Management of Chronic Kidney Disease

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ACP Meeting November 7, 2020

We humbly acknowledge those who have come before us

The University of Washington acknowledges the Coast Salish peoples of this land, the land which touches the shared waters of all tribes and bands within the Suquamish, Tulalip and Muckleshoot nations.

Management of CKD: Learning Objectives

Recognize	Recognize chronic kidney disease (CKD)
Identify and manage	Identify and manage risk factors in CKD
Learn	Learn how to manage CKD-associated complications
Determine	Determine when it is appropriate to refer to nephrology for further evaluation and treatment

Stages of Chronic Kidney Disease (CKD)

Stage	Description	eGFR (ml/min/ 1.73m^2)	Population Estimates*
Stage 1	Kidney damage with normal or increased GFR	≥90	11 million
Stage 2	Kidney damage with mild decrease in GFR	60-89	8.5 million
Stage 3	Moderate decrease in GFR	30-59	14.5 million
Stage 4	Severe decrease in GFR	15-29	0.9 million
Stage 5	Kidney Failure	<15 or dialysis	700,000

KDOQI Guidelines define CKD as either known kidney damage (microalbuminuria) or GFR<60ml/min/1.73m^2 for 3 or more months, eGFR is defined using the MDRD

**Coresh, et.al. JAMA, 2007, Updated CDC CKD Surveillance 2020*

Prognosis of CKD based on eGFR and albuminuria

- Estimated Glomerular Filtration Rate (eGFR) less than 60ml/min/1.73m^2 twice over 90 days
- Albuminuria 30 mg alb/g Creatinine or other kidney disease

Prognosis of CKD by GFR and albuminuria category

Prognosis of CKD by GFR and albuminuria categories: KDIGO 2012				Persistent albuminuria categories Description and range		
				A1	A2	A3
				Normal to mildly increased	Moderately increased	Severely increased
				<30 mg/g <3 mg/mmol	30–300 mg/g 3–30 mg/mmol	>300 mg/g >30 mg/mmol
GFR categories (ml/min per 1.73 m^2) Description and range	G1	Normal or high	≥90			
	G2	Mildly decreased	60–89			
	G3a	Mildly to moderately decreased	45–59			
	G3b	Moderately to severely decreased	30–44			
	G4	Severely decreased	15–29			
	G5	Kidney failure	<15			

Green, low risk (if no other markers of kidney disease, no CKD); yellow, moderately increased risk; orange, high risk; red, very high risk.

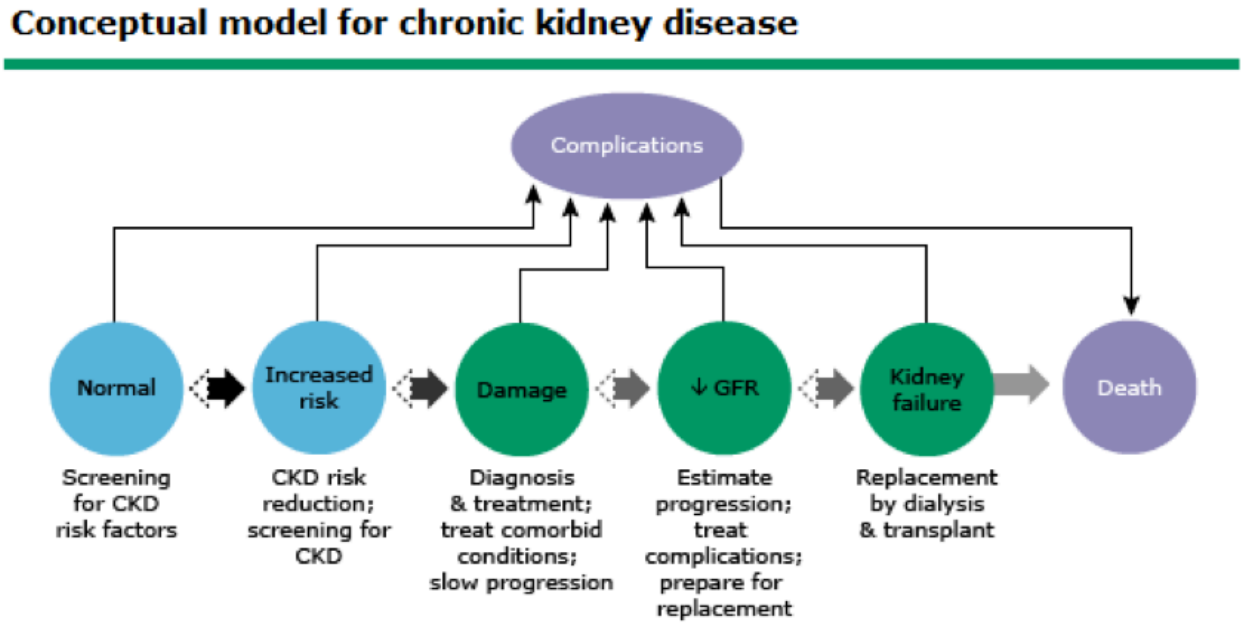
KDIGO Diabetes Guidelines, 2020

CKD is a Continuum of Clinical Findings

It is important to find a CAUSE for CKD.

It is critical to manage risk factors and complications early.

Preparation for dialysis is key.



Case 1

- **ID/CC:** 65-year old man with T2DM and now with worsening kidney function over the past year
- **PmHX:** HTN and early diabetic retinopathy
- **PE:** T 97.8, BP 130/80, HR 77
  - Lungs: clear bilaterally
  - CV: RRR no murmurs, rubs, gallops
  - Abd: soft nontender
  - Ext: trace+ edema
- **Labs:** Last 4 creatinine values:
  - 1.74 (eGFR 38), 2020
  - 1.35 (eGFR 53), 2019
  - 1.47 (eGFR 47), 2018
  - since 2002
- Na 140, K+ 4.3, HC03 19, BUN 40
- Albuminuria: 350 mg Alb/gCr
- HbA1c = 8.5%

Questions

- How would you define this patient's CKD and risk of progression?
- What of is the cause of his CKD
- What additional tests should you do?
- What is his risk of progressive kidney disease?
- What management strategies should you consider?

Estimated GFR or Creatinine Clearance

- Creatinine clearance is based on the 24-hour urine and measures the clearance of creatinine.
- Newer formulas estimate Glomerular filtration Rate (eGFR) based on the serum creatinine, age, sex, and race
- Many labs still use MDRD, Modification of Diet in Renal Disease Formula
- Newer CKD-EPI formula is more accurate for earlier stages of CKD
- Movement to remove the race variable in calculation of eGFR
  - Many academic medical have removed the variable
  - Cystatin C is another laboratory test that can measure kidney function that can be used to estimate GFR.

Definition of Albuminuria

- Urine Albumin to Creatinine Ratio (UACR)
- Preferred method for screening, assessing, and monitoring kidney damage.
- Can be measured on a spot morning urine
- Albumin level is normalized by the creatinine
- Total protein can be measured by spot total protein to creatinine ratio
  - Quantitate to make sure no gap in amount of urinary protein-
  - mg Protein/mg Creat= grams/day

Persistent albuminuria categories Description and range		
A1	**A2**	**A3**
Normal to mildly increased	Moderately increased	Severely increased
<30 mg/g <3 mg/mmol	30–300 mg/g 3–30 mg/mmol	>300 mg/g >30 mg/mmol

How do you manage patients with CKD?

- **C**ause
  - Work up reversible causes of CKD
- **K**idney
  - Prevent or slow progression of CKD
- **D**rugs
  - Adjust drug doses for eGFR, avoid renal toxic meds
- **C**omplications
  - Address CKD complications

- Causes of CKD
  - Vascular/Cardiac
    - Cardio-renal syndrome
  - Glomerular
    - GNs
  - Interstitial
    - Interstitial nephritis
  - Systemic
    - Diabetes, lupus, IgA, Amyloid, monoclonal gammopathy
  - Ureters/Bladder
    - Obstruction
    - Stones

GN→Nephrotic or Nephritic Syndrome: Refer to Nephrology

	Nephrotic syndrome	Nephritic syndrome
Predominant cell of injury	Podocyte	Mesangial / endothelial
Proteinuria	>3.5g/24h	variable
Edema	3-4+	mild
Blood pressure	variable	Elevated
Onset	Insidious / variable	abrupt
Urine sediment	lipiduria	Dysmorphic rbc & casts
Renal function	Normal / slow ↓	faster ↓ / RPGN

How do you manage patients with CKD?

- **C**ause
  - Work up reversible causes of CKD
- **K**idney
  - Prevent or slow progression of CKD
- **D**rugs
  - Adjust drug doses for eGFR, avoid renal toxic meds
- **C**omplications
  - Address CKD complications

- Rule out reversible causes of CKD
  - Urinary obstruction
  - Discontinue kidney toxic medications such as NSAIDS, Chinese Herbs, other meds
  - Is the patient on a high dose of diuretics or recently started a new medication such as an ACE-inhibitor or ARB?
  - Is there decreased renal perfusion
    - Hypovolemia-vomiting, diarrhea, bleeding
    - Hypotension secondary to medications, cardiac disease

Case 1

- **78-year old man with T2DM, worsening kidney function over the past year, now with Cr of 1.74 (eGFR=38 ml/min/m²)**
- Bladder scan showed elevated PVR. He was started on alpha-blocker
- Albuminuria: 350 mg/g,
  - Currently on high dose losartan 100mg
  - BP is well controlled and within goal
- **Stage Gb3, A2→Risk is HIGH for progression**
- HbA1c = 8.5%, DM is not well controlled
  - Consider SGLT-2 inhibiters

Prognosis of CKD by GFR and albuminuria category

Prognosis of CKD by GFR and albuminuria categories: KDIGO 2012

GFR categories (ml/min per 1.73 m²) Description and range				Persistent albuminuria categories Description and range		
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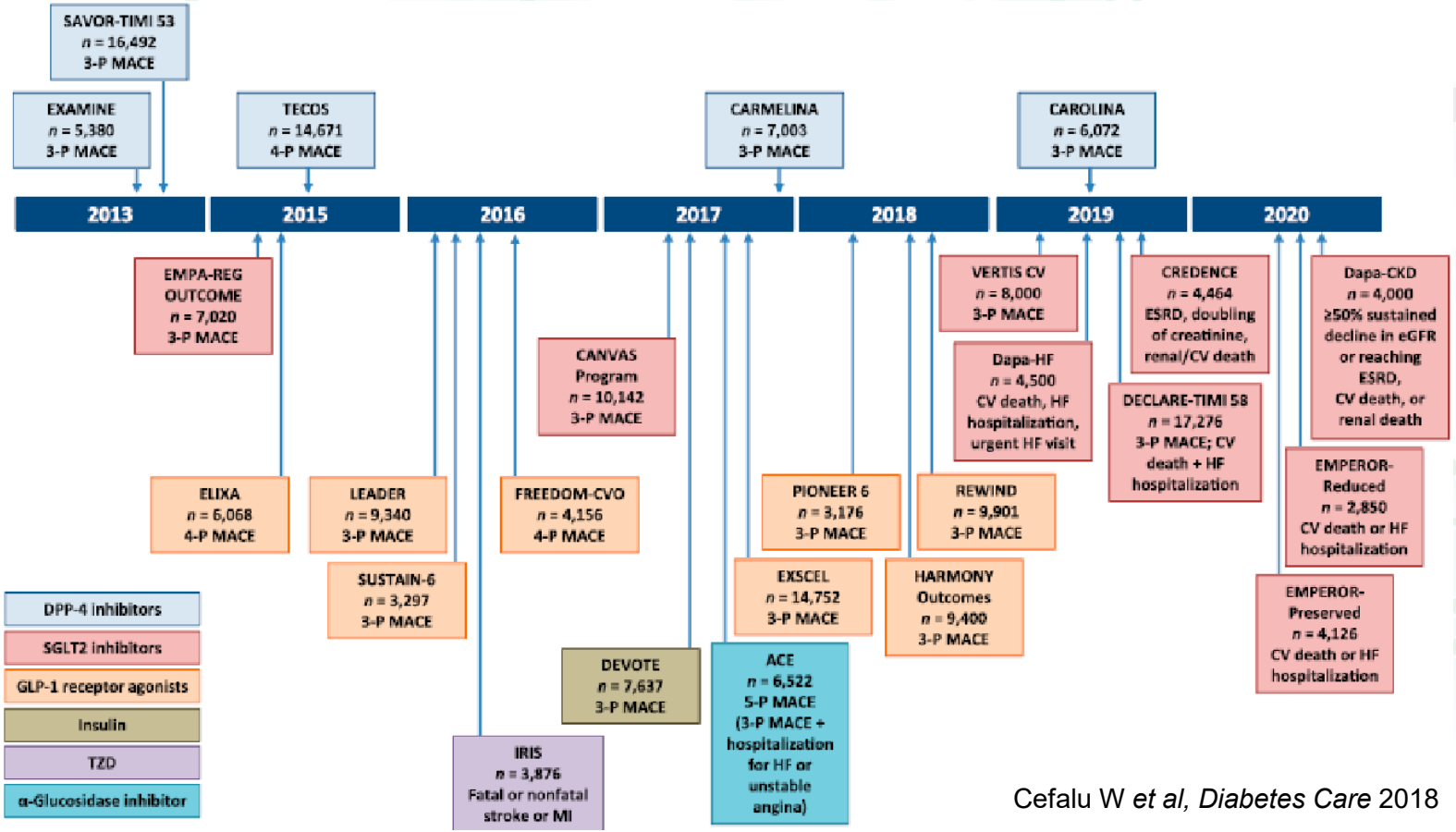
Clinical Trials of New Diabetes Drugs



Cefalu W *et al, Diabetes Care* 2018

CREDENCE Study

Enrolled Type2 DM patients with CKD

Double blind RCT

Albuminuria 300-5000mg/24 hours

eGFR 30-90ml/min/1.73m2

The NEW ENGLAND JOURNAL of MEDICINE

ESTABLISHED IN 1812 JUNE 13, 2019 VOL. 380 NO. 24

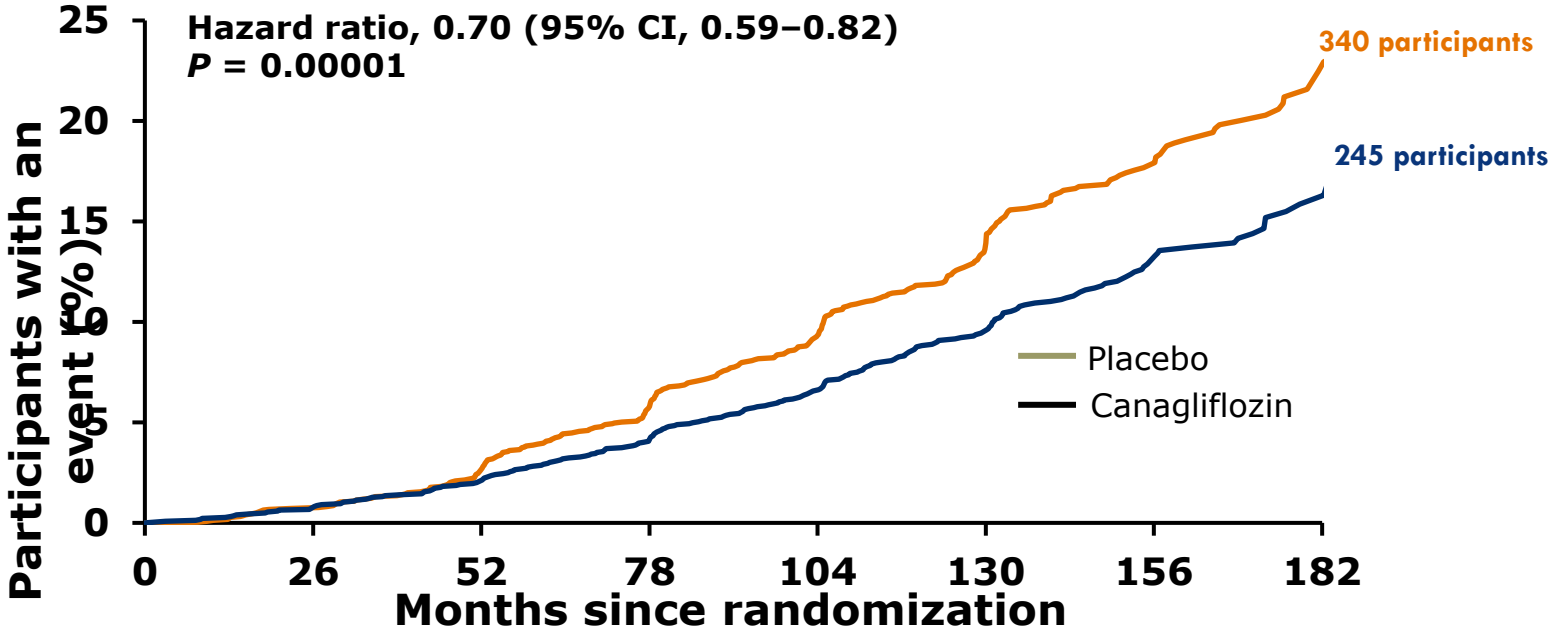
Canagliflozin and Renal Outcomes in Type 2 Diabetes and Nephropathy

V. Perkovic, M.J. Jardine, B. Neal, S. Bompoint, H.J.L. Heerspink, D.M. Charytan, R. Edwards, R. Agarwal, G. Bakris, S. Bull, C.P. Cannon, G. Capuano, P.-L. Chu, D. de Zeeuw, T. Greene, A. Levin, C. Pollock, D.C. Wheeler, Y. Yavin, H. Zhang, B. Zinman, G. Meininger, B.M. Brenner, and K.W. Mahaffey, for the CREDENCE Trial Investigators*

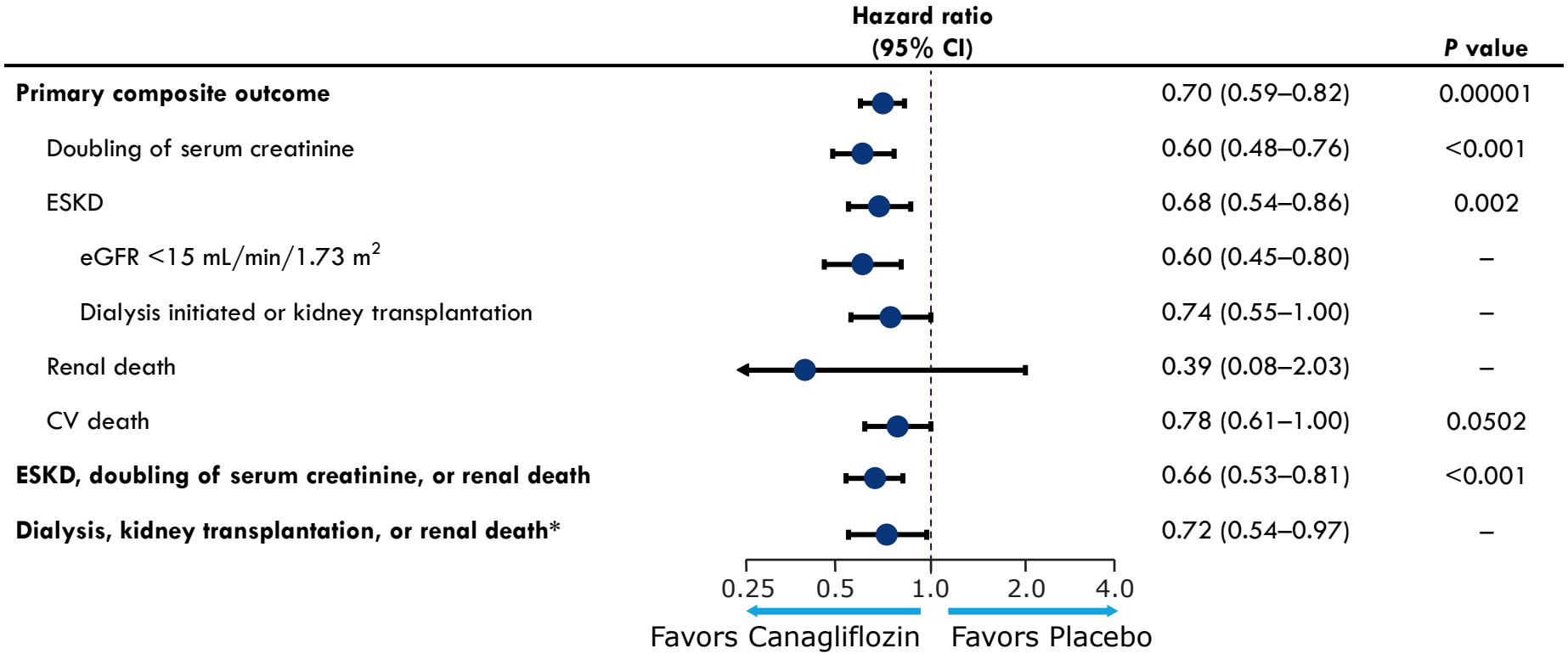
CREDENCE Study: Primary Endpoint Definitions

- **ESKD**
  - Chronic dialysis for ≥30 days
  - Kidney transplantation
  - eGFR <15 mL/min/1.73 m^2 sustained for ≥30 days by central laboratory assessment
- **Doubling of serum creatinine**
  - Doubling from the baseline average sustained for ≥30 days by central laboratory assessment
- **Renal death**
  - Deaths in patients who have reached ESKD who die prior to initiating renal replacement therapy
- **CV death**
  - Death due to MI, stroke, heart failure, sudden death, death during a CV procedure or as a result of procedure-related complications, presumed sudden CV death, death of unknown cause, or death resulting from a documented CV cause other than those listed

Primary Outcome: ESKD, Doubling of Serum Creatinine, or Renal or CV Death



CREDENCE: Summary Forest Plot



DM and non DM: DAPA-CKD

-Enrolled DM and non-DM subjects, n=4304

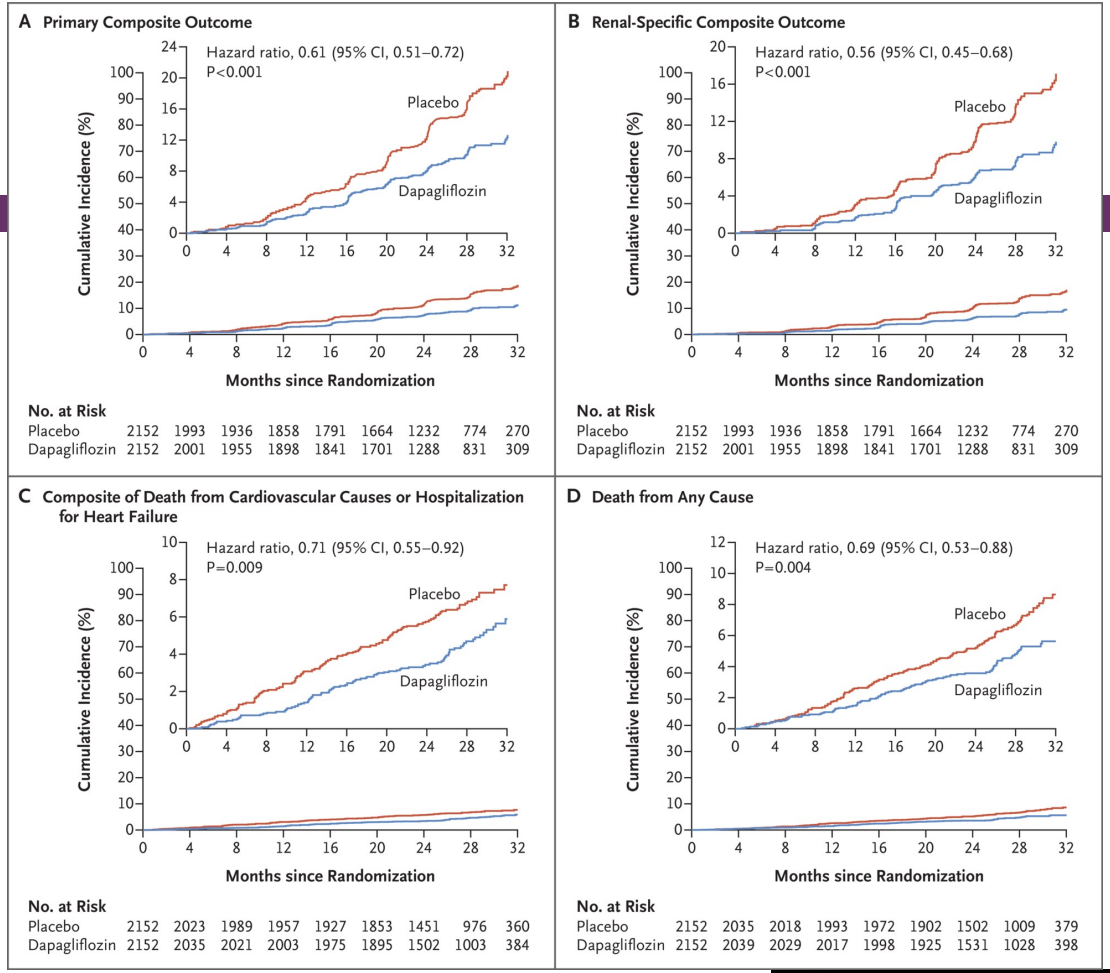
-eGFR 25-75 ml/min/1.73m^2 or

ACR 200-5000 mg/d

-Trial stopped at 2.4 yrs

-39% decrease in composite outcome

-44% decrease kidney outcomes

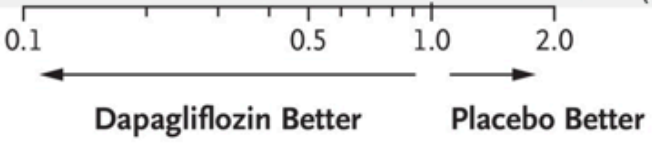


Heerspink HJL et al. N Engl J Med 2020;383:1436-1446

The NEW ENGLAND JOURNAL of MEDICINE

DAPA-CKD: Outcome According to Prespecified Subgroups at Baseline.

Subgroup	Dapagliflozin	Placebo	Hazard Ratio (95% CI)
Type 2 diabetes			
Yes	152/1455	229/1451	0.64 (0.52–0.79)
No	45/697	83/701	0.50 (0.35–0.72)
Estimated GFR			
<45 ml/min/1.73 m^2	152/1272	217/1250	0.63 (0.51–0.78)
≥45 ml/min/1.73 m^2	45/880	95/902	0.49 (0.34–0.69)
Urinary albumin-to-creatinine ratio			
≤1000	44/1104	84/1121	0.54 (0.37–0.77)
>1000	153/1048	228/1031	0.62 (0.50–0.76)
Systolic blood pressure			
≤130 mm Hg	46/793	96/749	0.44 (0.31–0.63)
>130 mm Hg	151/1359	216/1403	0.68 (0.56–0.84)



≤130 mm Hg 46/793 96/749 0.44 (0.31–0.63)
>130 mm Hg 151/1359 216/1403 0.68 (0.56–0.84)
0.1 0.5 1.0 2.0
Dapagliflozin Better Placebo Better

Heerspink HJL et al. N Engl J Med 2020;383:1436-1446

The NEW ENGLAND JOURNAL of MEDICINE

SUMMARY OF THE BENEFITS AND HARMS OF SGLT2 INHIBITORS, GLP-1 RECEPTOR AGONISTS, AND DPP-4 INHIBITORS, BY CLASS, AS OBSERVED IN LARGE, PLACEBO-CONTROLLED CLINICAL OUTCOMES TRIALS

		Cardiovascular effects		Kidney effects		
Drug	**HbA_{1c} lowering**	**Major atherosclerotic cardiovascular events**	**Heart failure**	**Albuminuria or albuminuria-containing composite outcome**	**GFR loss***	**Notable adverse effects**
SGLT2 inhibitors	↓ 0.6–0.9% (CKD G1–G2) ↓ 0.3–0.5% (CKD G3a) ↔ (CKD G3b–G4) NA (CKD G5)	↓/–	↓↓	↓↓	↓↓	Genital mycotic infections, diabetic ketoacidosis, possibly amputations (canagliflozin)
GLP-1 receptor agonists	↓ 1.0–1.2% (CKD G3a–4)	↓/–	–	↓	↓/–	Gastrointestinal, primarily nausea and vomiting
DPP-4 inhibitors	↓ 0.5–0.7% (CKD G3a–4)	–	–/↑	↓	–	Possibly heart failure (saxagliptin)

Effect of SGLT2 inhibitors on cardiovascular, renal and safety outcomes in patients with type 2 diabetes mellitus and chronic kidney disease: a systematic review and meta-analysis

Toyama & Neuen et al.

Diabetes, Obesity and Metabolism doi: 10.1111/dom.13648

@brendonneuen

27 included studies

Up to 7,363 participants

eGFR <60mL/min/1.73m^2

Overall effect estimate

P-heterogeneity for differences between individual agents

CV death, nonfatal MI, nonfatal stroke	Hospitalization for heart failure	eGFR slope	Renal composite outcome
RR 0.81 (95% CI 0.70-0.94)	**RR 0.61** (95% CI 0.48-0.78)	**1.35mL/min/1.73m^2/year** (95% CI 0.78-1.93)	**RR 0.71** (95% CI 0.53-0.95)
0.41	0.68	0.11	0.93

Conclusion: SGLT2 inhibitors reduce the risk of cardio-renal outcomes in patients with T2DM and CKD, without clear evidence of additional safety concerns beyond those already known for the class

The George Institute for Global Health

Case 2

- **ID/CC**: 55 yo female with CKD and decrease in eGFR over the last year. Patient has had more difficulty with blood pressure control.
- **PMHx**: HTN and CKD
- **PE**: T 97.8, BP 160/71, HR 77
  - Lungs: clear bilaterally
  - CV: RRR no murmurs, rubs, gallops
  - Abd: soft nontender
  - Ext: 1+ edema
- **Meds**: Losartan, HCTZ, amlodipine
- **Labs**: eGFR decreased from 55- to 40 ml/min/1.73m2 to over the last year
- Na 140, K+ 5.1, HC03 21, BUN 50, Creatinine 2.0 mg/dL
- Calcium is 8.5, phosphate 4.5
- UA showed 1+ proteinuria, no hematuria

Questions

- What is the cause of this persons HTN in the setting of CKD?
- What additional tests should you order?
- When should you refer to a nephrologist?

Resistant Hypertension

- Definition: HTN above goal in patients on 3 medications from different classes with one of the drugs a diuretic

Causes of Resistant HTN

- Improper BP measurement
- Excessive sodium intake
- Inadequate diuretic therapy
- Medications
  - Drug actions and interactions
    - NSAIDS
    - Illicit drugs
    - Contraceptives
    - Over the counter medications
- Excessive Alcohol
- Identifiable Secondary Causes of HTN
  - renal artery stenosis
  - Hypothyroidism
  - hyperparathyroidism
  - hyperaldosteronism
  - CKD
  - obstructive sleep apnea
  - pheochromocytoma
  - Cushing's disease

Resistant Hypertension Work up

- Make the diagnosis!
  - Renal artery duplex doppler
  - Thyroid function
  - PTH, calcium
  - Aldosterone/renin ratio
  - Cortisol level
  - Serum metanephrins
  - Renal ultrasound
  - Sleep study to rule out sleep apnea
- Ambulatory Blood pressure monitoring (ABPM)
- To establish non-dipper status or nocturnal hypertension
- Assess large variations in self-measured blood pressure values
- Evaluate whether antihypertensive therapy is moderating the early morning BP
- Assess elevated office BP in pregnant women, with suspected preeclampsia

Indications for ABPM

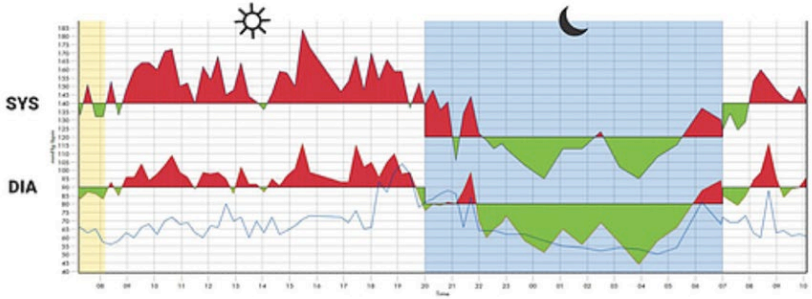
- Suspected masked hypertension
- Suspected white coat hypertension
- Suspected episodic hypertension (e.g., pheochromocytoma)
- Hypertension resistant to increasing medications
- Hypotensive symptoms while taking antihypertensive medications
- Autonomic dysfunction

APBM - Definitions

ABPM	Normal	HTN
24 hour SBP/DBP	<130/80	≥ 135/85
Daytime SBP/DBP	< 135/85	≥ 140/90
Night-time SBP/DBP	< 120/70	≥ 125/75

Ambulatory Blood Pressure Measurement
24 Hour ABPM Data Sample Report

Patient Name : Susan Hart
Test Date: 6/9/2015
Patient ID : 74642-D
Date of Birth : 3/11/1950
Gender : Female



Brachial BP Results

Period	Time	Samples	Mean SYS mmHg (+/- Std. Dev)	Mean DIA mmHg (+/- Std. Dev)	Mean HR BPM (+/- Std. Dev)	BP Load Sys (%)	BP Load Dia (%)
Overall	07:11-10:07 (26:56)	78	142 (+/-19.8)	88 (+/-15.3)	69 (+/-11.2)	68	55
Awake Period	07:00-20:00	55	151 (+/-13.3)	95 (+/-8.7)	69 (+/-10.5)	78	69
Asleep Period	20:00-07:00	23	120 (+/-15.8)	71 (+/-14.1)	67 (+/-12.9)	43	22
White Coat Period	07:11-08:10 (1st Hr.)	5	Max: 151 Mean: 137	Max: 87 Mean: 85	Max: 66 Mean: 63	20	0
Asleep Dip	SYS = 20.4% DIA =25.7%						

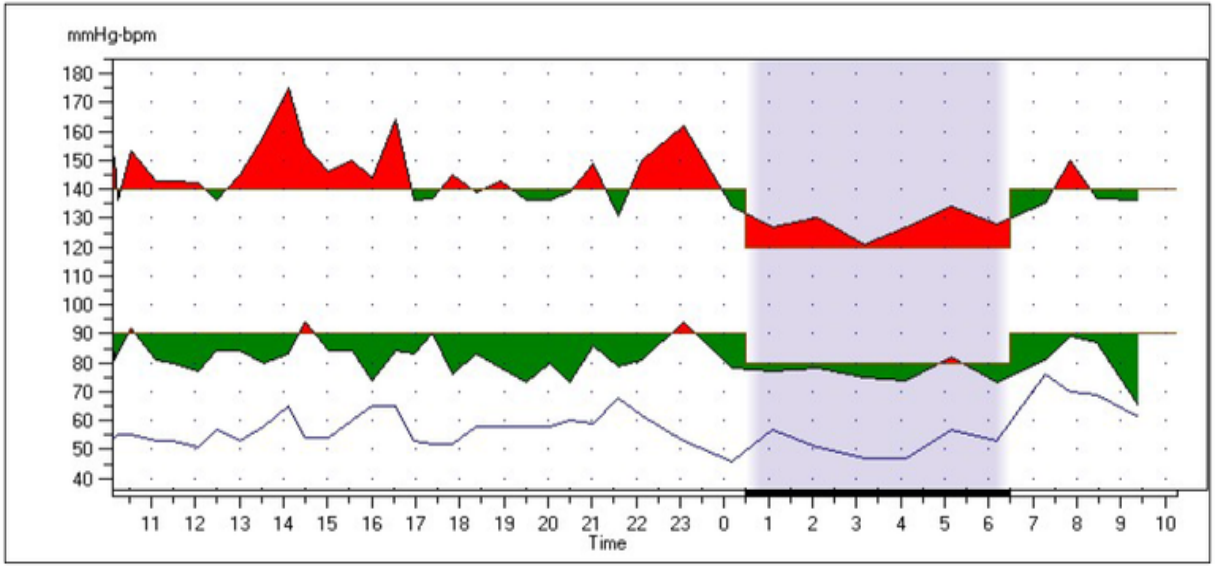
Interpretive Summary

Based upon ESH and AHA recommendations, the ABPM data suggests:
- 24 hour SYS and DIA hypertension (142/88 mmHg)
- awake SYS and DIA hypertension (151/95 mmHg)
- asleep SYS and DIA hypertension (120/71 mmHg)

Asleep dip is 20.4 % SYS and 25.7 % DIA, Dipper (normal).

Sun Tech Med

APBM: Case 2



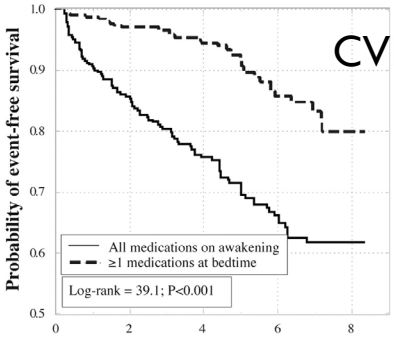
Period	Time	Samples	Mean Sys mmHg (+/- Std.Dev.)	Mean Dia mmHg (+/- Std.Dev.)	Mean HR BPM (+/- Std.Dev.)	BP Load Sys %	BP Load Dia %
Overall	10:09-09:53 (23:44)	39	142 (11.2)	81 (6.1)	57 (6.6)	67	10
Awake Period	06:30-00:30	33	145 (9.9)	82 (6.2)	58 (6.5)	61	9
Asleep Period	00:30-06:30	6	128 (4.3)	76 (3.3)	52 (4.5)	100	17
Asleep Dip: Sys = 11.8% Dia = 6.8%							

Case 2

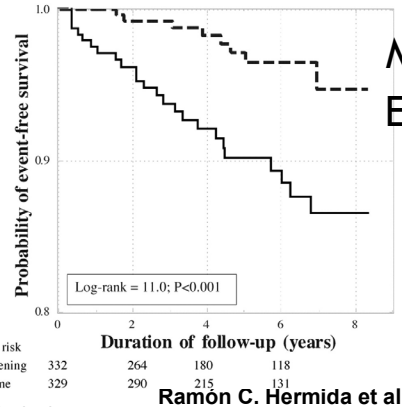
- **55 yo female with CKD and decrease in eGFR over the last year. Patient has had more difficulty with blood pressure control.**
- Aldosterone/renin were normal
- TSH normal
- Renal ultrasound and doppler showed normal sized kidneys with no renal artery stenosis
- ABPM showed non-dipper at night
- PTH was elevated at 150
- Patient thought to have secondary hyperparathyroidism from her CKD
- Hypertension thought to be due to resistant HTN and CKD
  - Pt was a non-dipper
- One antihypertensive moved to the evening

Kaplan-Meier survival curves comparing CVD events comparing taking BP meds in the evening

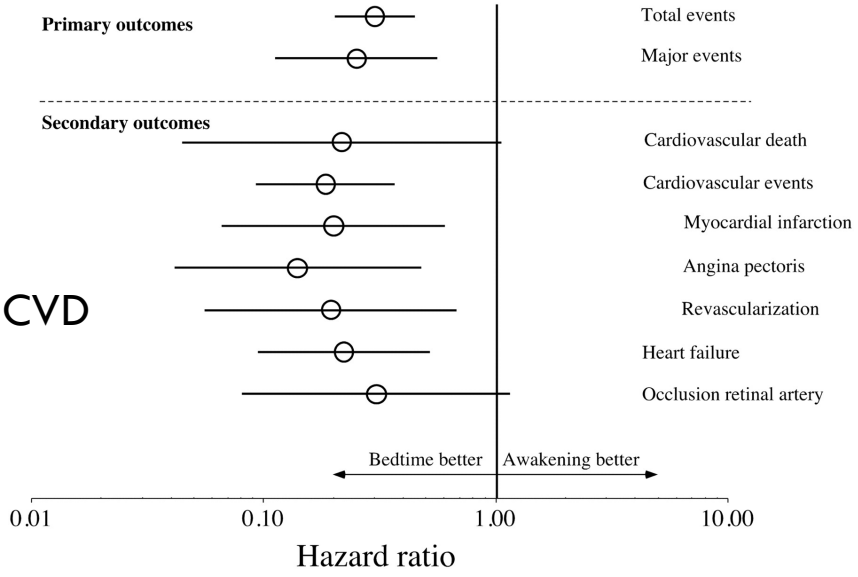
Taking one or more bp meds at night decreases CVD events and improves overall survival compared to regular regimen



CVD Events



Major CVD Events



Ramón C. Hermida et al. JASN 2011;22:2313-2321

JASN Journal of the American Society of Nephrology

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Resistant HTN in CKD

Consider ABPM

If a non-dipper, consider moving medication to evening

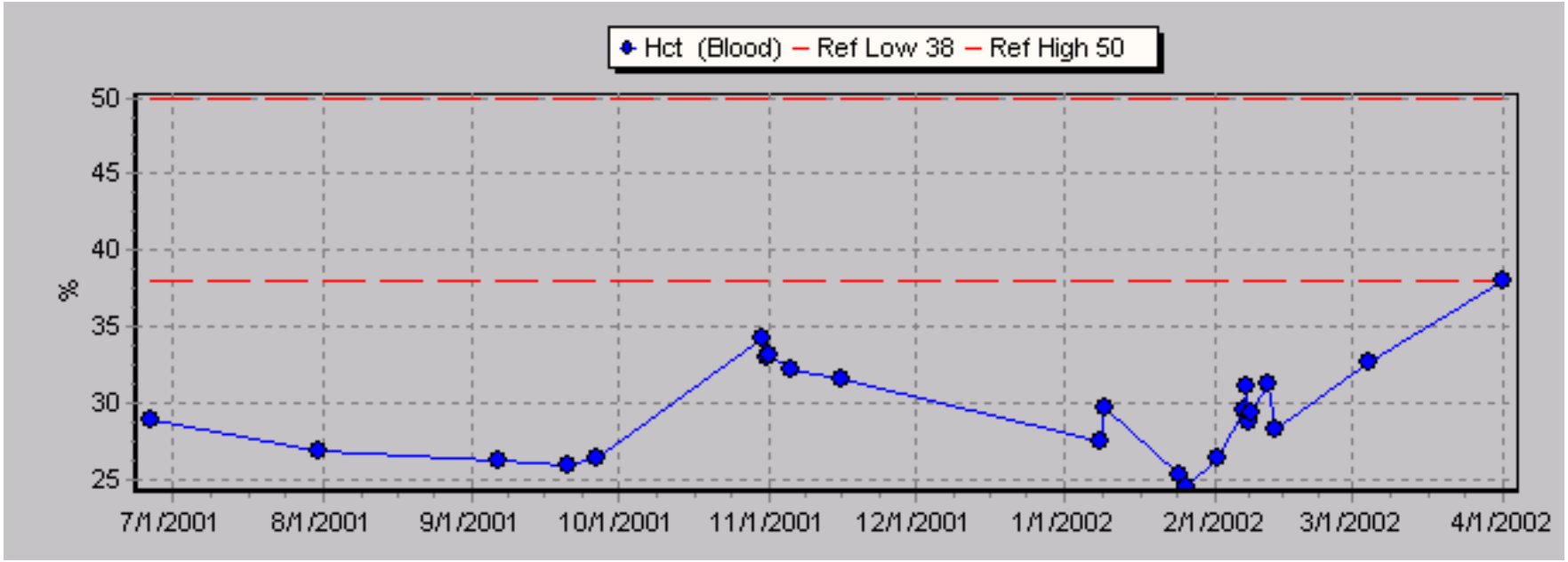
- Regimen can include one from each category
- (A or B) + (C or D)
  - Ace inhibitor or ARB with Ca+ Channel blocker or diuretic
    - Diuretic such as chlorthalidone (longer acting)
  - If eGFR <30ml/min, consider loop diuretic
  - Non-dihydropyridine Ca+ channel blockers decrease proteinuria
  - Other drugs to consider-low dose spironolactone or eplerenone-watch potassium

Case 3

- **ID/CC**: 60 yo with a history of stage 3 CKD and anemia over the past year with significant fatigue
- **PmHx**: CAD s/p MI, H pylori, DMT2 for 20 yrs with retinopathy, nephropathy and neuropathy
- **PE:** BP 135/80 , P 80
  - Lungs: clear
  - CV: RRR nl S1S2
  - ABD: soft nontender, no HSM
  - Ext: trace edema

- **Labs**
- Na 140, K+ 3.5, bicarb 19,
- Bun 54, Creat 2.5, eGFR 35 ml/min
- WBC 9.1
- HGB 8.2
- HCT 24.7, MCV 83.0, PLT 291
- TIBC 196, iron 26
- % Iron Sat 13, Ferritin 35 ng/mL
- Erythropoietin 13.7 mU/mL (normal)

Trajectory of HCT



Case 3

- The next part of his work up should include FIT testing for occult blood.
- **FIT results**: positive for heme

- **What procedure should be done next?**
- A. Repeat FIT next year
- B. Refer to GI for evaluation
- C. Transfuse
- D. Start PO iron
- E. Start erythropoietin

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- B. **Refer to GI for evaluation**
- C. Transfuse
- D. Start PO iron
- E. Start erythropoietin

- **Procedure:** Colonoscopy showed several polyps in the transverse colon, a pedunculated mass in the transverse colon, and a fungating friable tumor in the ascending colon highly suspicious for malignancy.
- Patient went on to have right hemicolectomy. Pathology showed an adenocarcinoma of the colon that invaded through the musclaris propria. Patient had recovery of hematocrit after surgery

What are CKD complications: ABCDE

How do you treat these complications?

When is it time to refer to nephrology?

When is it time to start dialysis?

- Patient is anemic
- Patient is acidotic
- Blood pressure is not well controlled.
- Calcium is low, phos and PTH are high
- Potassium is high

Treatment of Complications: ABCDEs

- Anemia and acidosis
- Blood pressure
- Calcium, phosphate, vitamin D (Bone Mineral Disease BMD)
- Dialysis and Kidney Replacement Therapy (KRT) preparation
- Electrolytes (potassium)

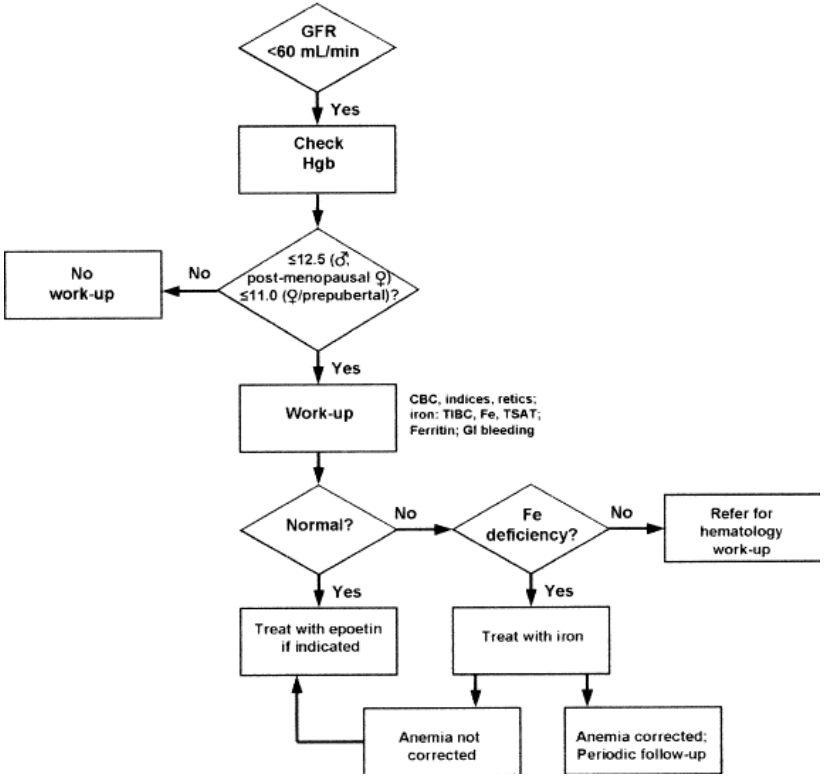
Anemia in non-dialysis CKD patients

- Anemia is common in patients with CKD
- Patients should be evaluated for cause of anemia
- Erythropoietin Stimulating Agents (ESA) considered if workup is negative and patient not responsive to iron.
  - Erythropoietin once a week
  - Darbepoetin every 2-4 weeks
- Recommend sending to nephrologist for treatment
- Work up includes:
- CBC with RBC indices
- Iron studies
  - Serum iron, TIBC, percent transferrin saturation (TSAT), serum ferritin
- Folate and B12
- Testing for occult blood in stool if no recent colonoscopy

Anemia in Treatment in CKD

- Complete work up for anemia
- Can treat with EPO or Darbepoetin
- May need IV iron
  - Sodium Ferric Gluconate (Ferrlicit)-given as 125mg (load with 1000mg over 8 weeks) as an outpatient.
  - Iron Sucrose (Venofer)-reportedly has a good safety profile 200mg IV q month

Anemia Management



Anemia is common in patients with CKD once the eGFR is <60ml/min/1.73m^2

Work up common causes of anemia first

Consider ESAs (erythropoietin stimulating agents) when hemoglobin <10g/dL

Consult nephrology to help with work up and initiation of ESAs

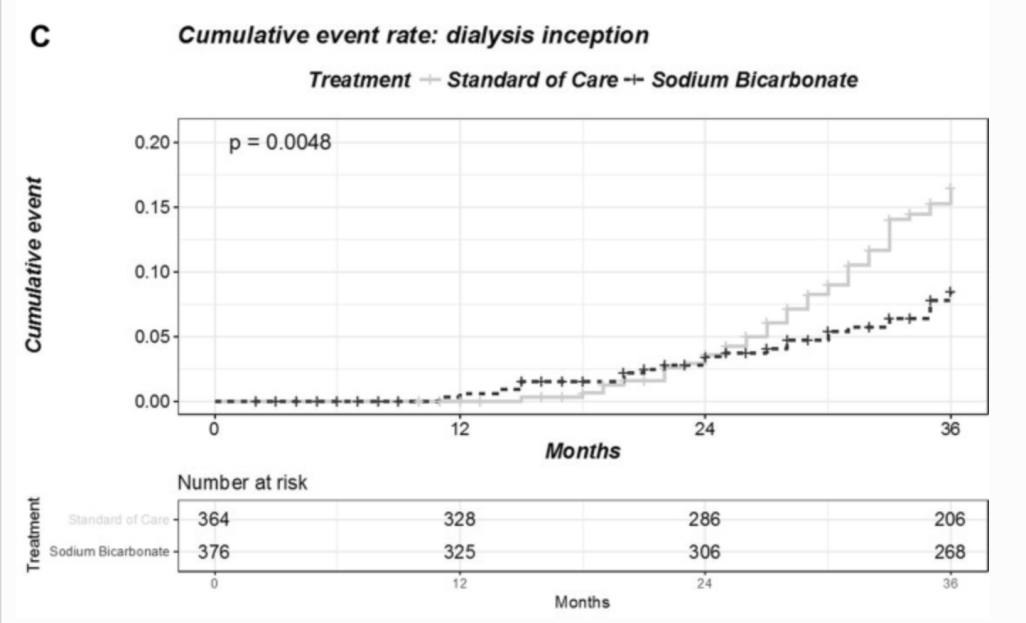
Target is not to normalize hematocrit in patients with CKD, but to a Hgb range between 10-11g/dL

Metabolic Acidosis

- Occurs as renal function worsens
- Hydrogen ions retained
- Decreased excretion of phosphoric acids
- HC03 values <22meq/L are associated with increased mortality 43%
- Acidemia also associated with progression of CKD

- Consequences of Metabolic Acidosis
  - Bone reabsorption
  - Increased muscle protein catabolism
  - Possible impairment of myocardial function
  - Worsening of secondary hyperparathyroidism

Metabolic Acidosis Treatment



- Open labeled RCT of sodium bicarbonate vs. placebo (n=740) showed decreased progression of CKD, initiation of dialysis and better survival for those on bicarbonate

Di Iorio, *Journal of Nephrology*. 32:989–1001(2019)

Case 4

- **ID/CC**: 82 yo male with CKD stage 3, DMT2, BPH, HTN, GERD
- **Meds:**
  - Amlodipine, atorvastatin Furosemide 20mg, glipizide metoprolol, Tamsulosin
  - losartan 12.5mg day
- **PE:** BP 120/80, P 70
  - lungs clear
  - CV RRR
  - Abd soft nontender
  - LE trace edema

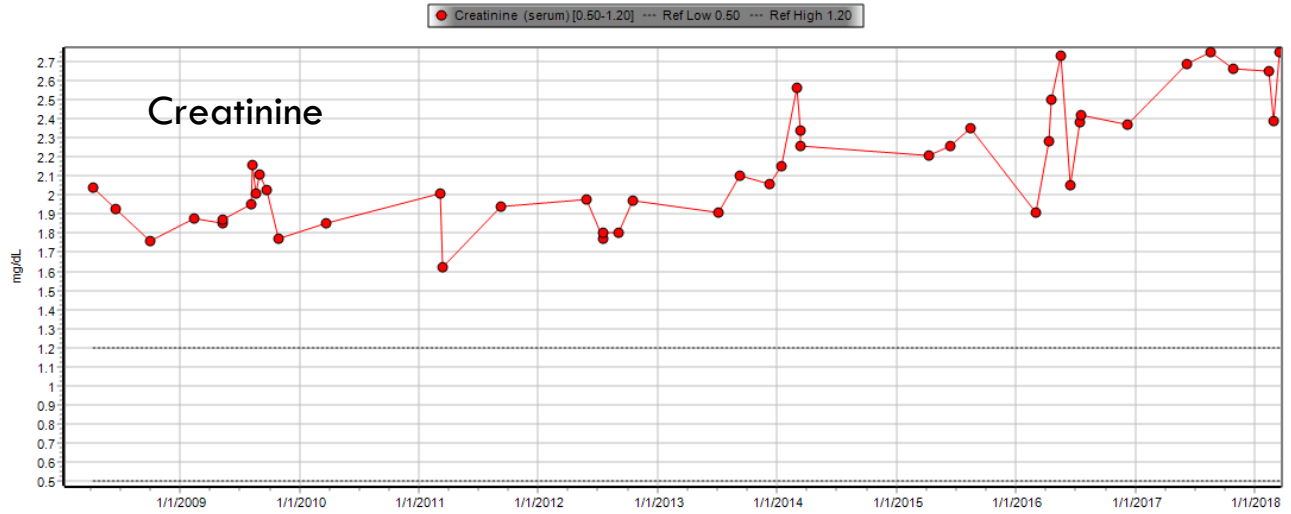
- **Labs:** A1c 7.8%, ACR 473

148 | 112 | 45
6.1 | 19 | 3.0 eGFR =18, 2020

144 | 106 | 43
4.6 | 23 | 2.4 eGFR =25, 2019

144 | 107 | 49
5.7 | 27 | 2.3 eGFR =30, 2018

PVR: 20ml of urine


Creatinine (serum) [0.50-1.20]
Ref Low 0.50
Ref High 1.20
Creatinine
mg/dL
2.7
2.6
2.5
2.4
2.3
2.2
2.1
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
1/1/2009
1/1/2010
1/1/2011
1/1/2012
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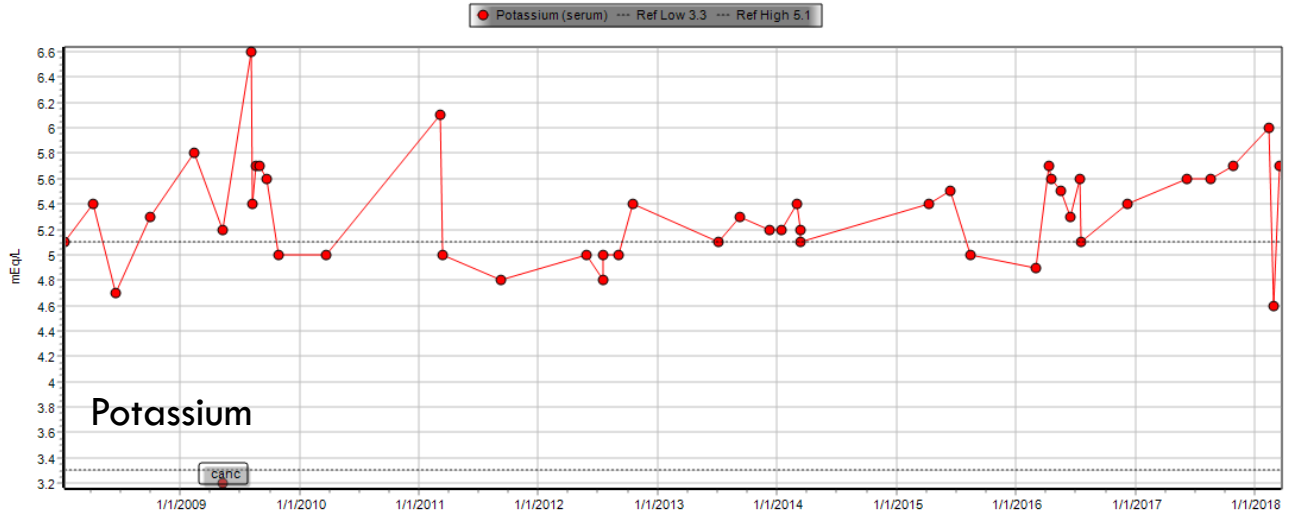
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018


Potassium (serum)
Ref Low 3.3
Ref High 5.1
Potassium
mEq/L
6.6
6.4
6.2
6
5.8
5.6
5.4
5.2
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
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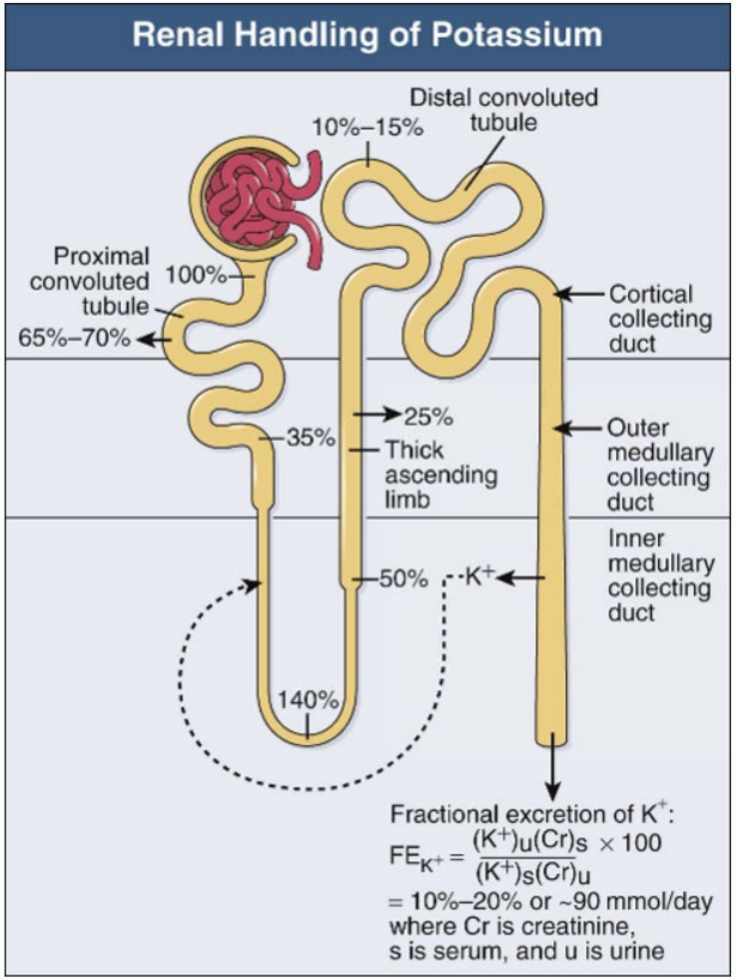
canc
1/1/2009
1/1/2010
1/1/2011
1/1/2012
1/1/2013
1/1/2014
1/1/2015
1/1/2016
1/1/2017
1/1/2018

Internal Potassium Balance

- Total body stores of K+ 3000-4000 mEq
  - (50-55 mEq/kg wt.),
- Regulation of K+ after ingestion occurs by the initial uptake in cells, which is mediated by:
  - Plasma K+ concentration
  - Insulin and epinephrine via □2 adrenergic receptors, and
  - Na/K+ATPase

Potassium Transport

- Potassium is freely filtered at the glomerulus
- 65% reabsorbed in proximal tubule
  - passive, follows Na+ and H2O
- 25% reabsorbed in the thick ascending limb
  - Na+/K+/2Cl- carrier
- K+ secretion occurs in the **Principal Cells** in the Cortical Collecting Duct



Potassium Excretion

- Excretion of potassium occurs via the urine in 6-8 hours → this is mediated by
  - aldosterone
  - distal flow of Na+ and water,
  - plasma K+ concentration, and
  - pH or acid/base status
- K+ is restricted to the intracellar space (98%);
  - intracellular K+ =140meq/L, extracellular K+=4.0meq/L

Hyperkalemia

- Usually due to increased intake and CKD
- May be due to medications
  - ACEs or ARBs, NSAIDS
  - Spironolactone, eplerenone
- Can also be due to increased Aldosterone or aldosterone resistance
  - Type IV RTA in diabetes

Drugs causing hyperkalemia

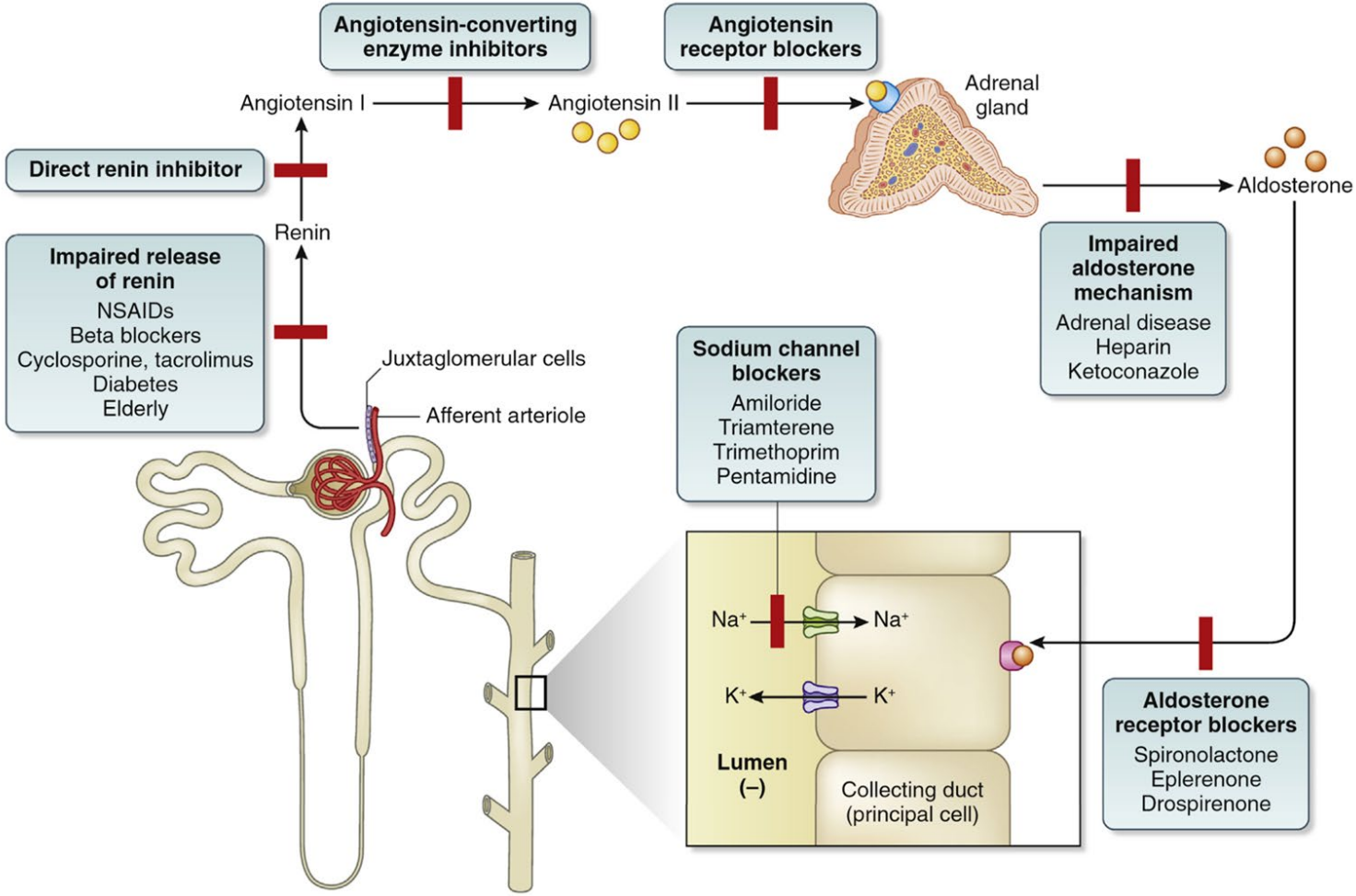
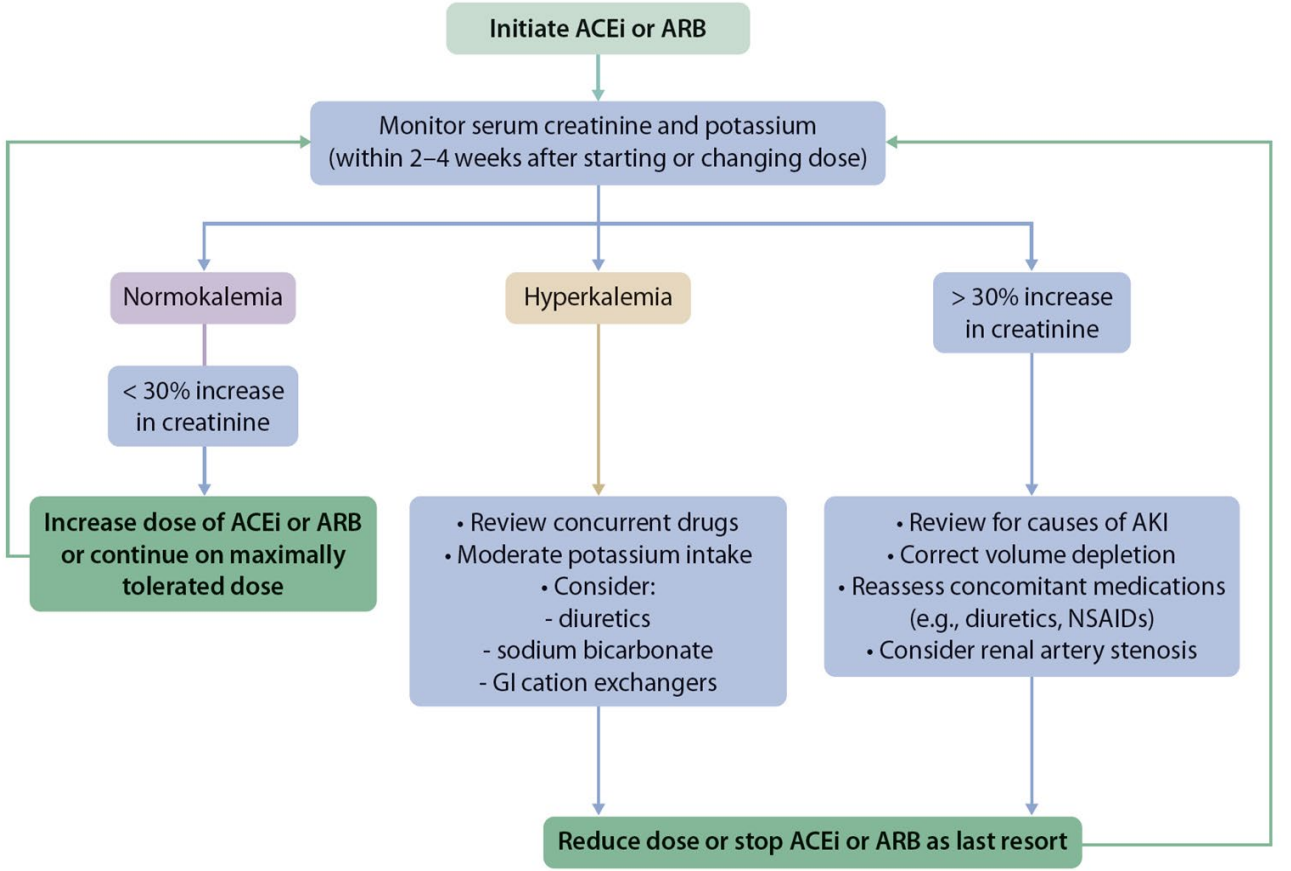


FIGURE 4. MONITORING OF SERUM CREATININE AND POTASSIUM DURING ACEI OR ARB TREATMENT - DOSE ADJUSTMENT AND MONITORING OF SIDE EFFECTS



Case 4

- **82 yo with CKD stage 3, DMT2, BPH, HTN, GERD**
- Meds:
  - Furosemide 20mg,
  - metoprolol,

losartan 12.5mg qday

LABs

148 | 112| 45

6.0 | 19 | 2.65 eGFR =18

- Treatment
  - Nutrition consult for hyperkalemia
  - Can increase diuretic
  - Can stop losartan
  - Would treat acidosis with bicarbonate
  - Consider binder
  - Patiromer (Valtessa)
    - Used for chronic hyperkalemia
    - Can consider kayexalate for acute treatment

Preparation for Kidney Replacement Therapy

Patients should be referred to nephrology for education, dialysis preparation and transplant evaluation

Dialysis education

Nutrition

Dialysis access

Conservative Care (CC)

Dialysis Access

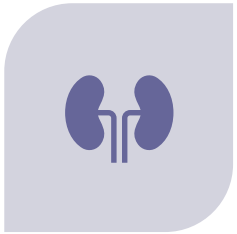
Hemodialysis: AV-fistula

Home Dialysis: PD or HD

Transplant Evaluation

Can be referred when eGFR is $<20 ml/min/1.73m^2$

Kidney Replacement Therapy



PATIENTS NEED REFERRAL TO NEPHROLOGY WHEN EGFR IS <30ML/MIN/1.73M2

DIALYSIS FOR UREMIC SYMPTOMS

- Need to start dialysis when…
- Uremic symptoms increase: nausea, vomiting, fluid retention
- Refractory hyperkalemia
- Repeat hospitalizations for HF/fluid overload

Management of CKD

Manage your patients with CKD

Nephrologist are there to help co-manage patients

Refer early

C = Causality

Make sure you know why your patient has CKD

K = Kidney Disease progression

Assess for ways to decrease kidney disease progression

D = Drugs

Make sure all drugs are adequately dosed for level of kidney function

Manage the ABCs of Complications

ANEMIA AND ACIDOSIS

BLOOD PRESSURE

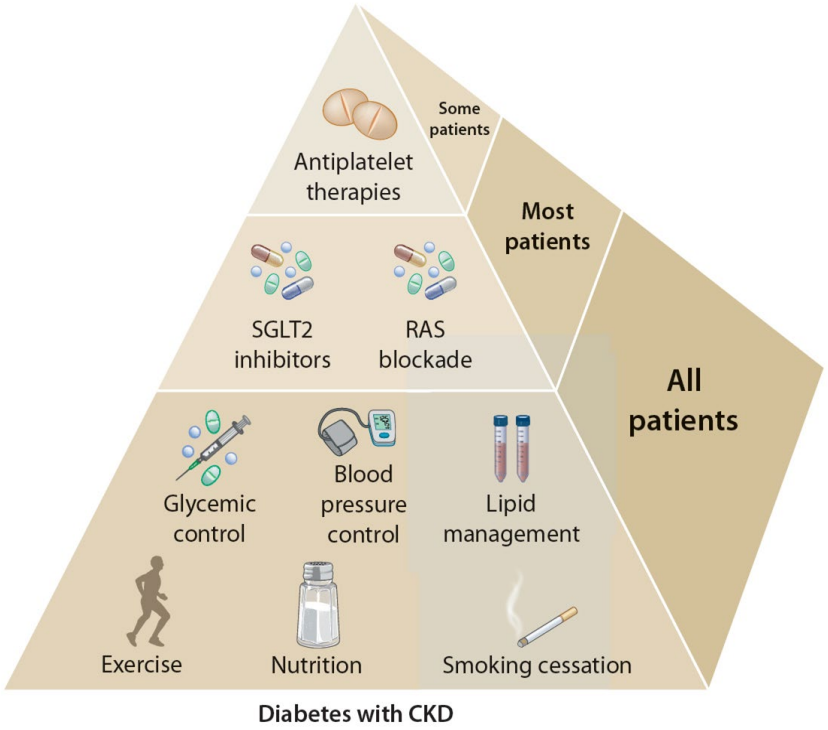
CALCIUM, PHOSPHATE AND PTH

DIALYSIS PREPARATION

ELECTROLYTES

Comprehensive Care for CKD

- Patients with diabetes and chronic kidney disease (CKD) should be treated with a comprehensive strategy to reduce risks of kidney disease progression and cardiovascular disease



Summary: CKD Management

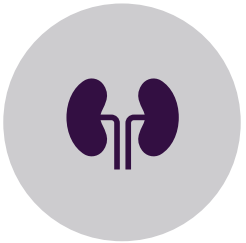
CKD is common

Treat diabetes with SGLT-2 inhibitors

Manage hypertension

Refer early to nephrology for co-management

MEDICATIONS



KIDNEYS

BLOOD PRESSURE

Thanks!

Questions?

youngb@uw.edu