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KINETIC ESTIMATED GLOMERULAR FILTRATION RATE: A BEDSIDE TOOL FOR EARLY DETECTION OF ACUTE KIDNEY INJURY

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OBJECTIVES

- Recognize the limitations of serum creatinine in assessing renal function during acute kidney injury
- Explore the utility of kinetic estimated glomerular filtration rate (KeGFR) as an alternative tool in accurately evaluating renal function during acute kidney injury.

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INTRODUCTION

- Serum creatinine (Scr) is a valid measure of renal filtration function in steady-state conditions, but not a reliable marker during acute kidney injury (AKI)
- Unreliable because of rapid changes to volume status[7] and the time it takes for creatinine to accumulate in order to reflect changes to kidney function[2]
- Kinetic estimated glomerular filtration rate (KeGFR) is a simplified formula that is helpful in determining renal function in AKI
- We report a case of a patient with oliguric AKI and demonstrate the utility of KeGFR to assess renal function and make an earlier diagnosis of AKI

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WHAT IS KINETIC ESTIMATED GLOMERULAR FILTRATION RATE?

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Kinetic eGFR is:

- An equation that estimates renal function (ie **GFR)** in the setting of a changing serum creatinine
- Calculates the GFR it would have taken to get from creatinine “A” to creatinine “B” in “x” amount of time

1972: Jelliffe & Jelliffe → 1975: Chiou & Hsu → 1985: Moran & Myers → 2012: Yashiro et al

1985: Moran & Myers: $KeGFR = \left(Gen - \frac{d[Cr]}{dt} \cdot V_0\right) / [Cr]_{(t)}$

2012: Yashiro et al: $KeGFR = \left(Gen - \frac{\Delta[Cr]}{\Delta t} \cdot V_0\right) / [Cr]_{Mean}$

2013: Chen[2]

$$KeGFR = \frac{SSPCr \text{ x } CrCl}{MeanPCr} x(1 - \frac{24x\Delta PCr}{\Delta Time(h)xMax\Delta PCr/day})$$

SSP_{Cr}: Steady state plasma creatinine, CrCl: Creatinine clearance (using Cockgroft-Gault or MDRD equations which rely on steady state creatinine), $MeanP_{Cr}$: Mean plasma creatinine, ΔP_{C}: End plasma creatinine minus start plasma creatinine, ΔTime(h): Hours in between creatinine measurements, $Max\Delta P_{Cr}$/Day: Maximum change in plasma creatinine in a day

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$$KeGFR = \frac{SSPCr \text{ x } CrCl}{MeanPCr} x(1 - \frac{24x\Delta PCr}{\Delta Time(h)xMax\Delta PCr/day})$$

- Takes something physicians are doing qualitatively every day and turns it into a quantitative value
- Kinetic eGFR has been validated in at least 3 independent studies[4, 5, 6]
  - Was shown to perform sufficiently well in intensive care unit and kidney transplant settings, and in head-to-head comparisons with biomarkers (NGAL, [TIMP-2]*[IGFBP7])

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CASE PRESENTATION

ID: An 83 y/o M with history of severe AS and chronic HFrEF

Presented w/ acute decompensated heart failure and was scheduled for transcatheter aortic valve replacement (TAVR)

Three days before TAVR, received intravenous contrast for imaging studies. One day before TAVR, received further contrast during cardiac catheterization.

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CASE PRESENTATION

During the procedure, he received omnipaque contrast and had hypotension.

Postoperative course was complicated by cardiogenic shock requiring 3 pressors in the ICU.

On postoperative day (POD) 2, he developed oliguria.

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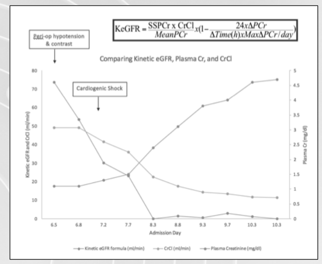

Figure 1: Comparing Kinetic eGFR, Plasma Creatinine, and Creatinine Clearance
SSP_{Cr}: Steady state plasma creatinine, CrCl: Creatinine clearance (using Cockgroft-Gault or MDRD equations), $MeanP_{Cr}$: Mean plasma creatinine, ΔP_{Cr}: End plasma creatinine minus start plasma creatinine, ΔTime(h): Hours in between creatinine measurements, $Max\Delta P_{Cr}$/Day: Maximum change in plasma creatinine in a day

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OBJECTIVE DATA

PHYSICAL EXAM

No peripheral edema
Euvolemic

LABORATORY DATA

Serum Creatinine:
- Baseline 0.9 – 1.1
- POD2: 2.4
- POD4: 4.7

Kinetic eGFR (ml/min)
- Baseline 73 ml/min
- POD0: 53
- POD2-POD4: 0

URINE STUDIES

FENa: 0.33%
FEUrea: 19.49%
Microscopy: muddy brown casts

RENAL ULTRASOUND
No hydronephrosis

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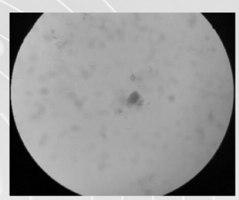

Figure 2: Urine microscopy
Clean catch, 40x: shows 0 - 1 muddy brown granular cast / LPF

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Sample Application of Kinetic eGFR

Date	Day	Hours between Creatinine Measurements	Plasma Creatinine (mg/dl)	Kinetic eGFR formula (ml/min)	SSPcr	CrCl (ml/min)	MeanPcr	delta Pcr	Max DltaPcr /day
2/1	0.00		1.3		1.2	41.5			
2/2	0.25	6	1.1	73.6363636	1.2	49.1	1.2	-0.2	1.6
2/3	1.25	24	1.3	36.3461538	1.2	41.5	1.2	0.2	1.6
2/3	1.83	14	0.9	93.5064935	1.2	60	1.1	-0.4	1.6
2/4	2.29	11	1.2	30.3896104	1.2	45	1.05	0.3	1.6
2/4	2.83	13	1.1	57.1359076	1.2	49.1	1.15	-0.1	1.6
2/5	3.21	9	1.2	39.1304348	1.2	45	1.15	0.1	1.6
2/5	3.79	14	1.4	27.9748823	1.2	38.6	1.3	0.2	1.6
2/6	4.33	13	1.3	41.183432	1.2	41.5	1.35	-0.1	1.6
2/7	5.33	24	1.3	38.3431953	1.2	41.5	1.3	0	1.6
2/7	5.79	11	1.1	62.4793388	1.2	49.1	1.2	-0.2	1.6
2/8	**6.29**	**12**	**1.3**	**31.1538462**	**1.2**	41.5	**1.2**	**0.2**	**1.6**
2/8	**6.54**	**6**	**1.1**	**73.6363636**	**1.2**	49.1	**1.2**	**-0.2**	**1.6**
2/8	**6.75**	**5**	**1.1**	**53.553719**	**1.2**	49.1	**1.1**	**0**	**1.6**
2/9	7.21	11	1.3	30.2097902	1.2	41.5	1.2	0.2	1.6
2/9	7.71	12	1.5	23.1428571	1.2	36	1.4	0.2	1.6
2/10	8.25	13	2.4	-0.53254438	1.2	22.5	1.95	0.9	1.6
2/10	8.79	13	3.1	1.46176404	1.2	17.4	2.75	0.7	1.6
2/11	9.29	12	3.8	0.61784897	1.2	14.2	3.45	0.7	1.6
2/11	9.71	10	4	2.90769231	1.2	13.5	3.9	0.2	1.6
2/12	10.29	14	4.6	1.170013	1.2	11.7	4.3	0.6	1.6
2/12	10.33	1	4.7	-1.48249828	1.2	11.5	4.65	0.1	1.6
2/12	10.50	4	4.5	5.47826087	1.2	12	4.6	-0.2	1.6

$$\mathrm{KeGFR} = \frac{\mathrm{SSPCr \ x\ CrCl}}{MeanPCr} x\left(1 - \frac{24x\Delta PCr}{\Delta Time(h)xMax\Delta PCr/day}\right)$$

SSP_{Cr}: Steady state plasma creatinine

CrCl: Creatinine clearance (using Cockgroft-Gault equation)

CrCl (male) = ([140-age] × body weight) / (serum **creatinine** × 72)

$MeanP_{Cr}$: Mean plasma creatinine

ΔP_C: End plasma creatinine minus start plasma creatinine

ΔTime(h): Hours in between creatinine measurements

$Max\Delta P_{Cr}$/Day: Maximum change in plasma creatinine in a day

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FINAL DIAGNOSIS

Acute Kidney Injury- KDIGO Stage 3

Acute tubular necrosis secondary to hypotension and contrast-induced nephropathy

Section 2: AKI Definition

2.1.1: AKI is defined as any of the following (*Not Graded*):

- **Increase in SCr by ≥0.3 mg/dl (≥26.5 μmol/l) within 48 hours; or**
- **Increase in SCr to ≥1.5 times baseline, which is known or presumed to have occurred within the prior 7 days; or**
- **Urine volume <0.5 ml/kg/h for 6 hours.**

2.1.2: AKI is staged for severity according to the following criteria (Table 2). (*Not Graded*)

Table 2 | Staging of AKI

Stage	Serum creatinine	Urine output
1	1.5–1.9 times baseline OR ≥0.3 mg/dl (≥26.5 μmol/l) increase	<0.5 ml/kg/h for 6–12 hours
2	2.0–2.9 times baseline	<0.5 ml/kg/h for ≥12 hours
3	3.0 times baseline OR Increase in serum creatinine to ≥4.0 mg/dl (≥353.6 μmol/l) OR Initiation of renal replacement therapy OR, In patients <18 years, decrease in eGFR to <35 ml/min per 1.73 m^2	<0.3 ml/kg/h for ≥24 hours OR Anuria for ≥12 hours

KDIGO Clinical practice guidelines for acute kidney injury (2012)

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MANAGEMENT/OUTCOME/FOLLOW-UP

Patient was successfully weaned off pressors

AKI was managed by maintaining adequate blood pressure, avoiding nephrotoxic agents

Renal recovery occurred by POD5, with urine output >0.5cc/kg/hr and serum creatinine ultimately down to 1.4 by POD7

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DISCUSSION

KeGFR is simple, only requires monitoring SCr, and better reflects renal function during acute change in SCr such as in AKI

Our case demonstrates the utility of KeGFR especially to determine onset of AKI prior to rising SCr

This can lead to early nephrology consultation proved to improve patient outcomes

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QUIZ

Using serum creatinine to determine the extent of acute kidney injury is limited by which of the following?

A. rapid changes to volume status
B. time required for creatinine to accumulate in order to reflect extent of the injury
C. validity of estimated GFR calculations depends on steady-state serum creatinine measurements
D. all of the above

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QUIZ

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D. all of the above

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QUIZ

Explanation

- Volume of distribution of serum creatinine alters the measured value and its interpretation.[7]
- In the acute phase, GFR drops significantly but there has not been enough time for filtration markers such as creatinine to accumulate in order for it to reflect the extent of the injury.[2]
- Current estimated GFR calculations such as the Cockcroft-Gault equation, the Modification of Diet in Renal Disease (MDRD) study equation, and the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) are not accurate when serum creatinine is changing rapidly.[2]

For an explanation of the principles behind the Kinetic GFR equation as well as a step-by-step walk through of how to apply it in several different clinical scenarios, see:

Chen S. Retooling the creatinine clearance equation to estimate kinetic GFR when the plasma creatinine is changing acutely. Journal of the American Society of Nephrology : JASN. 2013;24(6):877-88.

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UCI School of Medicine

Mr. M, our patient

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THANK YOU!

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