

UCPH,2025

# The challenge of appropriate medication prescribing for older adults

- focused on polypharmacy and renal function

Morten Baltzer Houliind

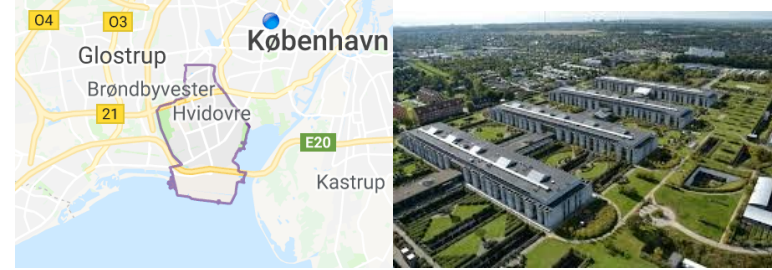
PhD, MSc Pharm. & Master of Pain Science and Multidisciplinary Pain Management



# Disclosures

- I have nothing to disclose

# Background

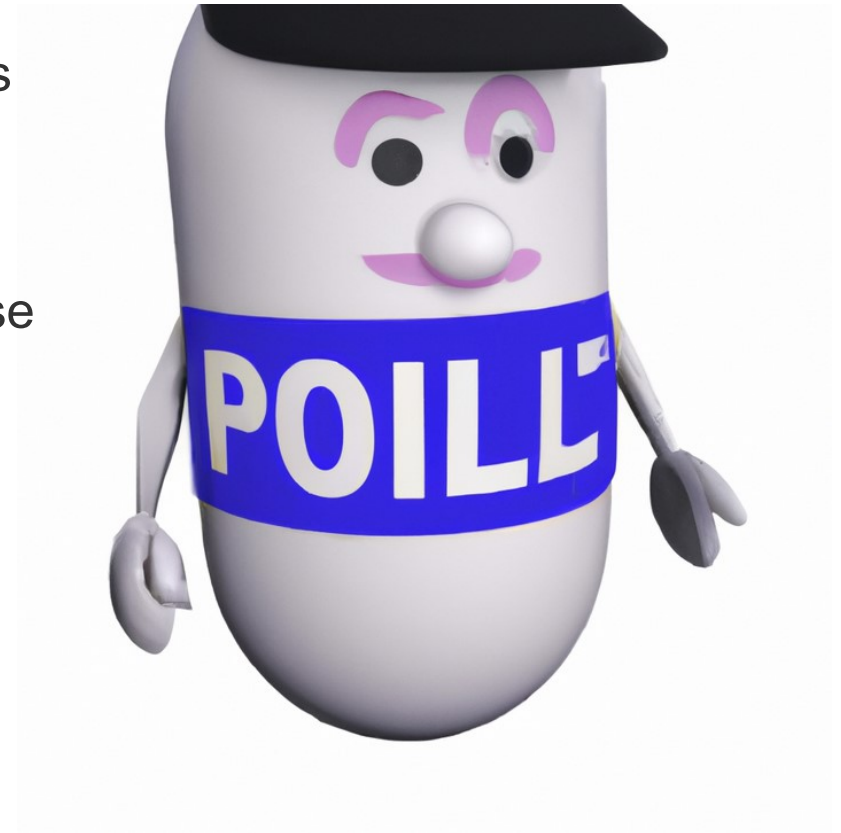


- 2011-, MSc Pharm 2011, University of Copenhagen (UCPH)
- 2012-2016, Clinical Pharmacist, Capital Region Pharmacy
  - Medicines Management
  - Acute hip fracture patients
  - One-Stop Dispensing
- 2016, Master of Pain Science and Multidisciplinary Pain Management, Aalborg University
- 2017-2020, PhD student
- 2020-2024, Postdoc
- 2021- , Assistant professor (10%), UCPH
- 2022-2024 BRIDGE fellow
  - Department of Clinical Research, Hvidovre, Copenhagen University Hospital
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  - Department of Drug Design and Pharmacology, UCPH
- 2023 sep. - Head of development and research, Capital Region Pharmacy, Amager and Hvidovre
- 2024 sep - Senior researcher - Department of Clinical Research & Department of Nephrology



# Research focus

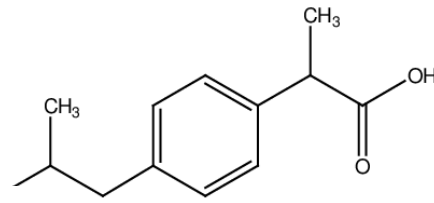
- Personalized medicine using modern biomarkers and techniques for assessing organ function
- Stratification of patients for medication review based on disease and medication burden
- Clinical Trials in frail patients (unsexy studies)
- Practical Hospital Pharmacy



# Motivation



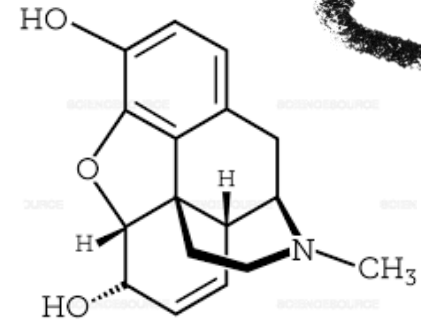
Acute hip fracture patient



Ibuprofen

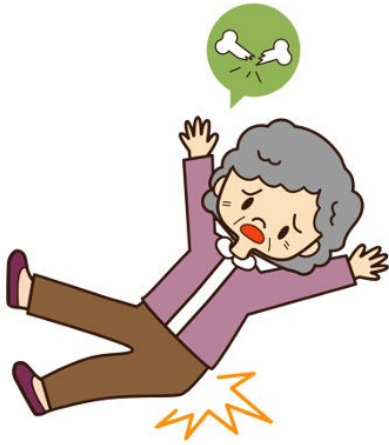


**OVERDOSE**



Morphine  
 $C_{17}H_{19}NO_3$

# Motivation continued



Acute hip fracture patient

Patients overdosed with standard prescribed analgesics according to estimated Glomerular Filtration Rate (eGFR) was characterized by:

- High age ( $\geq 80$  years)
- Low body weight ( $< 50$  kg)
- Mild decreased eGFR ( $> 60$  mL/min/1.73m<sup>2</sup>) based on  $\text{CKD-EPI}_{\text{creatinine}}$

Outcomes: naloxone, acute kidney injury (AKI), acute dialysis, prolonged hospitalization and mortality



# Learning Objectives

- Know the definition of polypharmacy
- Understand the challenges of polypharmacy in older patients
- Know the definition of renal risk medications
- Understand that kidney function decreases with age
- Understand the challenges and limitations of estimating renal function in older patients with multimorbidity

# Older medical patients



- In 2014, there were 114,000 older medical patients in Denmark

Ministry of Health, 2016

- About 70% of patients are in polypharmacy treatment

Jensen LD, Int J Clin Pharm. 2014

- Up to 15% of all ED admissions are expected to be related to the patient's medication

Kongkaew C, Ann Pharmacother. 2008

- Lack of medication prescribing according to current health condition and lack of deprescribing

Frank C, CMAJ Can. Med. Assoc. J. 2008  
Laroche ML, Br. J. Clin. Pharmacol. 2007

- About 1/3 of all medication-related admissions can be related to inappropriate prescribing of renal risk medication

Helldén A, Drugs Aging 2009

# Definition of polypharmacy

Masnoon et al. *BMC Geriatrics* (2017) 17:230  
DOI 10.1186/s12877-017-0621-2

BMC Geriatrics

RESEARCH ARTICLE

Open Access

## What is polypharmacy? A systematic review of definitions



Nashwa Masnoon<sup>1,2\*</sup> , Sepehr Shakib<sup>3,4</sup>, Lisa Kalisch-Elett<sup>1</sup> and Gillian E. Caughey<sup>1,3,4</sup>

- Use of multiple medications ( $\geq 5$  medications)
- Many different definitions are used in the literature
- **Rational polypharmacy vs. irrational polypharmacy**

# How many Danes use polypharmacy?

≈ 4 %

≈ 7 %

≈ 12 %

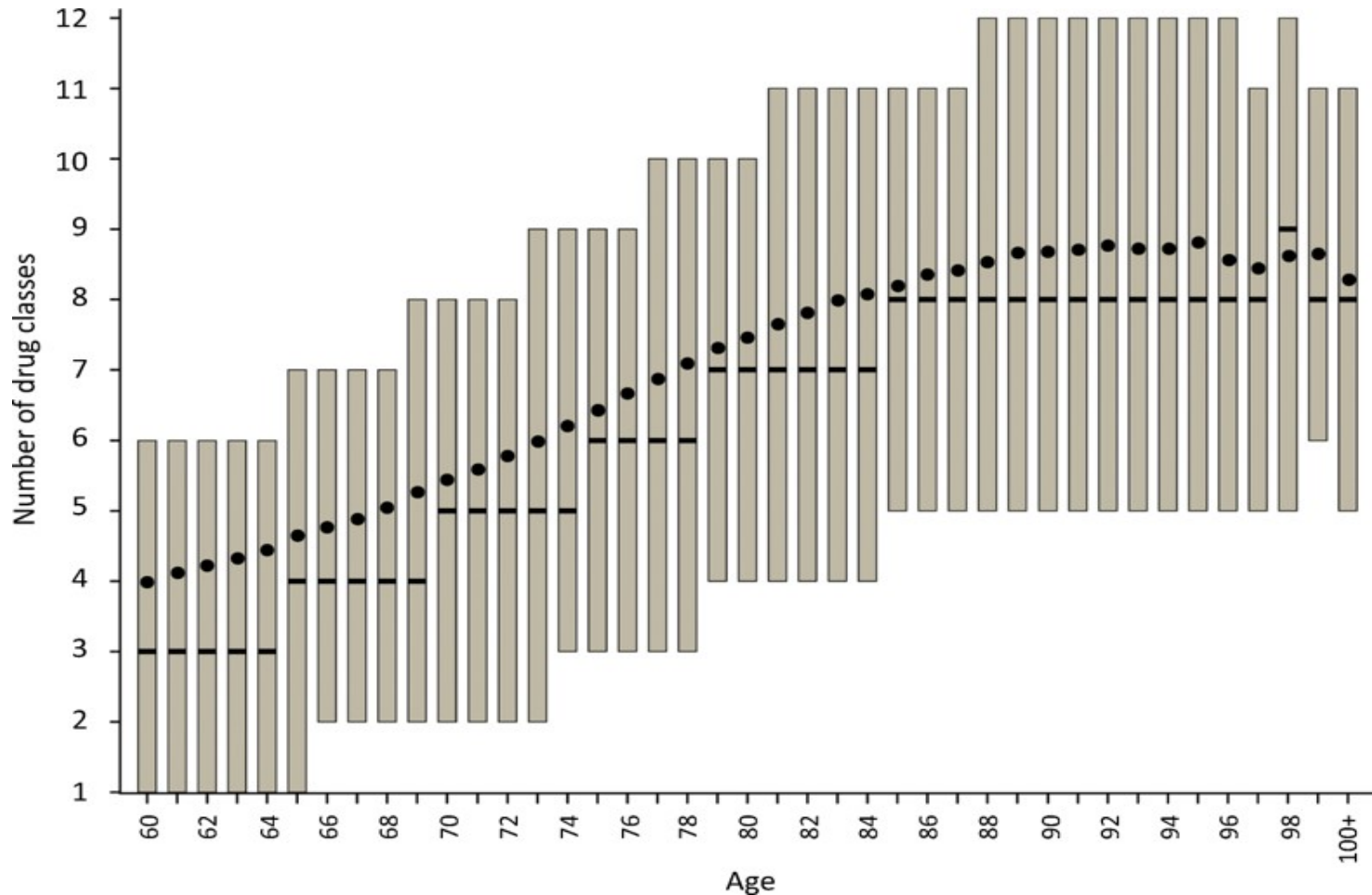


≈ 20 %

## What is the extent of polypharmacy in Denmark?

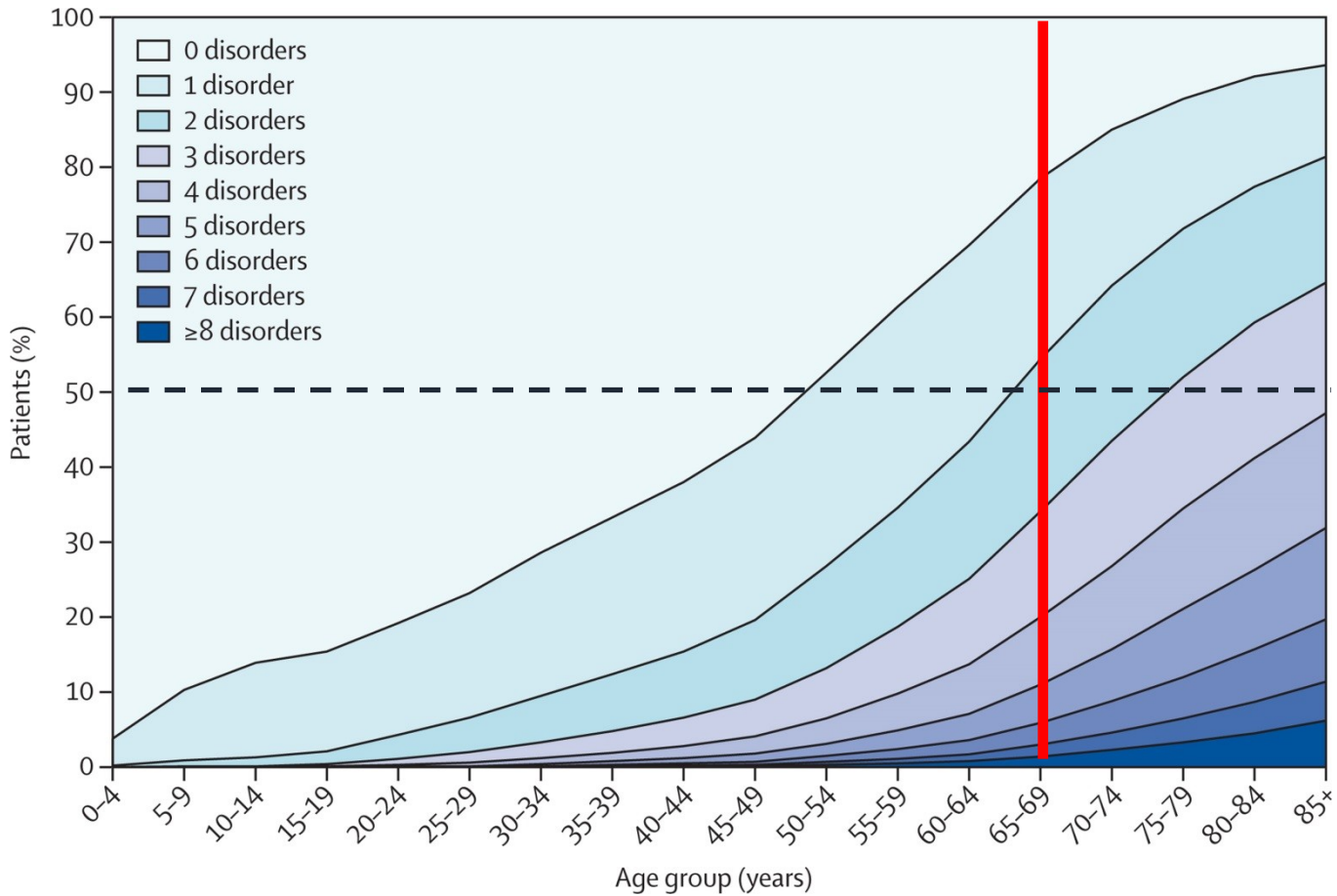
- 750.000 polypharmacy patients in Denmark
- 1.1 million older people 65+ years in Denmark
- 33% of the older patients use  $\geq 5$  prescribed medications
- Older accounts for 15% of the population and uses 40-50% of all prescribed drugs

# Development in medication use over the years



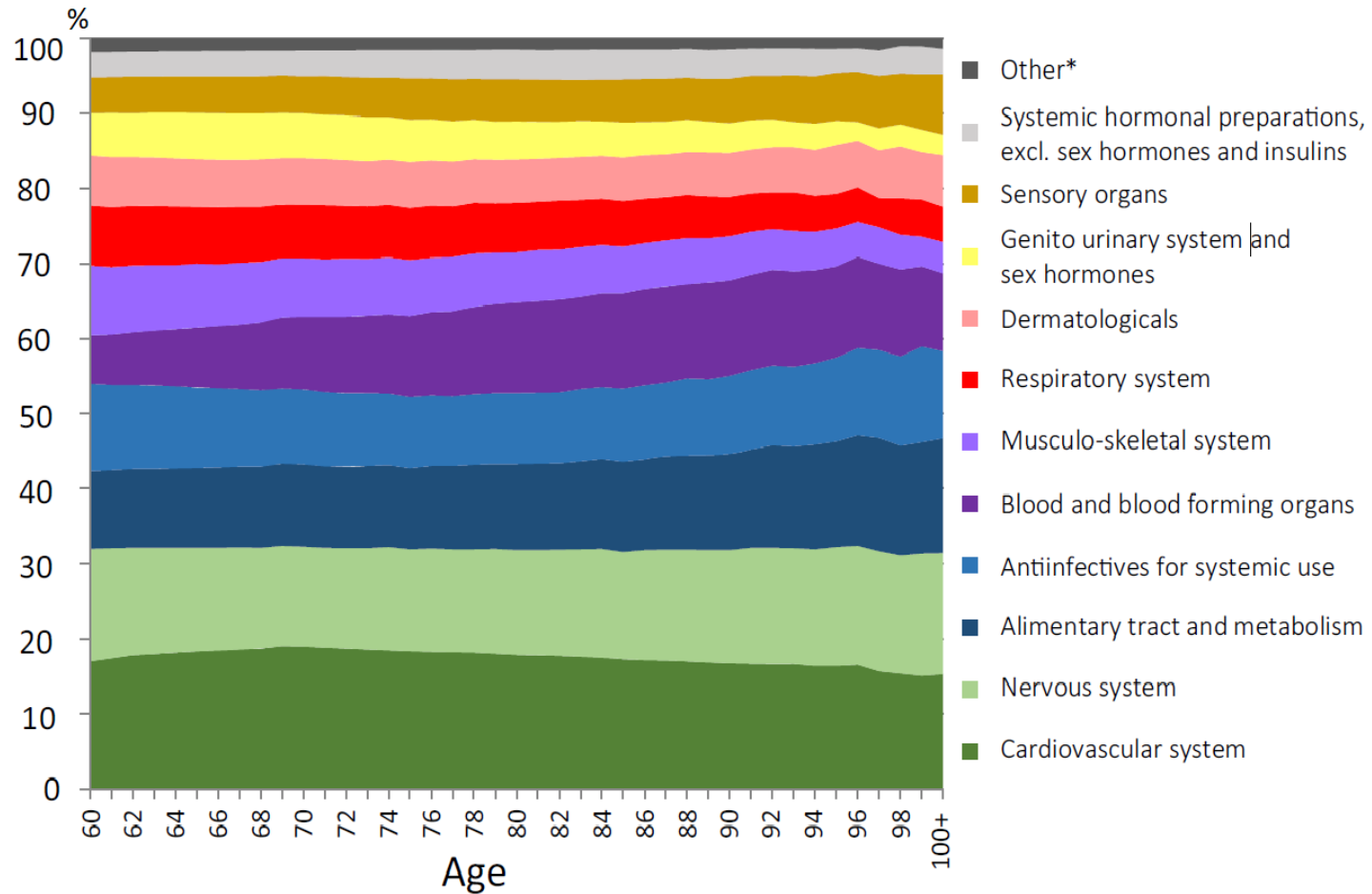
Reprinted from Christensen et al. 2019 with permission from Springer Nature.

# Aging and disease



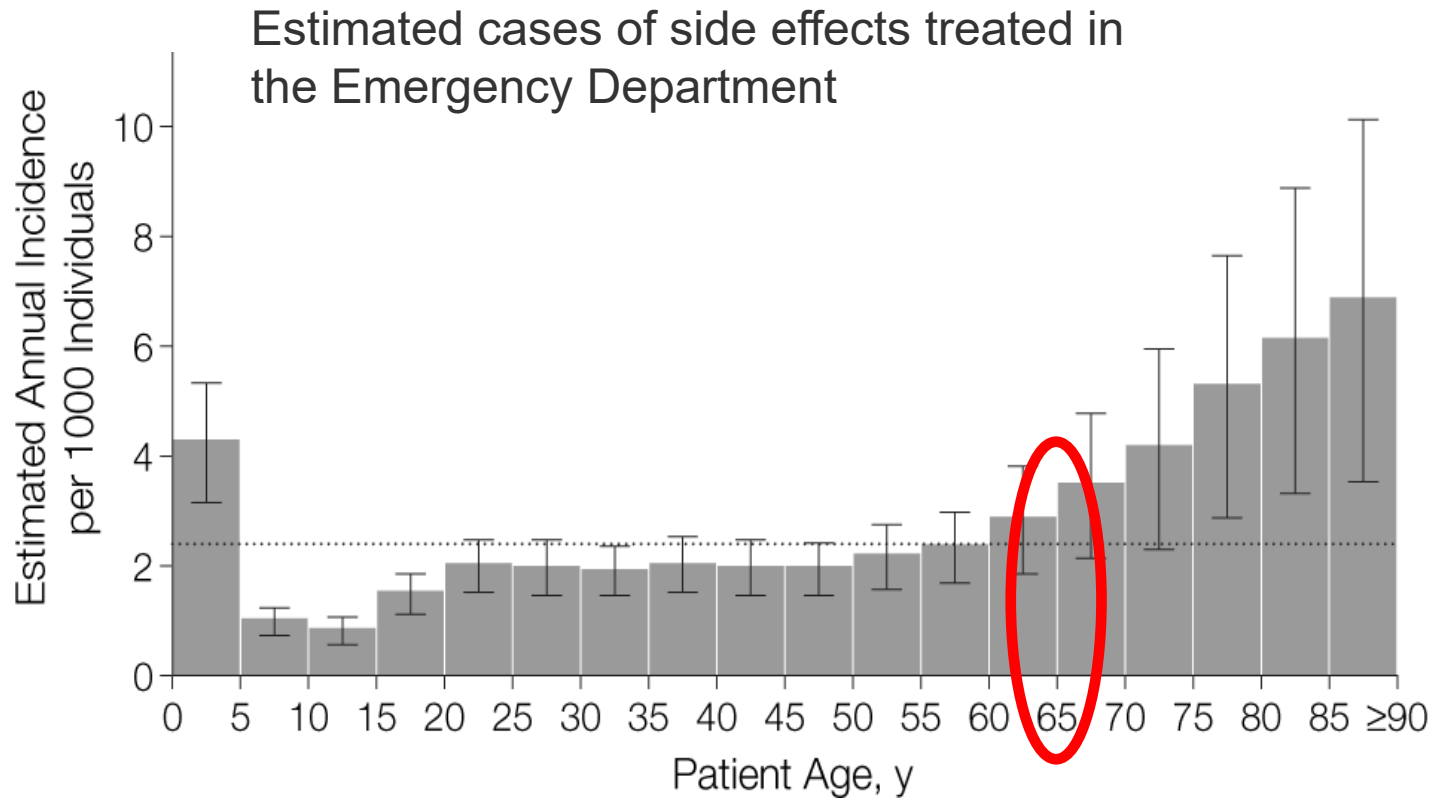
Barnett et al 2012, Lancet

# Types of medications used in individuals aged 60–100



Reprinted from Christensen et al. 2019 with permission from Springer Nature.

## Side effects ...



*Budnitz et al., JAMA 2006*

## Side effects related to hospitalization

<b>ADE</b>	<b>No. (%)</b>
Fall(s) while receiving benzodiazepines	24 (15.9)
Symptomatic orthostasis while receiving antihypertensives	17 (11.3)
Falls while receiving opiates	10 (6.6)
Hyponatremia while receiving diuretics	10 (6.6)
Constipation while receiving opiates	6 (4.0)
Falls while receiving sedative hypnotics	6 (4.0)
Acute kidney injury while receiving diuretics	6 (4.0)
Symptomatic orthostasis while receiving diuretics	5 (3.3)
Falls on neuroleptics	5 (3.3)
NSAID-related gastritis/peptic ulcer disease	4 (2.6)
Bradycardia while receiving $\beta$ -blockers	4 (2.6)

*Hamilton, JAMA 2011*

# Renal risk medication

A medication where the dose should be adjusted according to the patient's renal function or a medication that is contraindicated in patients with renal impairment.

Wehling M, 2013



# How many medications are renal risk medications?

≈ 10 %

≈ 20 %

≈ 40 % 

≈ 80 %



## Kidney function estimates using cystatin C versus creatinine: Impact on medication prescribing in acutely hospitalized elderly patients.

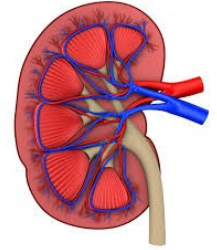
Iversen E<sup>1,2</sup>, Bodilsen AC<sup>1,3</sup>, Klausen H<sup>1</sup>, Tredal C<sup>1,4</sup>, Andersen O<sup>1,5,6</sup>, Houliind M<sup>1,2,4</sup>, Petersen J<sup>1,7,8</sup>.

**RESULTS:** Median eGFR values were 65.5, 60.7, 54.1, 57.1, 55.1, and 57.6 mL/min/1.73m<sup>2</sup> according to CKD-EPI<sub>Cr</sub>, CKD-EPI<sub>C<sub>omb</sub></sub>, CKD-EPI<sub>C<sub>ys</sub></sub>, BIS<sub>Cr</sub>, BIS<sub>C<sub>omb</sub></sub>, and CG<sub>Cr</sub>, respectively. Depending on choice of equation, renal risk medications were prescribed at higher than recommended dose in 13.6% to 22.5% of patients using normalized GFR units and 9.9% to 19.1% of patients using absolute units. Age, handgrip strength, CRP, suPAR, NGAL, and smoking status had significant association with eGFR discrepancies between creatinine- and cystatin C-based equations.

**CONCLUSIONS:** Significant discrepancies in eGFR and CKD classification were observed when switching between eGFR equations in acutely hospitalized elderly patients. Switching from a creatinine-based equation to its corresponding cystatin C-based equation resulted in lower GFR estimates, and these differences were larger than in community-dwelling older populations. Switching between CKD-EPI<sub>Cr</sub>, CG<sub>Cr</sub>, and the alternative equations would result in clinically relevant changes to medication prescribing. Discrepancies between equations were associated with high age, muscle weakness and inflammation. This article is protected by copyright. All rights reserved.

How to solve this challenge?

# Measurement of renal function



- Glomerular Filtration Rate (GFR) can be measured precisely with exogenous markers such as:

Inulin, Cr-51-EDTA, Tc-99m-DTPA or Iohexol.

Expensive, time-consuming and complicated setup.

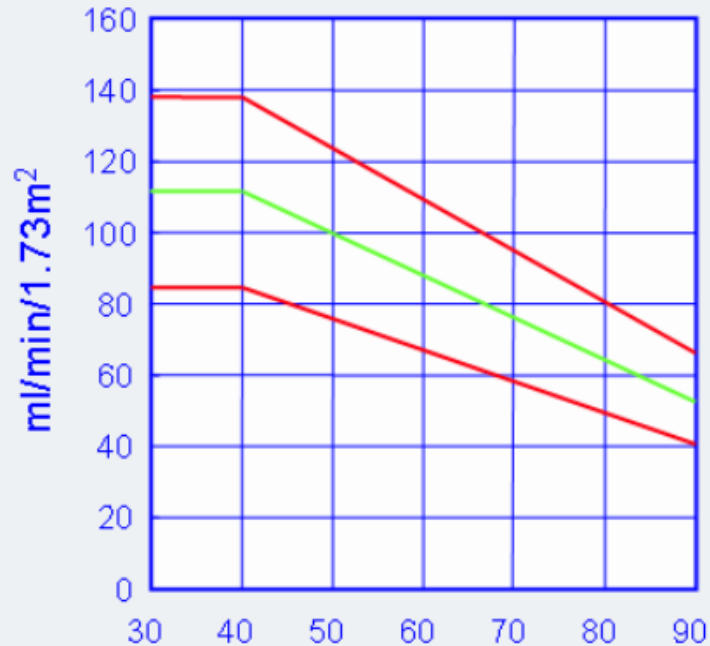
The price is approx. 500 EUR per measurement

- Estimated Glomerular Filtration Rate (eGFR) is used in the clinic to assess the renal function
- Creatinine is the standard biomarker used to calculate eGFR.  
The price is approx. 0.7 EUR per measurement

# The renal function decreases with age

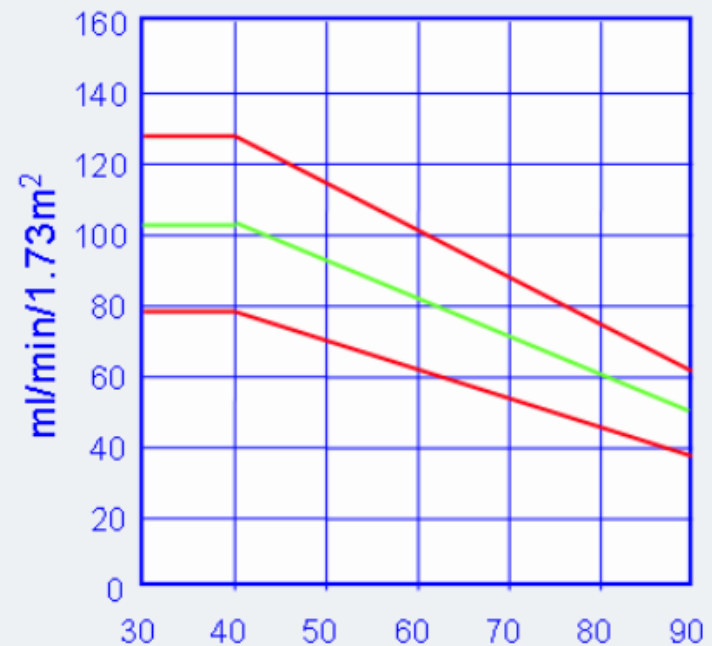
## GFR reference interval

Standard GFR men



Age, years

Standard GFR female



Age, years

\* Brøchner-Mortensen et al. 1977;11: 257-262

— Mean  
— ± 2SD

# Sex Differences in Age-Related GFR Loss

## METHODS

General population cohort, aged 50-62, no self-reported kidney disease, diabetes or CVD. N=1837



## The Renal Iohexol Clearance Survey (RENIS)

11 years follow-up with iohexol clearance



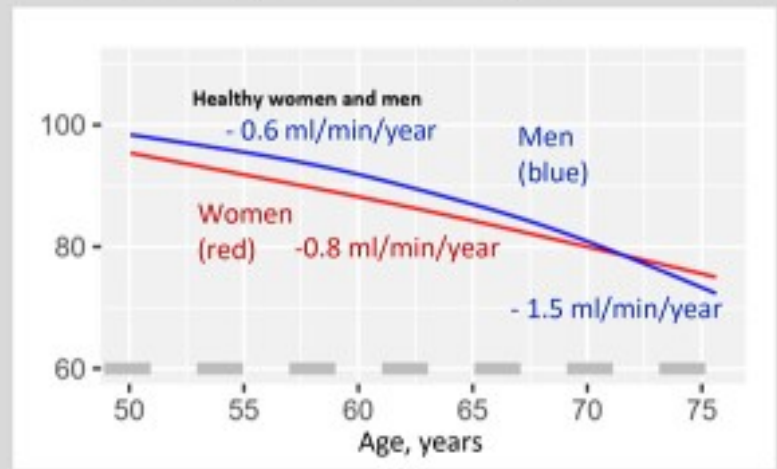
## OUTCOME:

Wehling M, 2013

«Healthy person» (ascertained at each visit):

- Non-smoking
- No diabetes
- No hypertension
- BMI < 30 kg/m<sup>2</sup>
- ACR < 30 mg/g
- No cardiovascular disease
- No cancer

## Mean GFR change rates for healthy women and men



## Conclusion

Women have a lower GFR, but a slower decline rate during aging, independent of health status.

doi: 10.1681/ASN.2022030323

Melson et al., 2022

# Causes of Renal Impairment

## Chronic

- Primary kidney diseases
- Diabetes
- Hypertension
- Heart failure
- Arteriosclerosis
- Malignancy
- Systemic inflammatory diseases

# 1.1 Definition of CKD

**1.1.1:** CKD is defined as abnormalities of kidney structure or function, present for  $\geq 3$  months, with implications for health (Table 2). (*Not Graded*)

Table 2 | Criteria for CKD (either of the following present for  $\geq 3$  months)

Markers of Kidney Damage	Albuminuria $> 30$ mg/day
	Urine sediment abnormalities (e.g., hematuria, red cell casts etc)
	Electrolyte and other abnormalities due to tubular disorders
	Abnormalities detected by histology
	Structural abnormalities detected by imaging
	History of kidney transplantation
Decreased GFR	GFR $< 60$ mL/min/1.73 m <sup>2</sup>



*Kidney Disease: Improving Global Outcomes*

www.kdigo.org

# Classification of chronic kidney disease

GFR category	GFR (mL/min/1.73 m <sup>2</sup> )	Terms
G1	≥90	Normal or high
G2	60–89	Mildly decreased
G3a	45–59	Mildly to moderately decreased
G3b	30–44	Moderately to severely decreased
G4	15–29	Severely decreased
G5	<15	Kidney failure

# Consequences of CKD?

**Which of the following justifies including GFR  $<60$  mL/min/1.73m<sup>2</sup> in defining CKD:**

- 1. increased risk for CVD**
- 2. increased risk of all-cause mortality**
- 3. increased risk of drug dosing errors**
- 4. increased risk of metabolic complications**
- 5. all of the above**

Approximately 10-15% of the world's population, with a significant number of unreported cases

# Potential challenges with the clinical standard eGFR equation

- The Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) equation based on creatinine (the standard equation) is recommended by KDIGO and The Danish Society of Nephrology KDIGO, 2012  
The Danish Society of Nephrology, 2015

- Creatinine is highly dependent on **muscle mass, age, sex and race**

Inker LA, Adv Chronic Kidney Dis. 2018

- Creatinine is poor at predicting future declines in eGFR

James MT, Lancet. 2010



- CKD-EPI creatinine was developed in a cohort where only 4% of participants were  $\geq 70$  years Levey AS, Ann. Intern. Med. 2009

- CKD-EPI<sub>crea</sub> was developed to increase the accuracy of GFR estimates  $> 60$  mL/min/1.73m<sup>2</sup> Levey AS, Ann. Intern. Med. 2009

## Potential challenges with the PK standard equation

- The Cockcroft-Gault (CG) equation from 1976 performs poorly across age and patient groups

Michels WM, CJASN 2010

$$eC_{cr} = \frac{(140 - \text{age}) \times \text{Mass} \times K}{\text{Creatinine}_{\text{serum}}} = \text{mL/min}$$

K = constant (1.23 in males, 1.04 in females)

Mass (kg)

Creatinine ( $\mu\text{mol/l}$ )



*The* NEW ENGLAND  
JOURNAL *of* MEDICINE

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## New Creatinine- and Cystatin C–Based Equations to Estimate GFR without Race

L.A. Inker, N.D. Eneanya, J. Coresh, H. Tighiouart, D. Wang, Y. Sang, D.C. Crews, A. Doria, M.M. Estrella, M. Froissart, M.E. Grams, T. Greene, A. Grubb, V. Gudnason, O.M. Gutiérrez, R. Kalil, A.B. Karger, M. Mauer, G. Navis, R.G. Nelson, E.D. Poggio, R. Rodby, P. Rossing, A.D. Rule, E. Selvin, J.C. Seegmiller, M.G. Shlipak, V.E. Torres, W. Yang, S.H. Ballew, S.J. Couture, N.R. Powe, and A.S. Levey, for the Chronic Kidney Disease Epidemiology Collaboration\*

Does not outperform the 2009 CKD-EPI equation in Northern European patients

# Now it's your turn to calculate!

<http://touchcalc.com/bis2.html> (use the equations CKD-EPI og BIS1)

<https://www.mdcalc.com/calc/3939/ckd-epi-equations-glomerular-filtration-rate-gfr> (CKD-EPI 2021)

<https://www.mdcalc.com/creatinine-clearance-cockcroft-gault-equation> (GC)

The patient is: female, 80 years, weight: 50 kg, p-creatinine 70  $\mu\text{mol/L}$

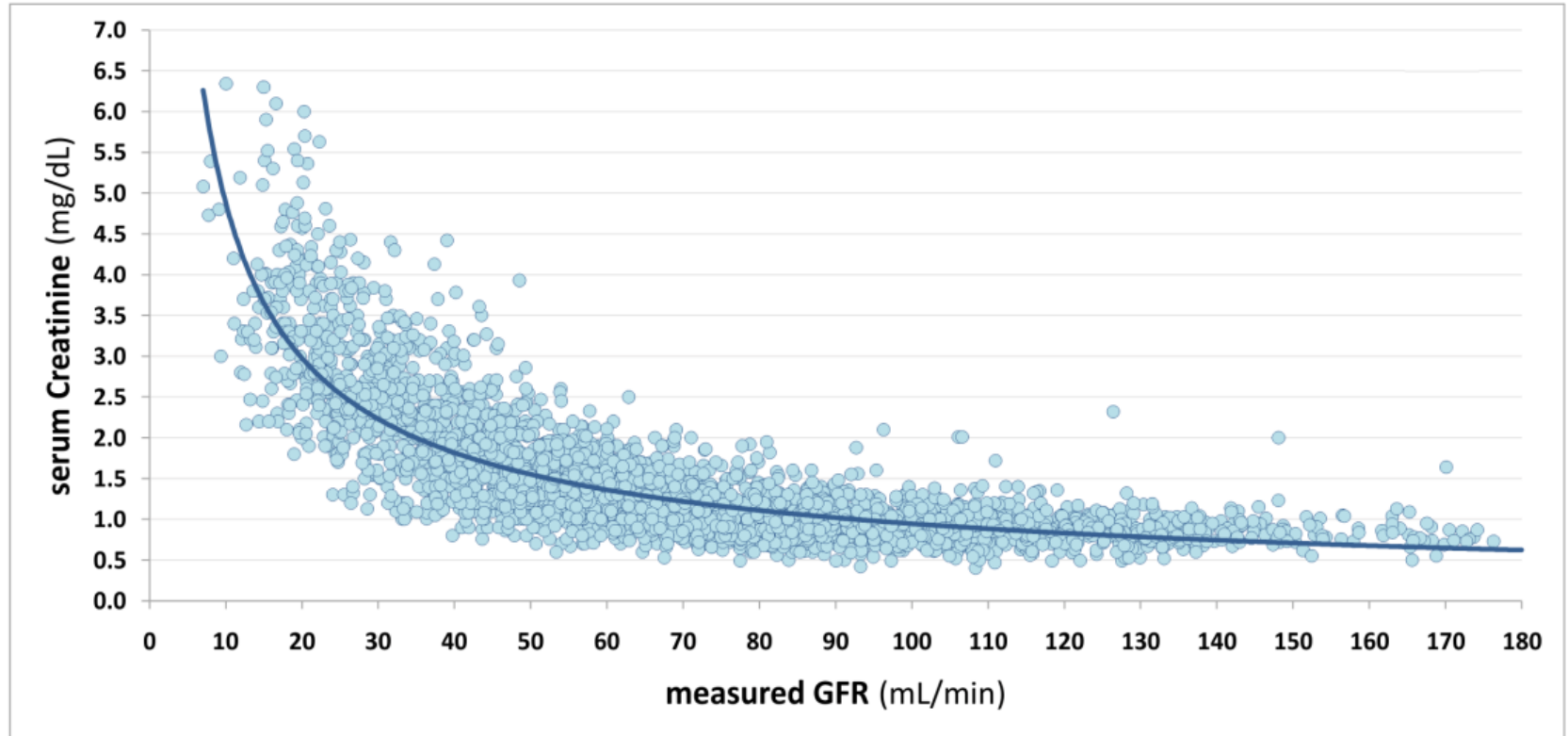
What result do you get?

**CKD-EPI = 71 mL/min/1,73m<sup>2</sup>**

**BIS1 = 58 mL/min/1,73m<sup>2</sup>**

**GC = 49 mL/min**

# Relationship between serum creatinine and mGFR



Sergio luis lima; 2017

# What is the accepted margin of error for the GFR estimates in clinical practice?

≈ 10 %

≈ 20 %

≈ 30 %



≈ 50 %

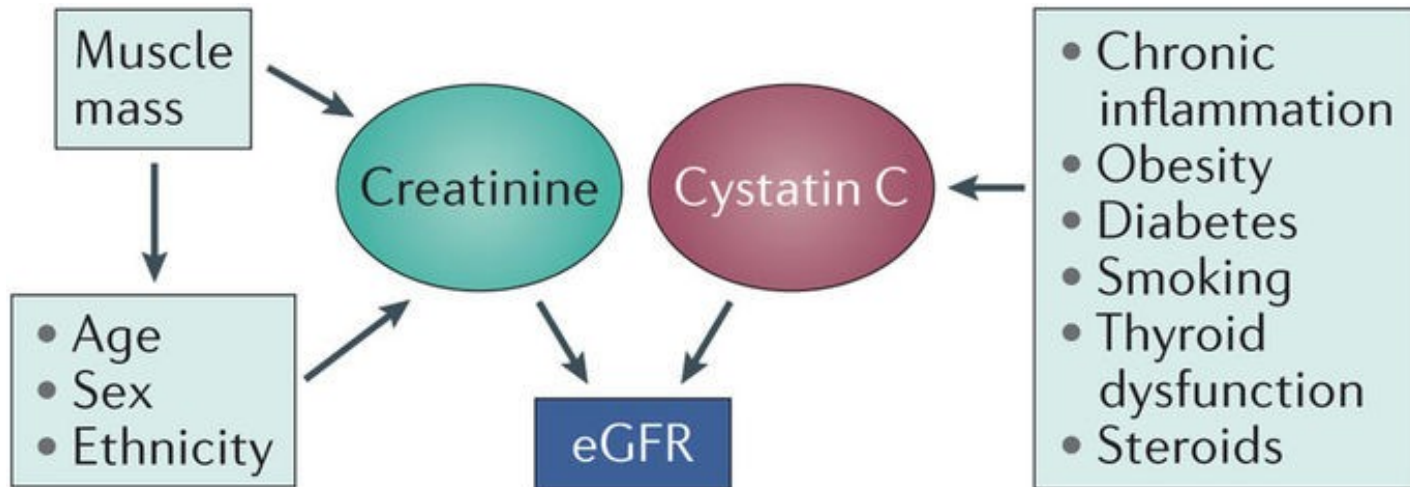
# Cystatin C



- Cystatin C is an alternative biomarker for eGFR  
KDIGO, 2012; The Danish Society of Nephrology, 2015
- Cystatin C is a protease inhibitor found in all body cells.
- The cystatin C concentration is largely independent of muscle mass, age and sex (as opposed to creatinine)  
Inker LA, Adv Chronic Kidney Dis. 2018
- Cystatin C is recommended by KDIGO and The Danish Society of Nephrology as a biomarker for eGFR in patients with reduced muscle mass  
KDIGO, 2012; The Danish Society of Nephrology, 2015
  - Malnourished patients
  - Amputation patients
  - Children
- Cystatin C sample price is approx. 5 EUR

# eGFR biomarkers and non-GFR determinants

No known endogenous biomarker for GFR is perfect alone!



*Reprinted from Glasscock et al. 2017 with permission from Nature Review Nephrology*

# The assumed best choice of eGFR equation?

- The CKD-EPI combination (CKD-EPI<sub>comb</sub>) equation based on creatinine and Cystatin C is more accurate than equations based on one biomarker alone....

Inker LA, NEJM 2012, 2021; KDIGO 2024

## A New Panel-Estimated GFR, Including $\beta_2$ -Microglobulin and $\beta$ -Trace Protein and Not Including Race, Developed in a Diverse Population



Lesley A. Inker, Sara J. Couture, Hocine Tighiouart, Alison G. Abraham, Gerald J. Beck, Harold I. Feldman, Tom Greene, Vilmundur Gudnason, Amy B. Karger, John H. Eckfeldt, Bertram L. Kasiske, Michael Mauer, Gerjan Navis, Emilio D. Poggio, Peter Rossing, Michael G. Shlipak, and Andrew S. Levey, on behalf of the CKD-EPI GFR Collaborators

CKD-EPI<sub>panel</sub>: creatinine, cystatin C, B2M and BTP  
Includes: age, sex and (race).

Table 2. Characteristics of endogenous biomarkers for Glomerular Filtration Rate [62–66].

Biomarker	Derived from	Distribution	Molecular mass (Kilo Daltons)	Non-GFR determinant
Creatinine	Muscle	Total body fluid	113	Sex, age, ethnicity, muscle mass, diet
Cystatin C	All nucleated cells	Extra-cellular fluid	13.300	Sex, age, smoking, steroids, thyroid dysfunction, C-reactive protein, obesity, diabetes
Beta-2-Microglobulin	All nucleated cells	Extra-cellular fluid	11.800	Sex, age, C-reactive protein, obesity, dyslipidemia
Beta-Trace Protein	Cerebrospinal fluid	Extra-cellular fluid	23.000 – 29.000	Sex, age, dyslipidemia



ARTICLE IN PRESS

Original Investigation

AJKD

## Performance of Panel-Estimated GFR Among Hospitalized Older Adults

*Esben Iversen, Anne Kathrine Bengaard, Aino Leegaard Andersen, Juliette Tavenier, Rikke Lundsgaard Nielsen, Helle Gybel Juul-Larsen, Lillian Mørch Jørgensen, Olivia Bornæs, Baker Nawfal Jawad, Anissa Aharaz, Anne Byriel Walls, Thomas Kallemose, Kim Dalhoff, Jan Olof Nehlin, Mads Hornum, Bo Feldt-Rasmussen, Morten Damgaard, Ove Andersen, and Morten Baltzer Houliind*

**Table 1.** Accuracy of CKD-EPI (current and new) and FAS Equations as Compared with Measured GFR Among Non-Black Older Medical Patients

Filtration Marker and eGFR Equation	Bias* in mL/min/1.73m <sup>2</sup> Median (95% CI)	P30* Percent (95% CI)	P15 <sup>§</sup> Percent (95% CI)	CKD class agreement* Percent (95% CI)
<i>Creatinine</i>				
CKD-EPI (ASR), current	-2.5 (-4.9 to 0.9)	91.5 (85.8 to 96.2)	67.9 (58.5 to 76.4)	68.9 (60.4 to 77.4)
CKD-EPI (AS), new	-7.1 (-9.2 to -5.1)	84.0 (76.4 to 90.6)	57.6 (48.1 to 67.0)	59.4 (50.0 to 68.9)
FAS (A)	5.5 (3.7 to 7.2)	92.5 (86.8 to 97.2)	56.6 (47.2 to 66.0)	56.6 (47.2 to 66.0)
EFKC (AS)	4.0 (1.8 to 6.4)	92.5 (86.8 to 97.2)	59.4 (50.0 to 68.9)	58.5 (49.1 to 67.9)
<i>Creatinine–Cystatin C</i>				
CKD-EPI (ASR), current	4.5 (2.9 to 6.5)	95.3 (90.6 to 99.1)	67.0 (57.5 to 75.5)	64.2 (54.7 to 72.6)
CKD-EPI (AS), new	1.7 (0.7 to 3.8)	95.3 (90.6 to 99.1)	75.5 (67.0 to 83.0)	69.8 (61.3 to 78.3)
FAS (AS)	9.9 (7.4 to 11.8)	94.3 (89.6 to 98.1)	44.3 (34.9 to 53.8)	50.0 (40.6 to 59.4)
<i>Panel#</i>				
CKD-EPI (AS) <sup>i</sup>	2.5 (0.6 to 4.5)	96.1 (92.2 to 99.0)	80.4 (72.5 to 88.2)	67.6 (58.8 to 76.5)
FAS (AS) <sup>ii</sup>	8.3 (6.2 to 10.7)	97.1 (93.1 to 100.0)	50.0 (40.2 to 59.8)	56.9 (47.1 to 66.7)



**Patient group, n=52**  
(≥65 years,  
acutely admitted)

Admission to  
the ED

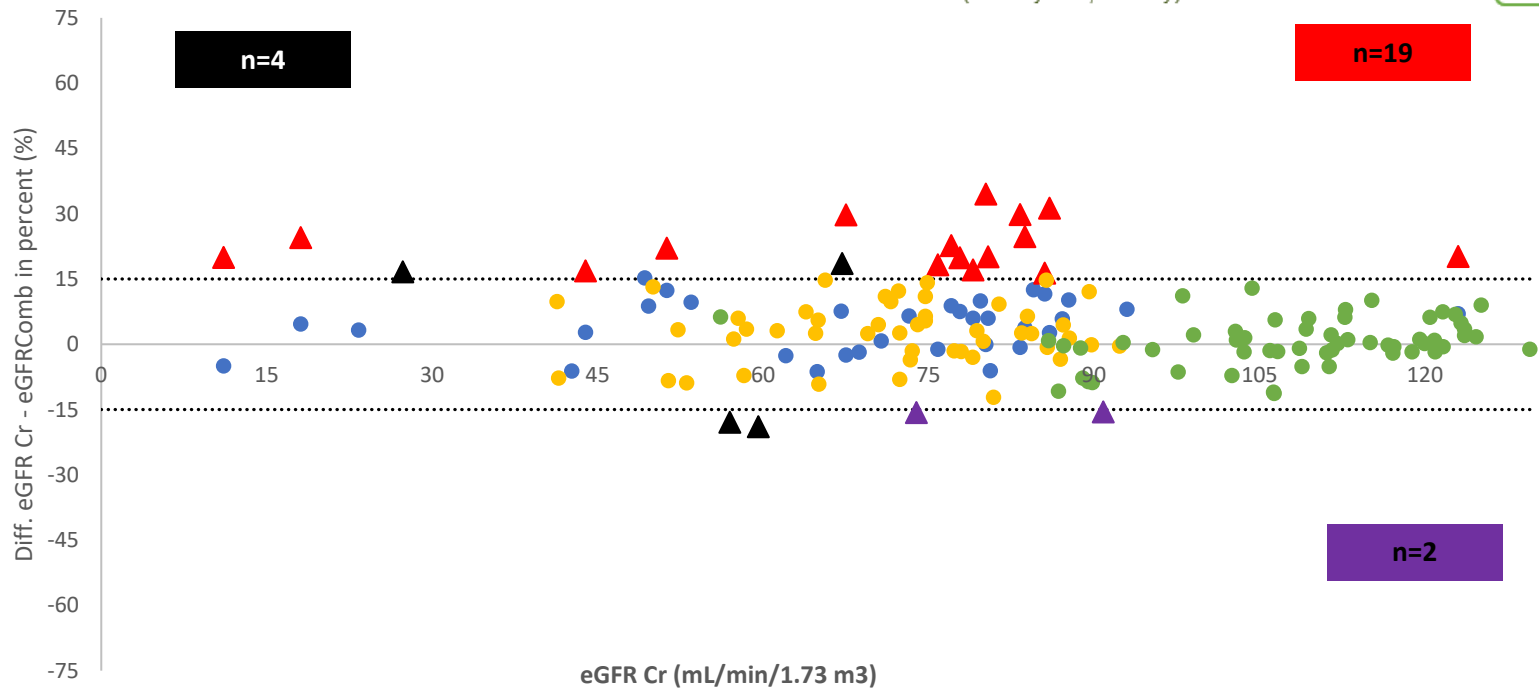
30-days after  
discharge

**Age-and sex-matched control group, n=52**  
(≥65 years, no acute admissions within 2 years  
prior to inclusion)

Inclusion

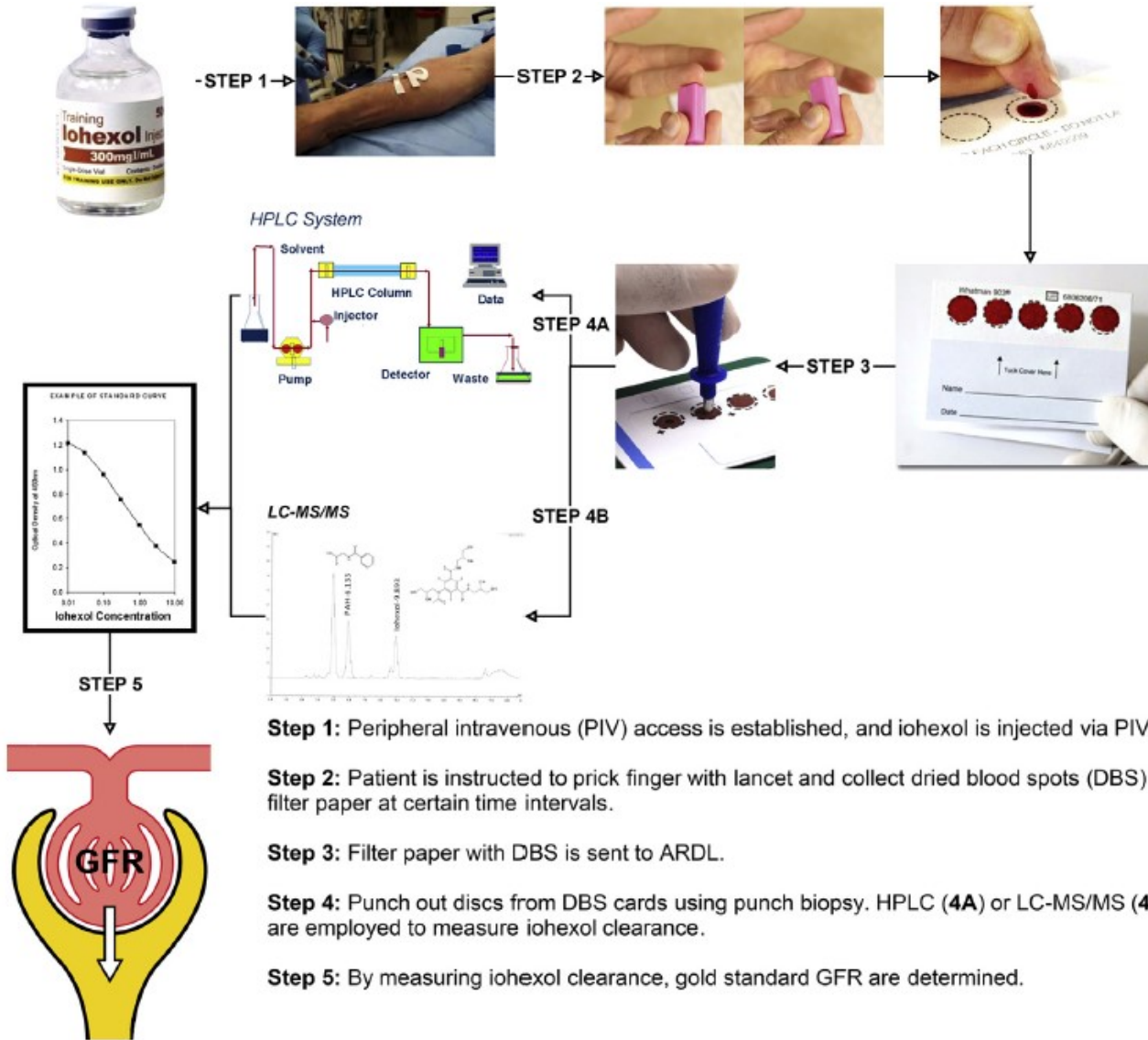
**Young control group, n=60**  
(20-35 years, healthy)

Inclusion



In review, 2025

# mGFR – Dried Blood Spots



**Step 1:** Peripheral intravenous (PIV) access is established, and iohexol is injected via PIV.

**Step 2:** Patient is instructed to prick finger with lancet and collect dried blood spots (DBS) on filter paper at certain time intervals.

**Step 3:** Filter paper with DBS is sent to ARDL.

**Step 4:** Punch out discs from DBS cards using punch biopsy. HPLC (**4A**) or LC-MS/MS (**4B**) are employed to measure iohexol clearance.

**Step 5:** By measuring iohexol clearance, gold standard GFR are determined.

# Dried blood spot testing versus standard i.v. sampling for GFR measurement with iohexol or $^{99m}\text{Tc}$ -DTPA



Table 1 | Performance of dried blood spot testing versus reference methods in 20 older adults

Variable	% Difference <sup>a</sup> (95% CI <sup>b</sup> )	P15 <sup>c</sup> (95% CI <sup>b</sup> )	P10 <sup>c</sup> (95% CI <sup>b</sup> )
mGFR <sub>iohexol-DBS</sub> vs. mGFR <sub>iohexol</sub>	3.5 (0.0 to 8.7)	100	100
mGFR <sub>iohexol-DBS</sub> vs. mGFR <sub><math>^{99m}\text{Tc}</math>-DTPA</sub>	-5.1 (-6.6 to -1.7)	100	80 (60 to 95)

CI, confidence interval; DBS, dried blood spot testing; mGFR, measured glomerular filtration rate;  $^{99m}\text{Tc}$ -DTPA,  $^{99m}\text{Tc}$ technetium-diethylene-triamine-pentaacetate.

<sup>a</sup>Percentage difference is calculated as follows:  $(\text{mGFR}_{\text{iohexol-DBS}} - \text{reference}) \times 100\%$ .

<sup>b</sup>The 95% CIs are calculated with bootstrap methods (10,000 iterations).

<sup>c</sup>P15 and P10 represent the percentage of mGFR<sub>iohexol-DBS</sub> values within 15% and 10%, respectively.



# Comparison of Kidney Function Measures as Covariates on Gentamicin Clearance

Covariate	Unit	OFV	-ΔOFV	Covariate effect
mGFR	mL/min	786.083	112.236	0.991
mGFR	mL/min/1.73 m <sup>2</sup>	813.380	84.939	1.001
eGFR <sub>CKD-EPI-21-COMB</sub>	mL/min	816.657	81.662	0.979
eGFR <sub>CKD-EPI-12-COMB</sub>	mL/min	817.322	80.998	0.974
eGFR <sub>PANEL</sub>	mL/min	817.474	80.845	1.001
eGFR <sub>EKFC-COMB</sub>	mL/min	821.862	76.457	1.088
eGFR <sub>CKD-EPI-CYSC</sub>	mL/min	826.487	71.832	0.877
eGFR <sub>EKFC-CYSC</sub>	mL/min	828.628	69.691	1.009
eGFR <sub>PANEL</sub>	mL/min/1.73 m <sup>2</sup>	830.139	68.180	1.040
eGFR <sub>EKFC-CYSC</sub>	mL/min/1.73 m <sup>2</sup>	830.813	67.506	1.127
eGFR <sub>CKD-EPI-09-CR</sub>	mL/min	831.618	66.701	1.016
eGFR <sub>CKD-EPI-21-CR</sub>	mL/min	831.768	66.552	1.047
eGFR <sub>CKD-EPI-21-COMB</sub>	mL/min/1.73 m <sup>2</sup>	832.332	65.987	0.993
eGFR <sub>CKD-EPI-CYSC</sub>	mL/min/1.73 m <sup>2</sup>	832.730	65.590	0.933
eGFR <sub>EKFC-CR</sub>	mL/min	833.300	65.019	1.027
eGFR <sub>CKD-EPI-12-COMB</sub>	mL/min/1.73 m <sup>2</sup>	833.454	64.865	0.983
eGFR <sub>EKFC-COMB</sub>	mL/min/1.73 m <sup>2</sup>	835.155	63.164	1.131
CrCL <sub>CG</sub>	mL/min/1.73 m <sup>2</sup>	838.050	60.269	0.828
CrCL <sub>CG</sub>	mL/min	844.002	54.317	0.710
eGFR <sub>EKFC-CR</sub>	mL/min/1.73 m <sup>2</sup>	850.159	48.160	0.987
eGFR <sub>CKD-EPI-09-CR</sub>	mL/min/1.73 m <sup>2</sup>	850.766	47.553	0.951
eGFR <sub>CKD-EPI-21-CR</sub>	mL/min/1.73 m <sup>2</sup>	850.768	47.551	0.986

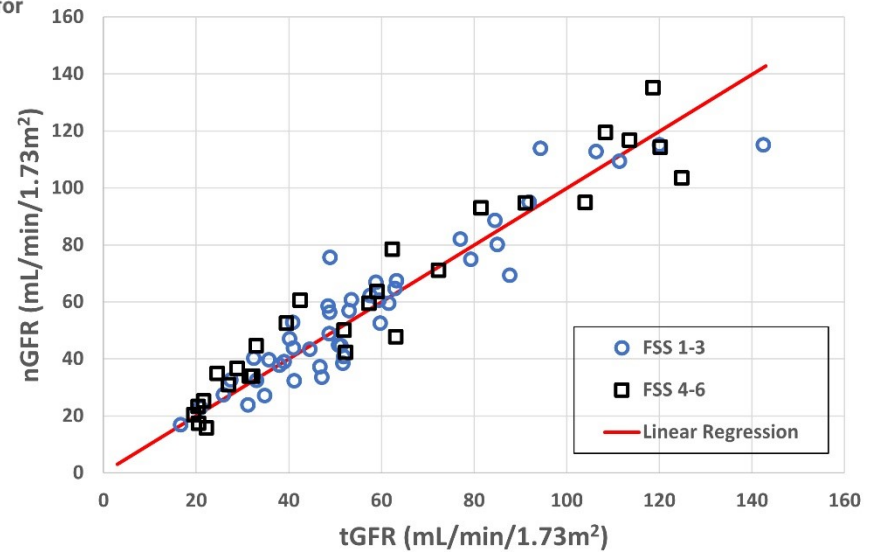
# Transdermal GFR measurement



## Kidney Function Measurement Technology



MediBeacon products are in various stages of clinical development and are NOT yet approved for human use.





ASN, 2022



**REVIEW**

# Reconsideration of the current models of estimated kidney function-based drug dose adjustment in older adults: The role of biological age

**Radin Alikhani**  | **Manjunath P. Pai** 

How does biological age affect the decline in mGFR and differences in eGFR?



# Thank you for your attention

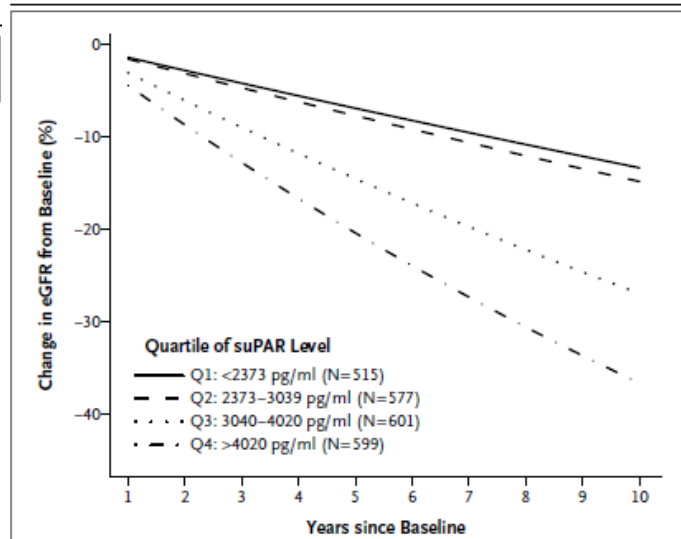


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ORIGINAL ARTICLE

## Soluble Urokinase Receptor and Chronic Kidney Disease

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Howard Trachtman, M.D., Mosaab Awad, M.D., Shikha Wadhvani, M.D.,  
Mehmet M. Altintas, Ph.D., Changli Wei, M.D., Ph.D.,  
Anna L. Hotton, Ph.D., M.P.H., Audrey L. French, M.D.,  
Laurence S. Sperling, M.D., Stamatios Lerakis, M.D., Arshed A. Qyyumi, M.D.,  
and Jochen Reiser, M.D., Ph.D.



ORIGINAL ARTICLE

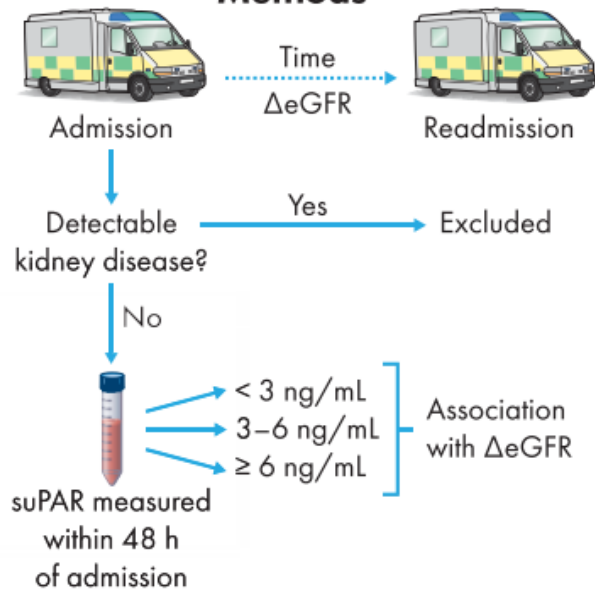
## Soluble Urokinase Receptor and Acute Kidney Injury

Salim S. Hayek, M.D., David E. Leaf, M.D., Ayman Samman Tahhan, M.D.,  
Mohamad Raad, M.D., Shreyak Sharma, M.B., B.S.,  
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Steven D. Weisbord, M.D., Arshed A. Qyyumi, M.D.,  
and Jochen Reiser, M.D., Ph.D.

# Soluble urokinase plasminogen activator receptor (suPAR) and decline in kidney function among patients without kidney disease

suPAR is a marker of systemic chronic inflammation that can be measured from routine blood samples. Elevated suPAR has been linked to a range of disease processes including kidney disease.

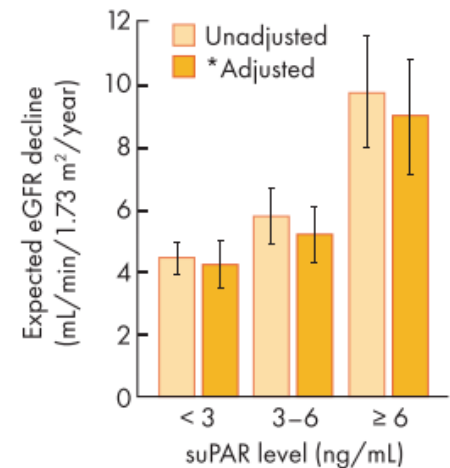
## Methods



## Results

### Cohort characteristics (N = 5124), median or percent

Age	66 years
Female	51%
Diabetes	16%
Hypertension	35%
suPAR	2.9 ng/mL
Baseline eGFR	88 mL/min/1.73 m <sup>2</sup>
Length of admission	0.9 days
Time to readmission	144 days



\*Adjusted for age, sex, C-reactive protein, sodium, diabetes, hypertension and cardiovascular disease

**Conclusion: Routine suPAR measurements may have utility for the early detection of kidney disease.**

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Clinical Kidney Journal (2022)  
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