic hormone secretion is considerably lower than for thirst, as if the hypothalamus is saying "Let's not bother him by invoking thirst unless the situation is bad enough that antidiuretic hormone cannot handle it alone."

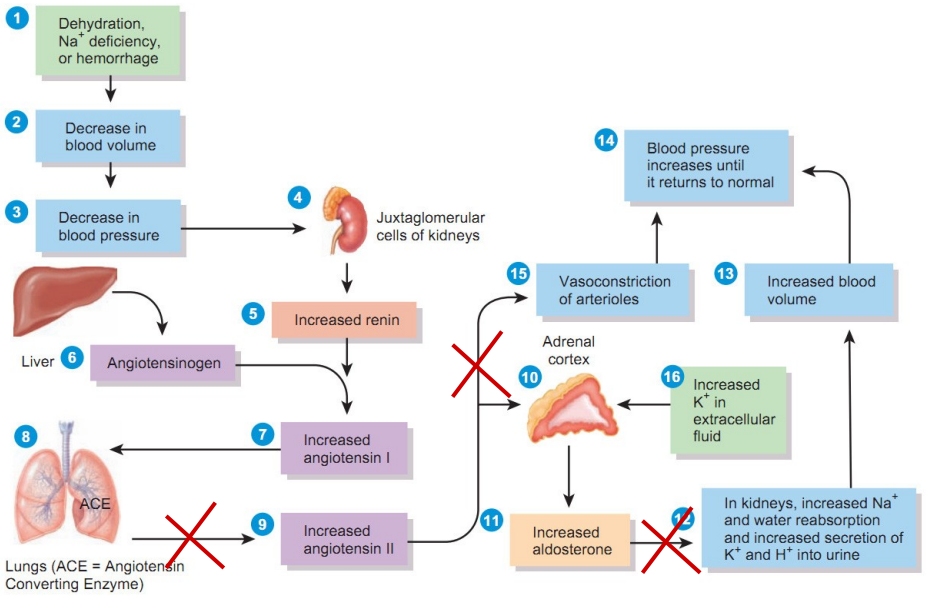
https://www.physiologyweb.com

Blood pressure regulation



https://antranik.org/the-renin-angiotensin-aldosterone-reflex/

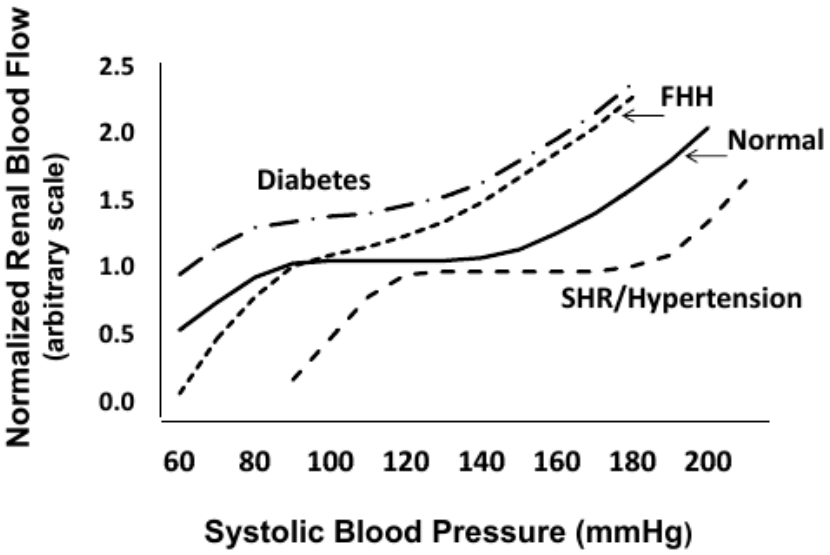
Blood pressure regulation



- ACE inhibitors (angiotensin converting enzyme inhibitors) prevents angiotensin I from converting into angiotensin II – the blood vessels remain relaxed and blood pressure decreases;
- ARBs (angiotensin-receptor blockers) also affect angiotensin, but they prevent angiotensin II from binding to the receptors on blood vessels – blood vessels remain relaxed and blood pressure decreases;
- A diuretic is a chemical that increases urin formation rate; used to treat e.g. heart failure and hypertension.

https://antranik.org/the-renin-angiotensin-aldosterone-reflex/

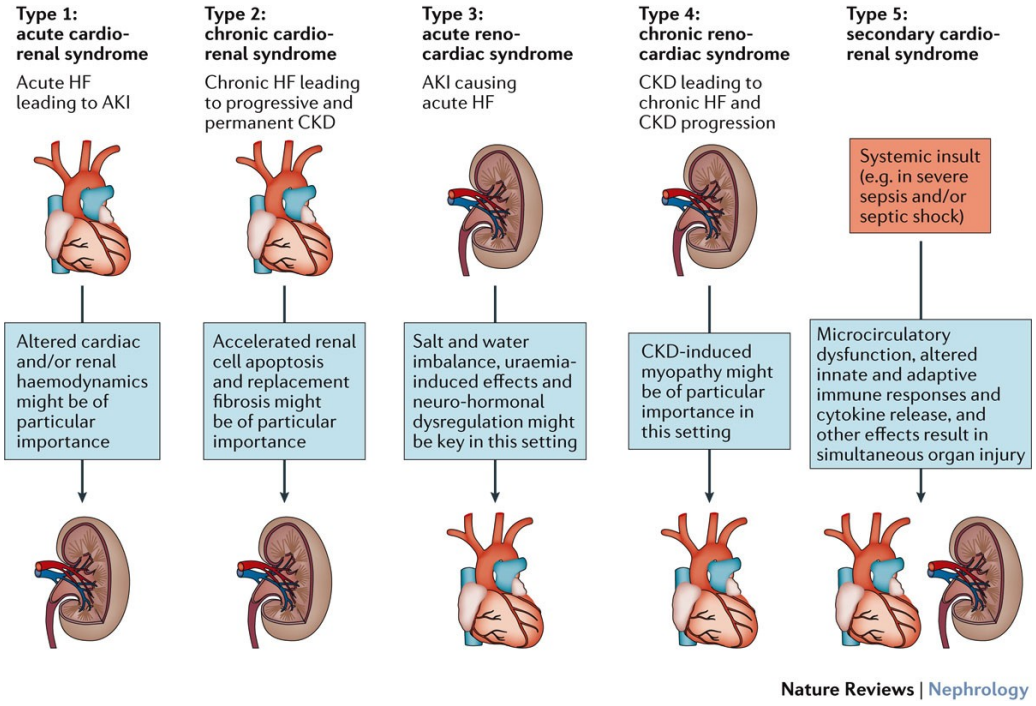
Impaired renal autoregulation



- Blood flow in normal subjects is maintained nearly constant over a range of arterial pressures from 70 to 120 mmHg;
- The autoregulatory range is shifted to higher pressures in mild to moderate hypertensive patients and animal models;
- Renal vascular resistance is reduced in diabetes and the efficiency of autoregulation is impaired;
- The fawn hooded hypertensive (FHH) rat exhibits a lack of a myogenic response in the preglomerular vasculature and impaired autoregulation of renal blood flow.

Burke et al,C urrent Vascular Pharmacology 12, 2014

Key cardio-renal interactions



- Heart failure and kidney disease are interconnected via numerous pathophysiological pathways;
- The complex interplay between the heart and the kidneys involves haemodynamic, (neuro)homonal and cardiovascular disease-associated mechanisms;
- The absence of a standardized terminology database and the lack of studies specific to cardio-renal syndrome has hampered efforts to develop novel treatments.

Schefold, J. C. *et al. Nat. Rev. Nephrol.* doi:10.1038/nrneph.2016.113, 2016

translational nephrology

http://www.kidney-international.org

The distant organ effects of acute kidney injury

Morgan E. Grams[1] and Hamid Rabb[1]

[1]Department of Medicine, Johns Hopkins School of Medicine, Baltimore, Maryland, USA

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Heart failure and kidney dysfunction: epidemiology, mechanisms and management

Joerg C. Schefold, Gerasimos Filippatos, Gerd Hasenfuss, Stefan D. Anker & Stephan von Haehling

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Castro *et al. BMC Neurology* (2018) 18:21
https://doi.org/10.1186/s12883-018-1025-4

BMC Neurology

RESEARCH ARTICLE Open Access

Chronic kidney disease and poor outcomes in ischemic stroke: is impaired cerebral autoregulation the missing link?

Pedro Castro[1*], Elsa Azevedo[1], Isabel Rocha[2], Farzaneh Sorond[3] and Jorge M. Serrador[4,5,6]

INVITED REVIEW

WILEY Microcirculation

Sepsis-induced acute kidney injury: A disease of the microcirculation

Shuai Ma[1,2] | Roger G. Evans[3] | Naoya Iguchi[1,4] | Marianne Tare[3,5] | Helena C. Parkington[3] | Rinaldo Bellomo[6] | Clive N. May[1] | Yugeesh R. Lankadeva[1]

Doctor House: Acute kidney injury (AKI)

- **Kidney–lung interactions:** Respiratory complications are frequently associated withAKI. In a study of AKI, 78% of patients developed subsequent respiratory failure. Similarly, AKI is a common occurrence in mechanically ventilated patients;

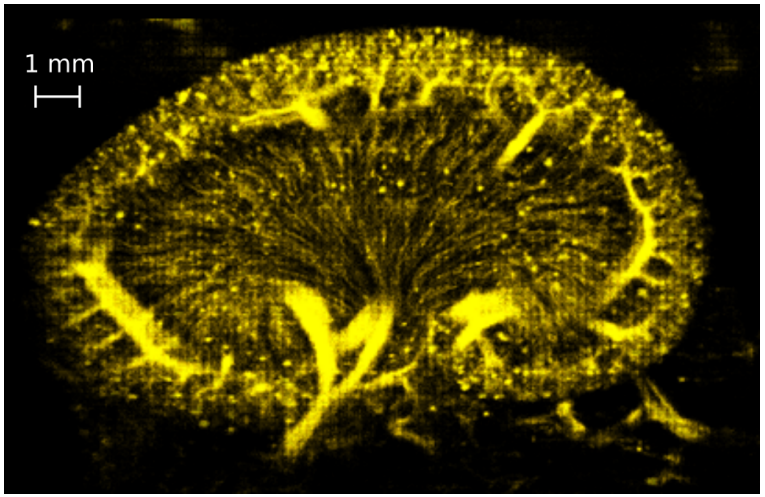
- **Kidney–heart interactions:** Approximately 20–30% of patients hospitalized with congestive heart failure will develop AKI. Among patients with established AKI, ‘cardiac failure’ has been reported as a common cause of death;

- **Kidney–brain interactions:** Neurological complications of AKI include central nervous system dysfunction, decreased mental status, seizures, and death. Approximately one-quarter of patients hospitalized for subarachnoid hemorrhage and acute stroke experienced AKI;

- **Kidney-sepsis interaction:** AKI is a common complication of sepsis and is significantly associated with mortality. Sepsis accounts for more than 50% of the cases of AKI, with a mortality rate of up to 40%.

Grams et al., Kindey Int 81, 2012

Open questions



- **What is the dynamics of EEG in different stages of chronic kidney disease?**
- **Impaired renal autoregulation: The real culprit behind diabetic nephropathy?**
- **How to monitor renal autoregulation?**
- **Atlas of renal communications**