UREA

From Food to Floor Drain

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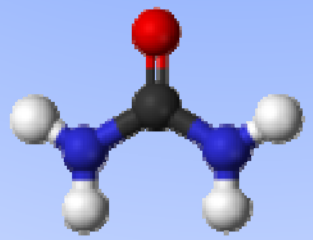
Old Dialysis Technical Guy

WHAT IS UREA?

- A compound formed in the liver by the process known as the urea cycle. Gram Molecular Weight = 60 Daltons



Carbon - Oxygen - Nitrogen - Hydrogen -

- Principal end product of protein catabolism.
- Constitutes about half of the total urinary solids.
- Elevated level in blood = Azotemia
- BUN = Blood Urea Nitrogen = Amount of nitrogen in blood. Ratio: Nitrogen / Urea = 28/60 = 0.467.

Protein Basics

- Proteins are large molecules made primarily from hundreds to thousands of α–amino acids.

- AMINO R ACID

$$(NH_3^+) - CH(R) - (COO^+)$$

- There are 20 amino acids used to build human proteins.
  - 9 are essential (You must eat them.)
  - 11 are nonessential (You can make them.)

Protein Possibilities

For a protein 100 amino acids long, there are 20^{100} possible combinations.

12,675,060,000,000,000,000,000,000,000,000,
000,000,000,000,000,000,000,000,000,000,
000,000,000,000,000,000,000,000,000,000,
000,000,000,000,000,000,000,000,000,000,
000 ,000 ,000 possibilities!!

(1.2675×10^{130})

Dietary Protein Intake - DPI

- **Normal DPI should be in the range of 1.0 - 1.4 grams/kilogram of body weight/day.**
- **Effects of malnutrition begin to appear when the DPI is reduced to the 0.3 - 0.5 gm/kg/day range.**
- **The type of protein consumed is important.**
  - **High-Biologic-Value Protein (Lean Meat, fish, and eggs)**
  - **Low-Biologic-Value Protein (Breads and Cereals)**
  - **HBV proteins contain the essential amino acids.**
  - **Without HBV protein, muscle tissue is broken down for its amino acids.**

Protein Content in Food

1 oz. Beef, Pork, Chicken = 8 grams

1 oz. Clams, Shrimp, Cod = 6 grams

1 oz. Cheese, Peanut Butter = 8 grams

1 cup cereal = 2 grams

1 Baked Potato = 5 grams

1/3 cup Spinach, Corn, Squash = 2 grams

1/2 cup Kidney Beans, Tomato = 2 grams

1/2 cup of fruit < 1 gram

Converting Protein to Urea

- In general, DPI will equal Protein Catabolic Rate (PCR) in the stable patient.
- The equation which relates protein intake to urea nitrogen generation rate (G) has been determined by monitoring diet and urea nitrogen in urine.

The Conversion Equation
Protein to Urea Nitrogen

$$PCR = 9.35\,G + 11.04$$

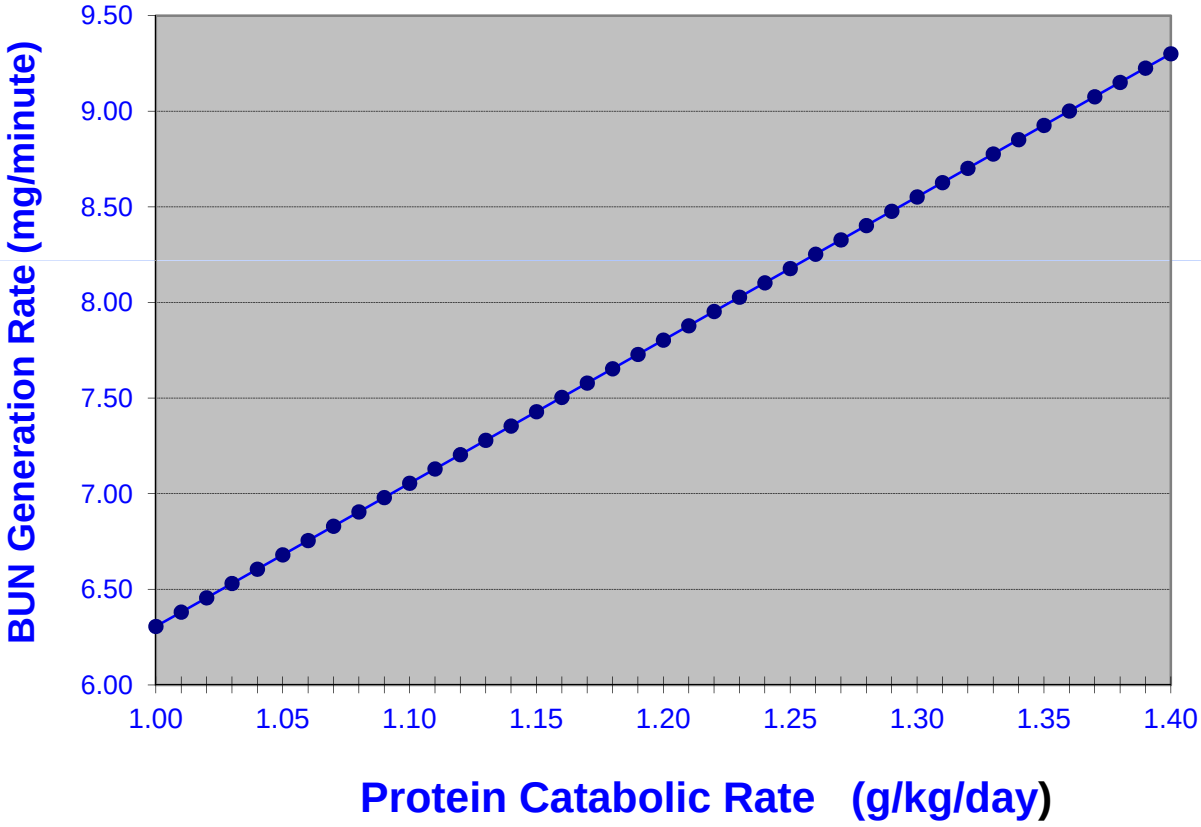
or

$$G = (PCR - 11.04) / 9.35$$

PCR (grams/day)

G (milligrams of urea nitrogen/minute)

BUN Generation Rate vs. Protein Catabolic Rate



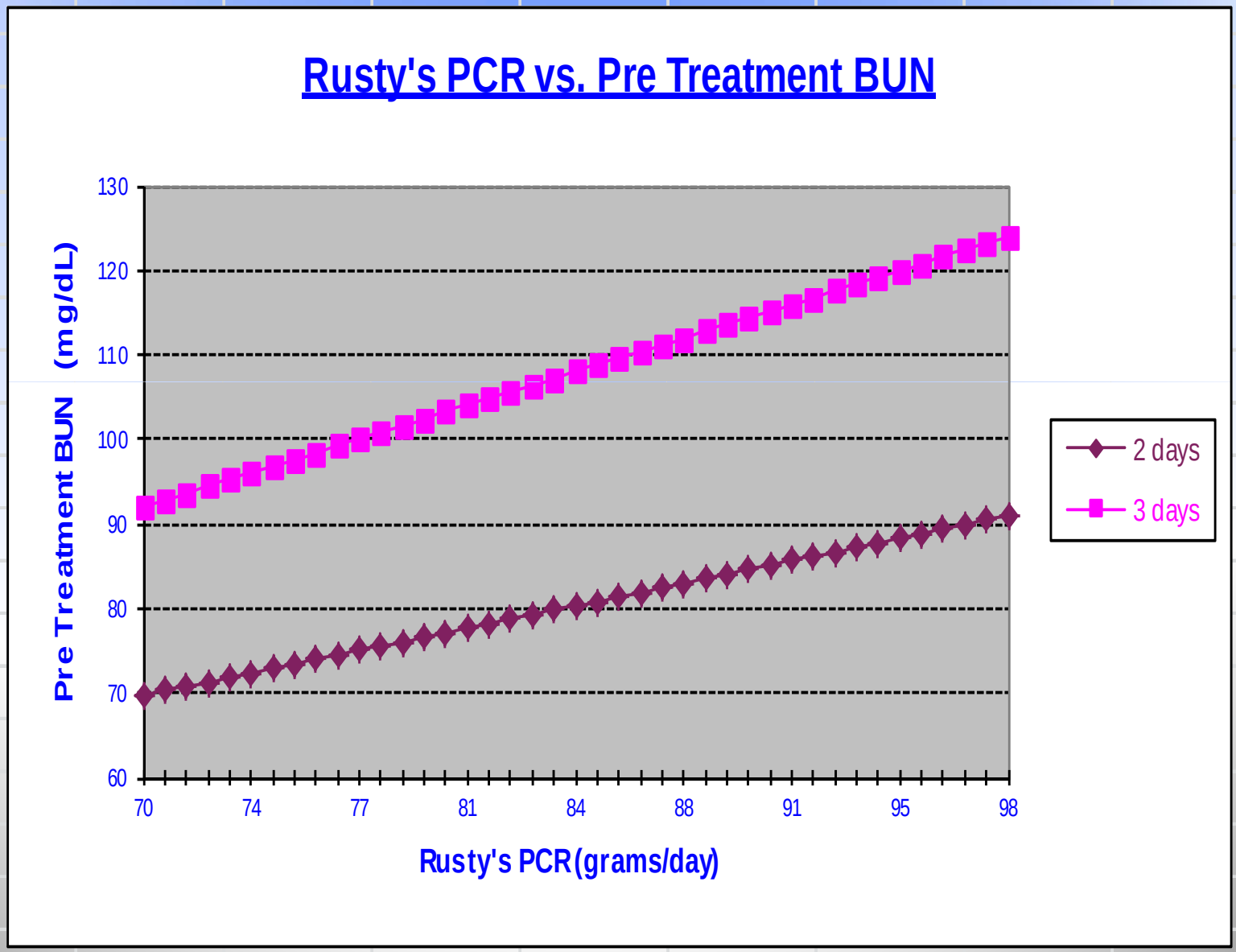
Introducing the Patient

- **Name: Rusty Pipes**
- **Occupation: Plumbing Specialist**
- **Weight: 70.0 kilograms (154.3 pounds)**
- **Fluid Volume: 40.6 liters (58% of his weight)**
- **Residual Renal Function: None**
- **DPI: Varies between 1.0 - 1.4 g/kg/day**
- **Nephrologist: Dr. I. M. Nephron**

BUN Build-up in Rusty

- **Rusty's Volume = 40.6 liters = 406 deciliters**
- **If DPI = PCR = 84 g/day (1.2 g/kg/day x 70 kg), then:**
- **G = (84 - 11.04) / 9.35 = 7.80 mg/min.**
- **7.80 mg/min x 60 min/hr = 468 mg/hr.**
- **468 mg/hr x 24 hr/day = 11,232 mg/day**
- **11,232 mg/day / 406 dL = 27.7 mg/dL/day.**

Rusty's PCR vs. Pre Treatment BUN



Dialyzer BUN Clearance

THE EMPIRICAL FORMULA FOR BLOOD CLEARANCE IS:

$$C_X = \left(\frac{A_X - V_X}{A_X} \right) Q_B$$

WHERE:

C_X = CLEARANCE OF SOLUTE X. (mL/min)

A_X = ARTERIAL CONCENTRATION OF X. (mg/dL)

V_X = VENOUS CONCENTRATION OF X. (mg/dL)

Q_B = BLOOD FLOWRATE (mL/min)

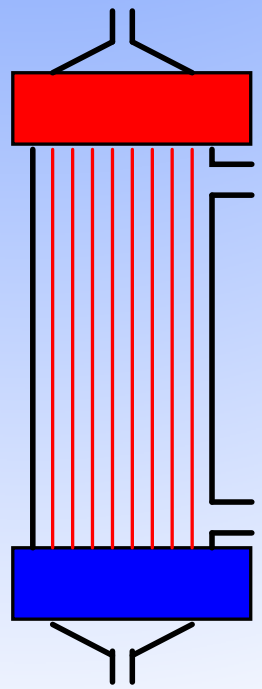
Urea Clearance in Blood and Dialysate

Rusty's Dialyzer: iP4U

$K_OA = 900$ mL/min
$Q_B = 300$ mL/min
$Q_D = 600$ mL/min

$Q_B \times \Delta BUN_B = Q_D \times \Delta BUN_D$

$300 \times (80 - 10) = 600 \times (35 - 0)$
$300 \times 70 = 600 \times 35$
$21{,}000 = 21{,}000$



ARTERIAL BLOOD
80 mg/dL

⇒ DIALYSATE OUT
35.0 mg/dL

⇐ DIALYSATE IN
0.0 mg/dL

VENOUS BLOOD
10.0 mg/dL

Rusty's iP4U Clearance

A_{BUN} = 80 mg/dL V_{BUN} = 10 mg/dL

Q_B = 300 mL/min

$C_{BUN} = [(A_{BUN} - V_{BUN}) / A_{BUN}] \times Q_B$

$C_{BUN} = [(80 - 10) / 80] \times 300$

C_{BUN} = 262 mL/min

Clearance vs. K_OA

- K_OA = Mass Transfer Coefficient for a Dialyzer
- K_OA is measured in mL/min.
- K_OA gives Clearance for Q_B and Q_D combinations.
- The range of K_OA values is 250 – 1200 mL/min.
- The higher the K_OA, the better the clearance.
- Once the K_OA for a dialyzer is known, the clearance of that dialyzer can be determined for any combination of blood and dialysate flow rates.
- *Of course, there's an equation…*

The K_OA Equation

$$KoA = \left[Q_B \Big/ 1 - \frac{Q_B}{Q_D} \right] \ln \left[\frac{1 - \frac{C_X}{Q_D}}{1 - \frac{C_X}{Q_B}} \right]$$

Where: C_X = Clearance of solute, X

Q_B = Blood flowrate

Q_D = Dialysate flowrate

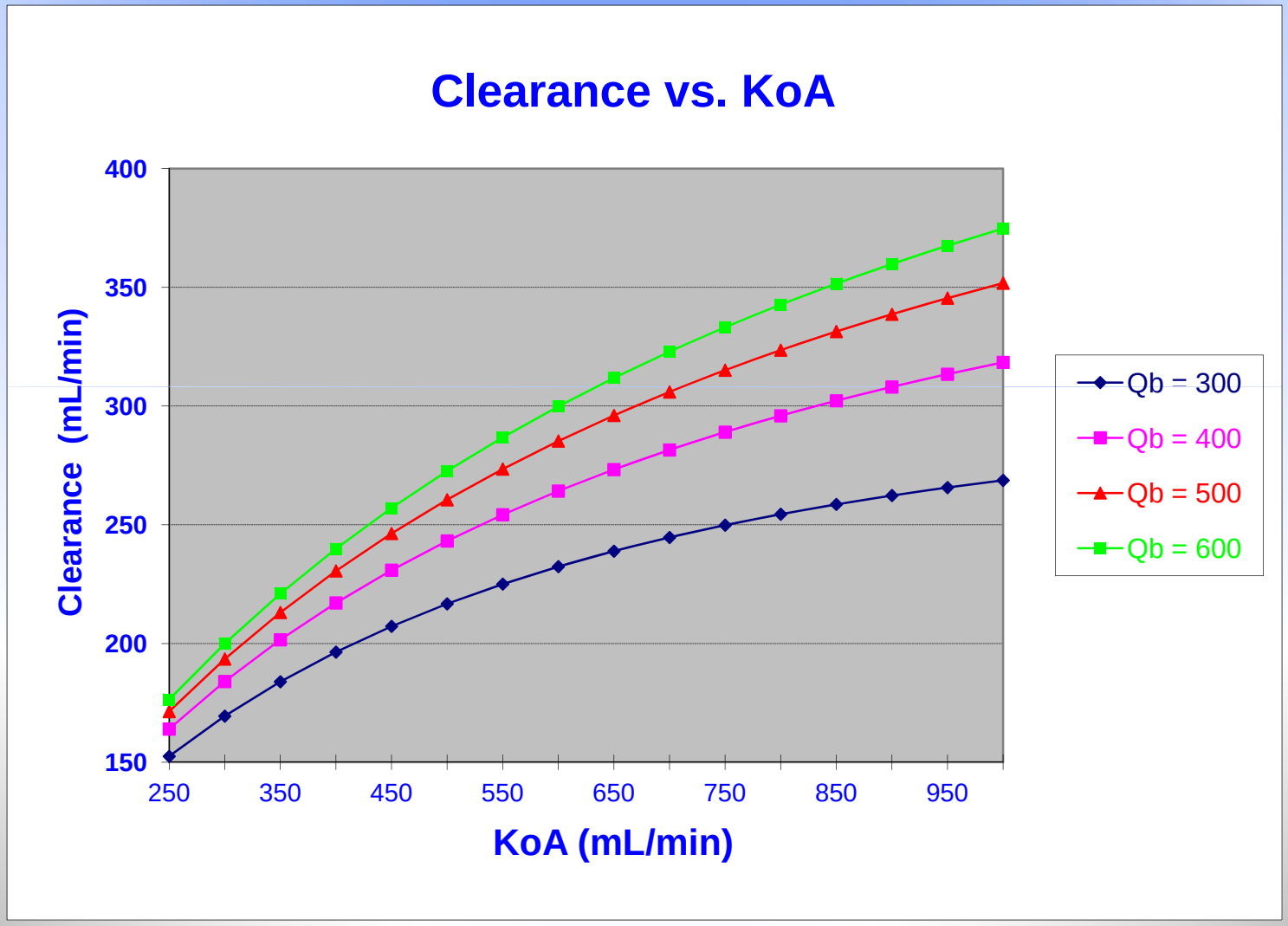
ln = Natural logarithm

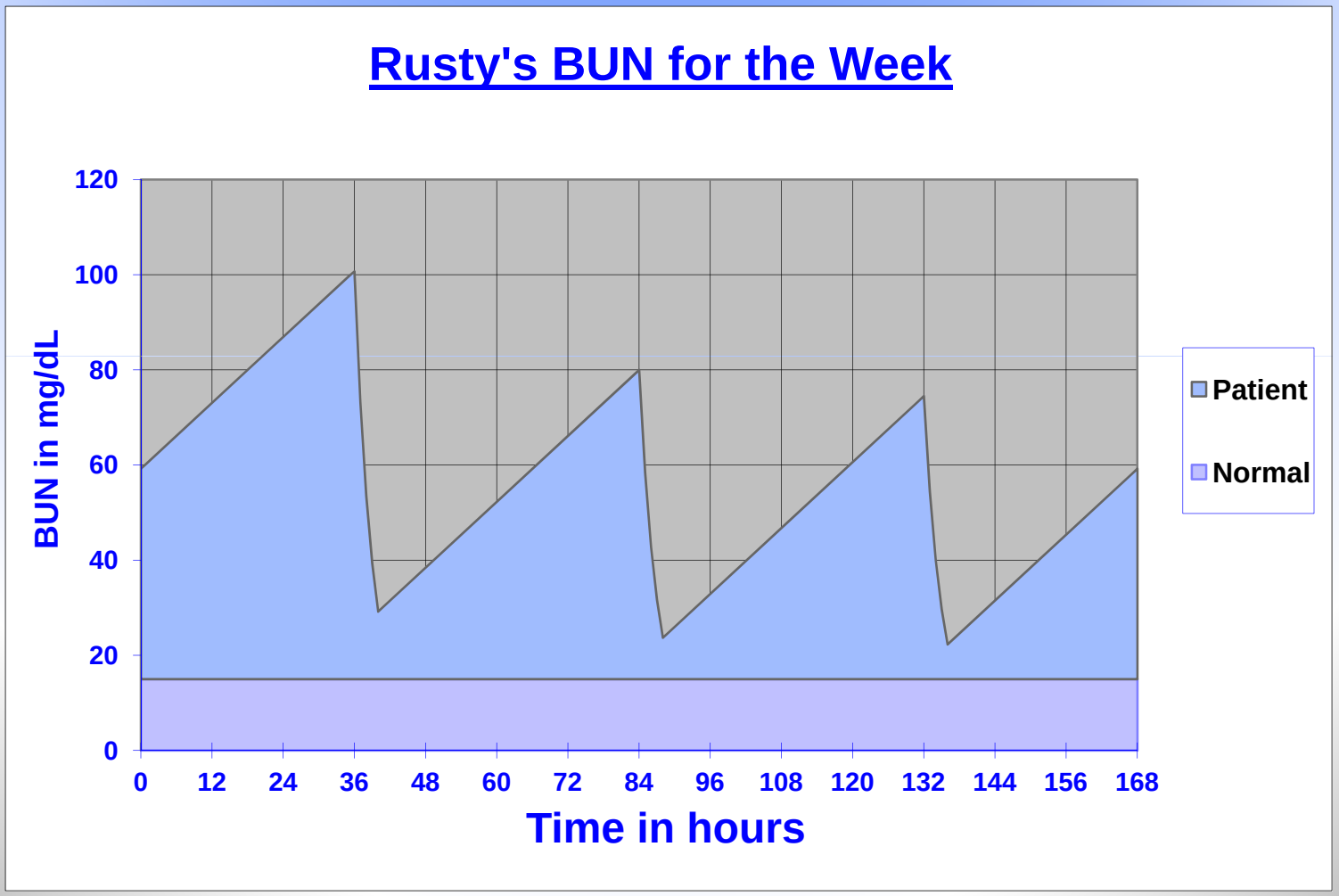
e = 2.718281828.....

BUN of Venous Blood based on Dialyzer KoA

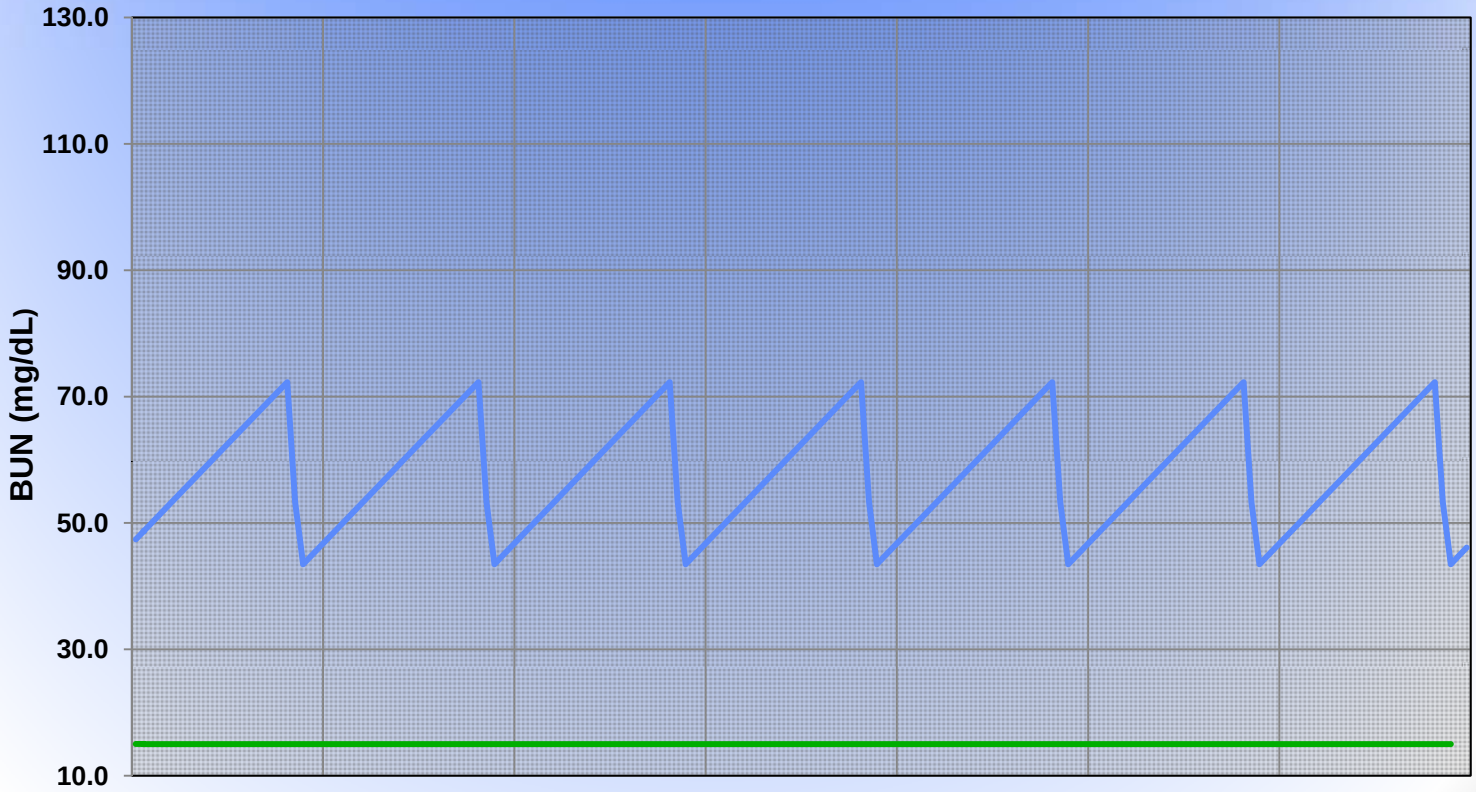
QB = 300 mL/min QD = 600 mL/min

KoA (mL/min)	Clearance (mL/min)	Arterial Blood BUN Values (mg/dL)				
		70	80	90	100	110
500	217	19.4	22.1	24.9	27.7	30.4
600	232	15.9	18.1	20.4	22.7	24.9
700	245	12.8	14.7	16.5	18.3	20.2
800	254	10.7	12.3	13.8	15.3	16.9
900	262	8.9	10.1	11.4	12.7	13.9
1000	269	7.2	8.3	9.3	10.3	11.4
1100	274	6.1	6.9	7.8	8.7	9.5
1200	278	5.1	5.9	6.6	7.3	8.1


Clearance vs. KoA
Clearance (mL/min)
400
350
300
250
200
150
250
350
450
550
650
750
850
950
KoA (mL/min)
Qb = 300
Qb = 400
Qb = 500
Qb = 600


Rusty's BUN for the Week
BUN in mg/dL
120
100
80
60
40
20
0
0
12
24
36
48
60
72
84
96
108
120
132
144
156
168
Time in hours
Patient
Normal

Rusty on Daily Home Hemodialysis



BUN (mg/dL) Variation Comparison					
	Avg. BUN	Std. Dev.	Highest	Lowest	Range
3X/WK	55.6	19.4	100.7	22.3	78.4
7X/WK	57.7	8.5	72.3	43.7	28.8

Urea Reduction Formula

(UFR = 0.0 mL/hr)

$$C = C_0 e^{-Kt/V} + G/K (1 - e^{-Kt/V})$$

C = Plasma BUN Concentration (mg/mL)*

C_0 = Predialysis BUN Concentration (mg/mL)*

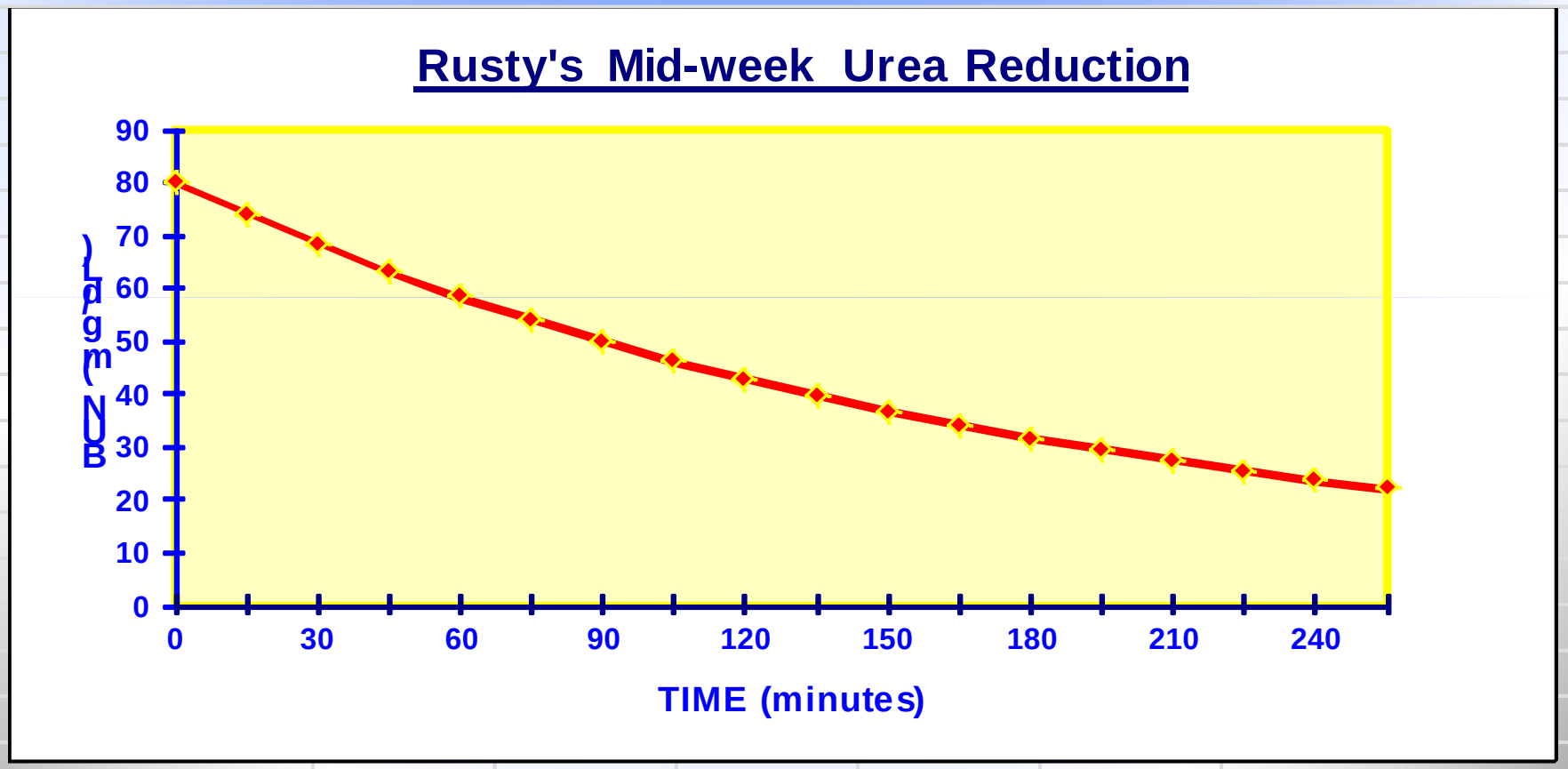
K = Dialyzer Clearance (mL/min)

t = time (minutes)

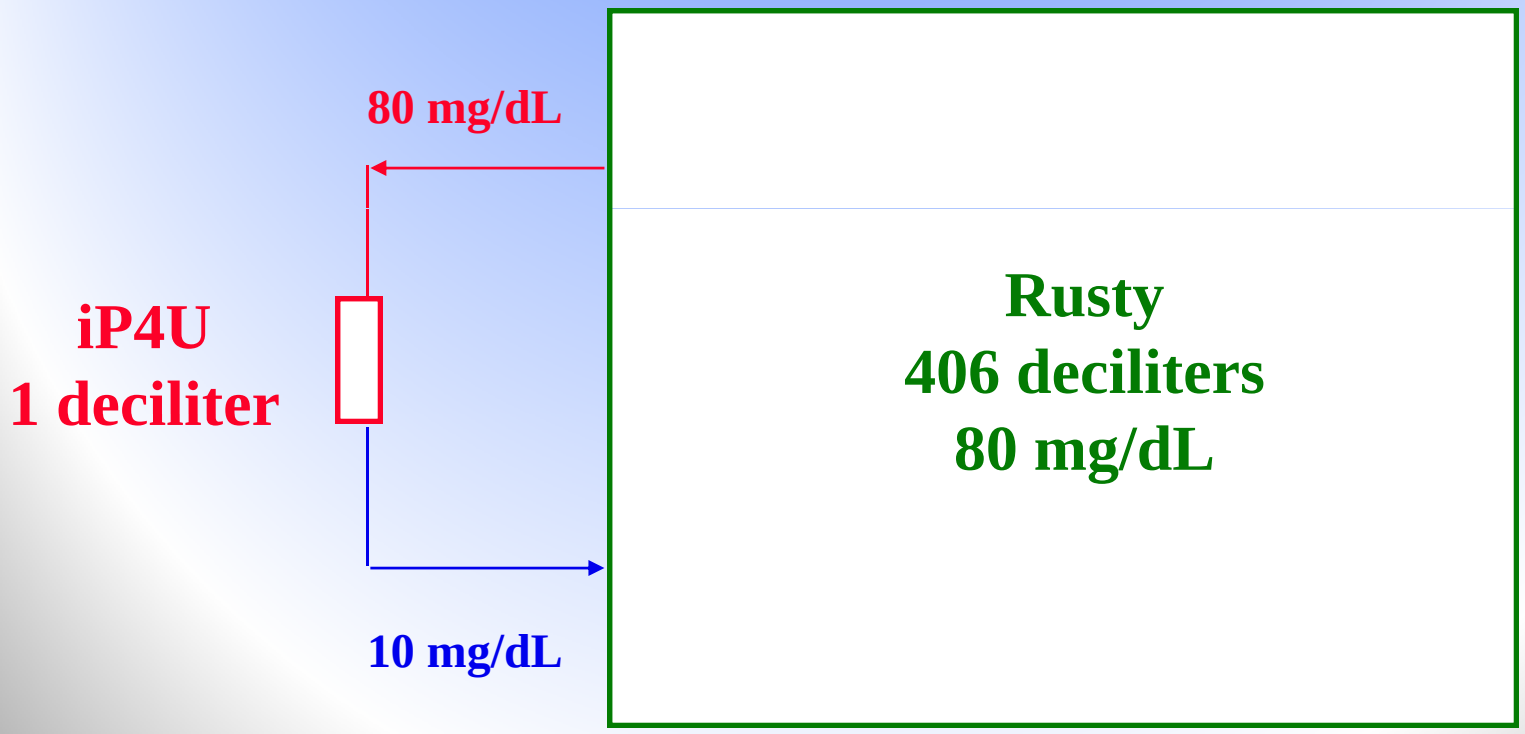
V = Patient Volume (mL)

G = Generation of urea (mg/min)

* mg/mL equals mg/dL divided by 100.


Rusty's Mid-week Urea Reduction
90
80
70
60
50
40
30
20
10
0
0
30
60
90
120
150
180
210
240
TIME (minutes)

Volume: Dialyzer vs. Rusty



Rusty's Week on Dialysis

URINE LUCK DIALYSIS CENTER

	TRX #1 Monday	TRX #2 Wednesday	TRX #3 Friday
Pre BUN (mg/dL)	100.7	80.0	74.5
Post BUN (mg/dL)	29.2	23.7	22.3
URR	71.0%	70.4%	70.1%
Kt/V	1.33	1.33	1.33
BUN Removed (g)	29.03	22.86	21.19
Urea Removed (g)	62.21	48.99	45.41

Rusty's Urea Loss

$BUN_{REMOVED} = (BUN_{PRE} - BUN_{POST}) \times V_{PATIENT}$

$BUN_{PRE} = 80.0$ mg/dL $BUN_{POST} = 23.7$ mg/dL

Rusty's Volume = 406 deciliters

$BUN_{REMOVED} = (80.0 - 23.7) \times 406$

$= 22{,}858$ mg $= 22.9$ grams

$UREA_{REMOVED} = (60/28) \times 22.9$ grams

$= 49.0$ grams

Urea down the Drain

URINE LUCK DIALYSIS CENTER

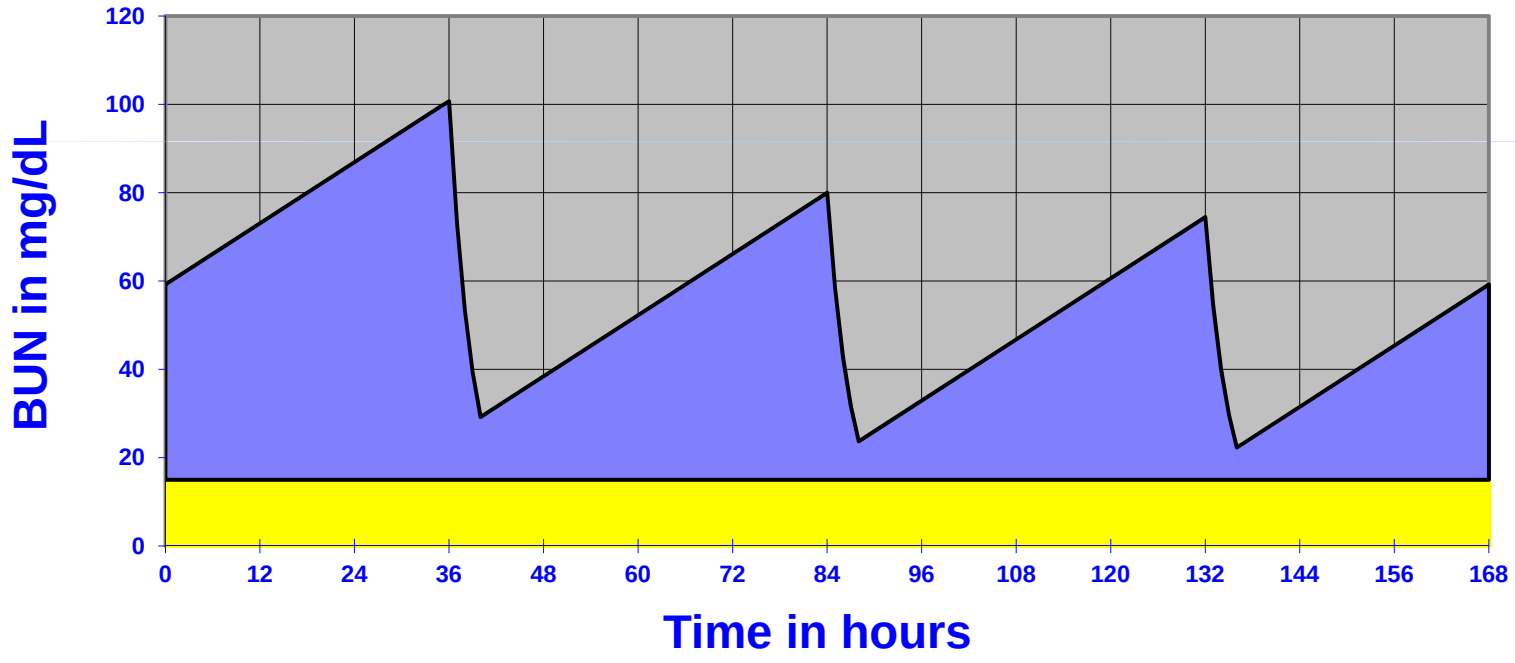
- **Number of stations:** 20
- **Shifts per day:** 3
- **Days of operation:** Monday - Saturday
- **Number of patients:** 105
- **Avg. urea loss / R_X:** 52.2 grams (24.4 g BUN)
- **Total R_X per week:** 295
- **Total drain urea:** 15.4 kg/wk (33.9 lbs/wk)
- **Equivalent urine:** 1,660 liters (438 gallons)

Additional Urine Information

- **Urine composition:**
  - **950 grams of water**
  - **9.3 grams Urea**
  - **1.87 grams Chloride**
  - **1.17 grams Sodium**
  - **0.75 grams Potassium**
  - **0.67 grams of Creatinine**
- **It's color comes from Urobilin from the breakdown of Hemoglobin**
- **Specific Gravity = 1.003 – 1.035 g/cm^3**
- **After eating Asparagus, urine will contain Asparagusic acid!**

Patient's Blood Urea Nitrogen for the Week

(Normal BUN in Yellow)



Patient's Mid-week Treatment Urea Reduction