Inpatient Diabetes Management

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Learning Objectives:

- Importance of inpatient glycemic control
- Glucose targets for hospitalized adults
- General principles of insulin therapy
- Insulin regimens for hospitalized patients- basal, bolus and correction insulin
- Calculation of initial doses of basal/ bolus insulin and adjustment of insulin regimen
- Glycemic management when NPO, on tube feeds, on steroids
- Hypoglycemia management

Diabetes is a Common Inpatient Comorbidity

4th most common inpatient comorbidity (2010)

38% of US inpatients[1]

33% previously undiagnosed [1]

$87B annually in direct inpatient medical costs[2]

1. Umpierrez GE, et al. J Clin Endocrinol Metab. 2002;87:978-82
2. ADA. Diabetes Care. 2008;31:595-615
3. Boord JB, et al. J Hosp Med. 2009;4:35-44

Hyperglycemia is associated with adverse hospital outcomes

- Increased risk of nosocomial and postoperative infections
- Increased mortality, CHF after acute MI (Capes et al Lancet 2000)
- Poor outcomes after acute stroke (Capes et al Stroke 2001)
- Adverse outcomes in patients with COPD (Baker et al Thorax 2006)
- Increased risk of death and hospital complications in community acquired pneumonia (McAlister Diab Care 2005)
- Increased complications post CABG (McAlister et al Diab Care 2003)
- Longer length of hospitalization

Thirty Day Mortality and Inhospital Complications in diabetic and non-diabetic subjects

†p = 0.1
* p= 0.001
#p=0.017

A Frisch et al. Diabetes Care, May 2010

Hypoglycemia is associated with adverse outcomes

- Cardiac arrhythmias, ischemia (Desouza et al Diab Care 2003)
- Brain damage (Cryer P Am J Med 2011)
- Death (Badawi et al Crit Car Med 2012, Egi et al Mayo Clin Proc 2010)

Hypoglycemia

Table 6.3—Classification of hypoglycemia (44)

Level	Glycemic criteria/description
Level 1	Glucose <70 mg/dL (3.9 mmol/L) and glucose ≥54 mg/dL (3.0 mmol/L)
Level 2	Glucose <54 mg/dL (3.0 mmol/L)
Level 3	A severe event characterized by altered mental and/or physical status requiring assistance

Glycemic Targets:
Standards of Medical Care in Diabetes - 2021.

What is the target glucose range for inpatient diabetes management ?

A. 80-110

B. 140-180

C. 160-200

D. 70-180

Glycemic Targets in Hospitalized Patients

- Dietary modifications should be made once glucose levels exceed 140 mg/dL
- Scheduled Insulin therapy should be initiated for treatment of persistent hyperglycemia starting at a threshold ≥180 mg/dL
- Once insulin therapy is started, a target glucose range of 140–180 mg/dL is recommended for the majority of critically ill patients and noncritically ill patients.
- More stringent goals, such as 110–140 mg/dL may be appropriate for selected patients if they can be achieved without significant hypoglycemia

American Diabetes Association Standards of Care 2021

SHM Glycemic Control Benchmarks at BUMCP

		Patient - Stay	Patient - Day
Percent stays or days with uncontrolled hyperglycemia (mean glucose ≥ 180 mg/dL)	Hospital	38.4%	34.7%
	Top Decile	≤ 24.9%	≤ 25.7%
	Top Quartile	≤ 27.9%	≤ 28.2%
	Mean	32.1%	31.6%
	Median	32.0%	31.6%
	Range	12.4% - 53.0%	14.9% - 50.2%
Percent Readings per Stay in Range (71 - 179 mg/dL)	Hospital	62.6%	
	Top Decile	≥ 71.5%	
	Top Quartile	≥ 69.7%	
	Mean	66.5%	
	Median	66.5%	

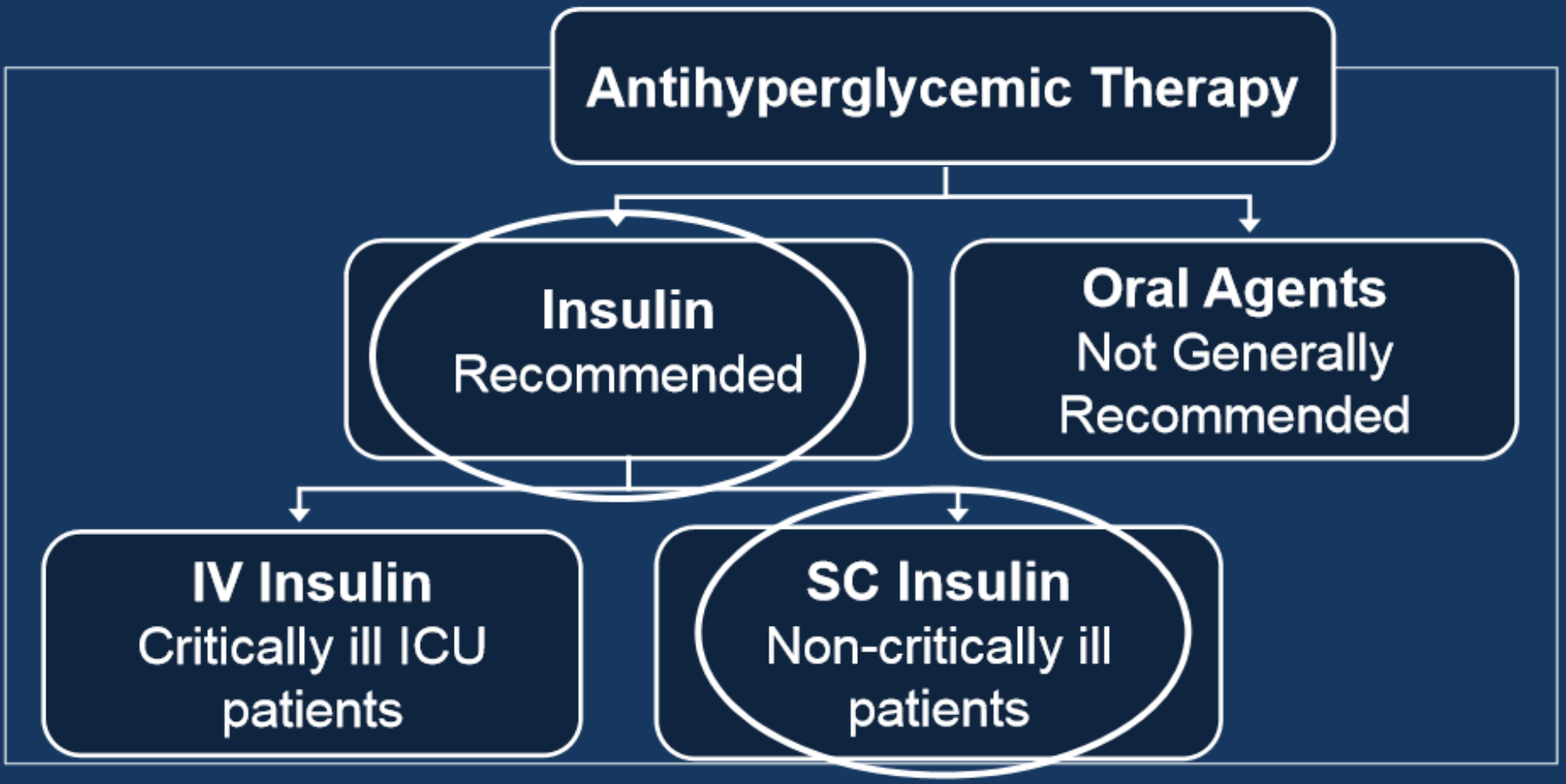
Percent of patients with hypoglycemia with at least one recurrent hypoglycemic day	Hospital	43.9%
	Top Decile	≤ 19.5%
	Top Quartile	≤ 26.0%
	Mean	29.3%
	Median	30.4%
	Range	0.0% - 50.0%

Percent of stays or days with hypoglycemia (<70 mg/dL)	Hospital	23.5%	5.3%
	Top Decile	≤ 09.3%	≤ 2.8%
	Top Quartile	≤ 11.3%	≤ 3.2%
	Mean	13.3%	3.9%
	Median	13.1%	3.8%
	Range	4.8% - 23.5%	1.3% - 7.5%

45 Y F admitted with cellulitis to medical floor. Glucose on admission 300. No prior history of diabetes. Weight 73 kg.
Which of the following is the most appropriate medical therapy to start on this patient in the hospital setting at this time?

A. IV insulin drip
B. Subcutaneous basal, bolus, and correctional insulin
C. Subcutaneous correctional (sliding scale) insulin
D. Oral metformin

Recommendations for Managing Inpatient Hyperglycemia



Clement S, et al. *Diabetes Care.* 2004; Moghissi ES, et al. *Endocr Pract.* 2009.

Most diabetes medications should be discontinued in the inpatient setting

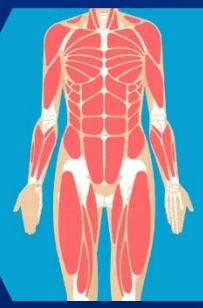
Agent	Inpatient risk	Safety concerns with inpatient use
Sulfonylureas (glyburide, glipizide, glimepiride)	**High**	Prolonged hypoglycemia in setting of reduced caloric intake, renal failure.
Metformin	Moderate	Many inpatient scenarios that can increase risk of lactic acidosis.
Pioglitazone	Moderate	Assc'd with edema in patients with heart failure, so d/c if there is any question of ventricular dysfxn.
DPP4i (sitagliptin, saxagliptin, linagliptin, alogliptin)	Low	Need to renally dose
GLP1a (exenatide, liraglutide, dulaglutide, semaglutide)	Low	Can be assc'd with nausea
SGLT2i (dapagliflozin, canagliflozin, empagliflozin, ertuglifozin)	**High**	Possible increased risk of euglycemic DKA.

Insulin Fundamentals

Insulin promotes glucose uptake in adipose tissue and conversion of glucose to triglyceride. It also inhibits burning of fat as metabolic fuel.

Metabolic Effects Of Insulin

↓ Protein breakdown



↓ Gluconeogenesis

↑ Glucose uptake (GLUT4)

↓ Glycogenolysis

↑ Glycolysis

↑ Protein synthesis

↑ Lipogenesis

↑ Glycogen synthesis

↓ Lipolysis

↑Glucose uptake (GLUT4)

↓ Ketogenesis

Insulin promotes glucose uptake in the muscle and promotes protein synthesis

Insulin shuts off liver glucose output and stimulates storage of glucose as glycogen

Physiologic insulin production

Constitutive (basal)

Occurs during fasting

~40-50%% total insulin output

Inhibits hepatic glycogenolysis, gluconeogenesis and ketogenesis

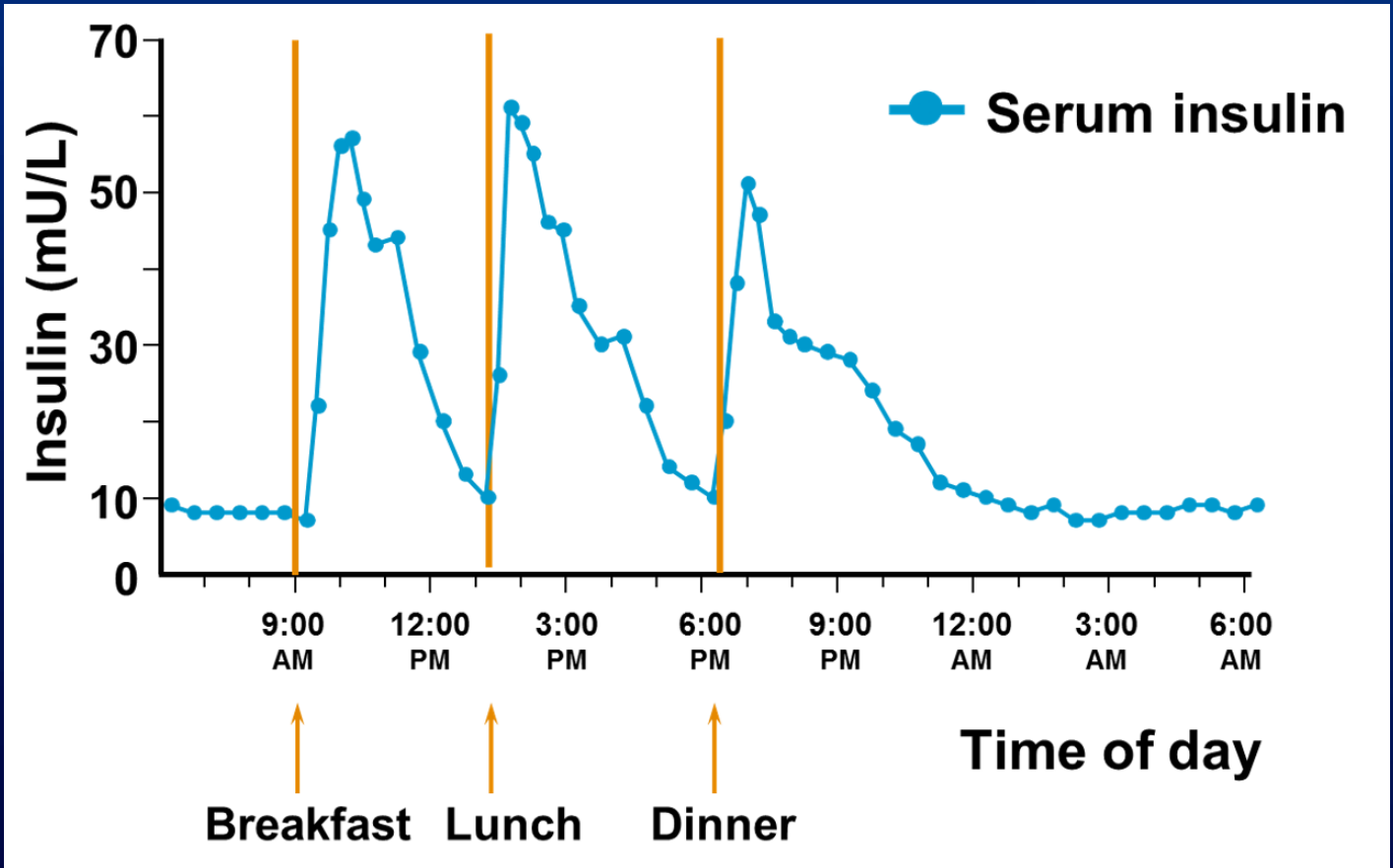
Stimulated (bolus)

Occurs after meals (postprandial) to restore euglycemia

~50- 60% total insulin output

Promotes peripheral glucose uptake

Physiologic Insulin production



Polonsky. *N Engl J Med.* 1996

Physiologic Insulin Replacement: Basal – Bolus Regimens

Aspart
Lispro
Glulisine
Regular

50% Bolus Insulin

50% Basal Insulin

Total Daily Dose (TDD)

Glargine
Detemir
NPH

Pharmacokinetics of commonly used insulin preparations

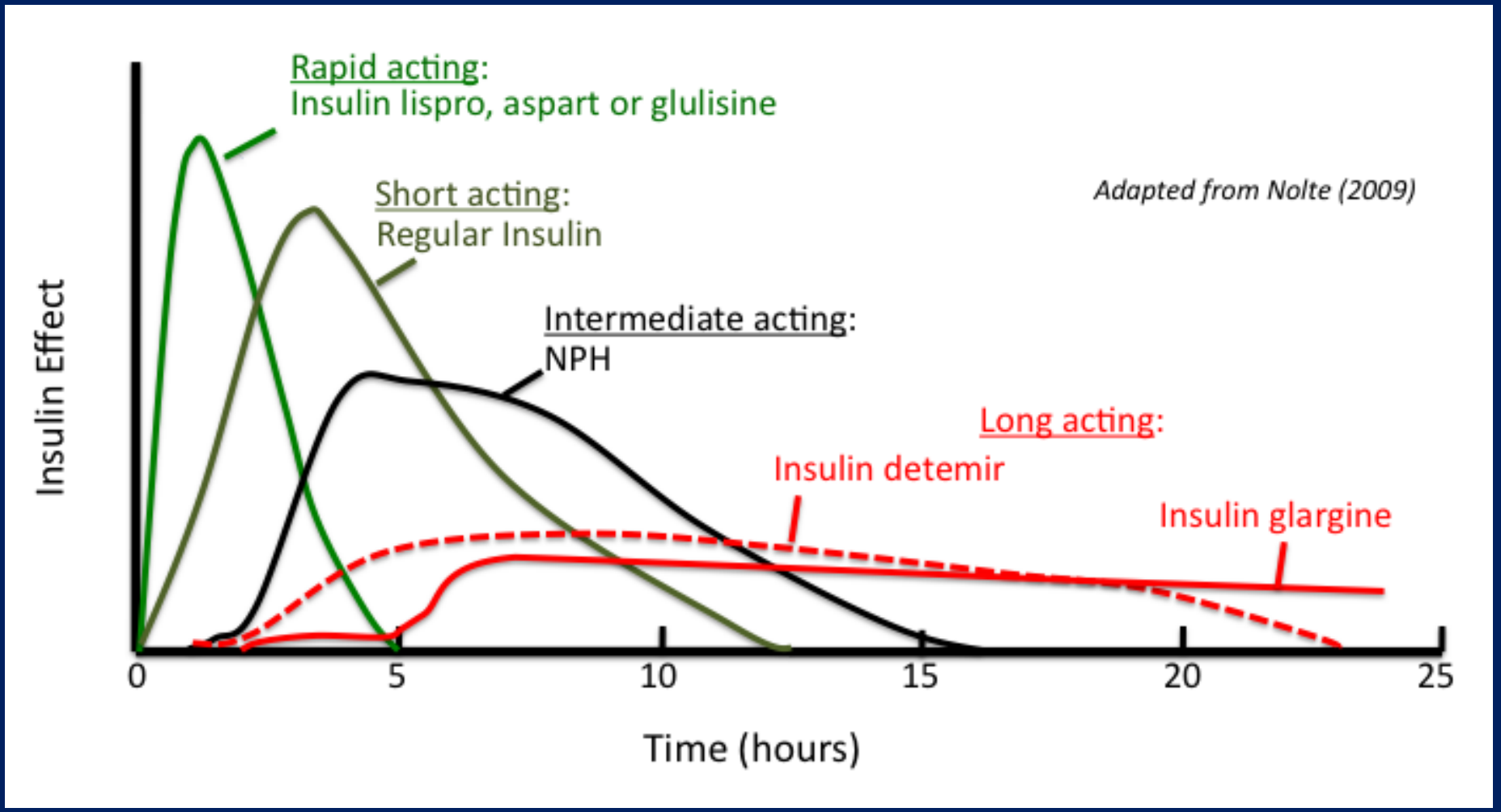
(A) Prandial insulin			
Insulin type	**Approximate onset of action**	**Effective peak**	**Approximate duration of action***
Lispro, lispro-aabc, aspart, faster aspart, glulisine ¶	15 to 30 minutes	1 to 3 hours	4 to 6 hours
Regular	30 minutes	1.5 to 3.5 hours	8 hours
(B) Basal insulin			
Insulin type	**Half-life Δ**	**Effective peak**	**Approximate duration of action***
NPH	4.4 hours	4 to 6 hours	12 hours
Insulin glargine			
U-100	12 hours	No pronounced peak	20 to >24 hours
U-300	19 hours	No pronounced peak	20 to >24 hours
Insulin detemir	5 to 7 hours	3 to 9 hours	6 to 24 hours ◊
Insulin degludec (U-100, U-200)	25 hours	No pronounced peak	>24 hours

* Glucose-lowering action may vary considerably in different individuals or within the same individual; the duration of action is dose dependent.

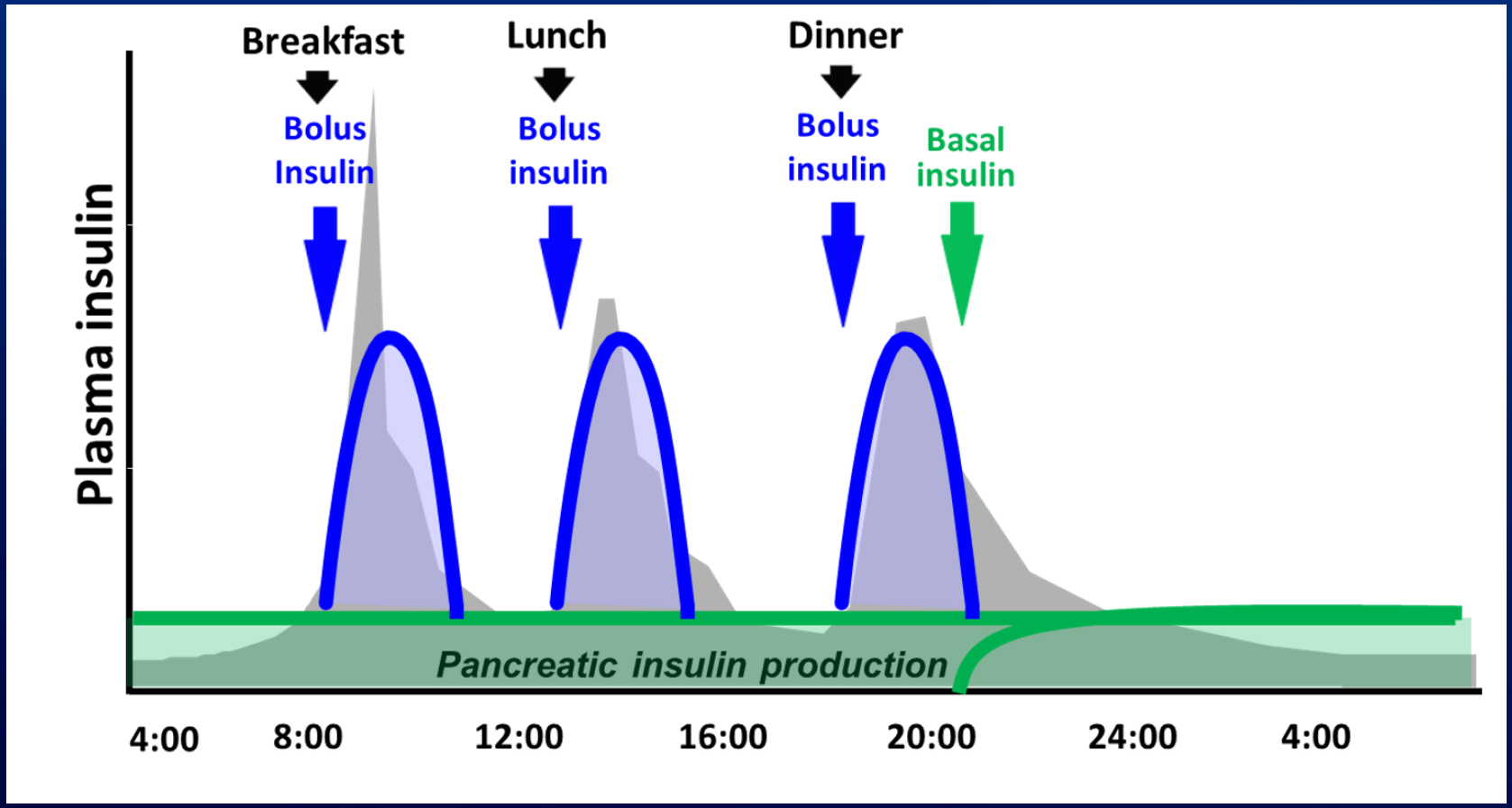
¶ Lispro-aabc and faster aspart have quicker pharmacokinetic profiles than standard lispro and aspart.

Δ In general, it takes 4 half-lives to reach steady state. Dose adjustments should not be made until after steady state is achieved.

◊ At higher doses (≥0.8 units/kg), mean duration of action is longer and less variable (22 to 23 hours).

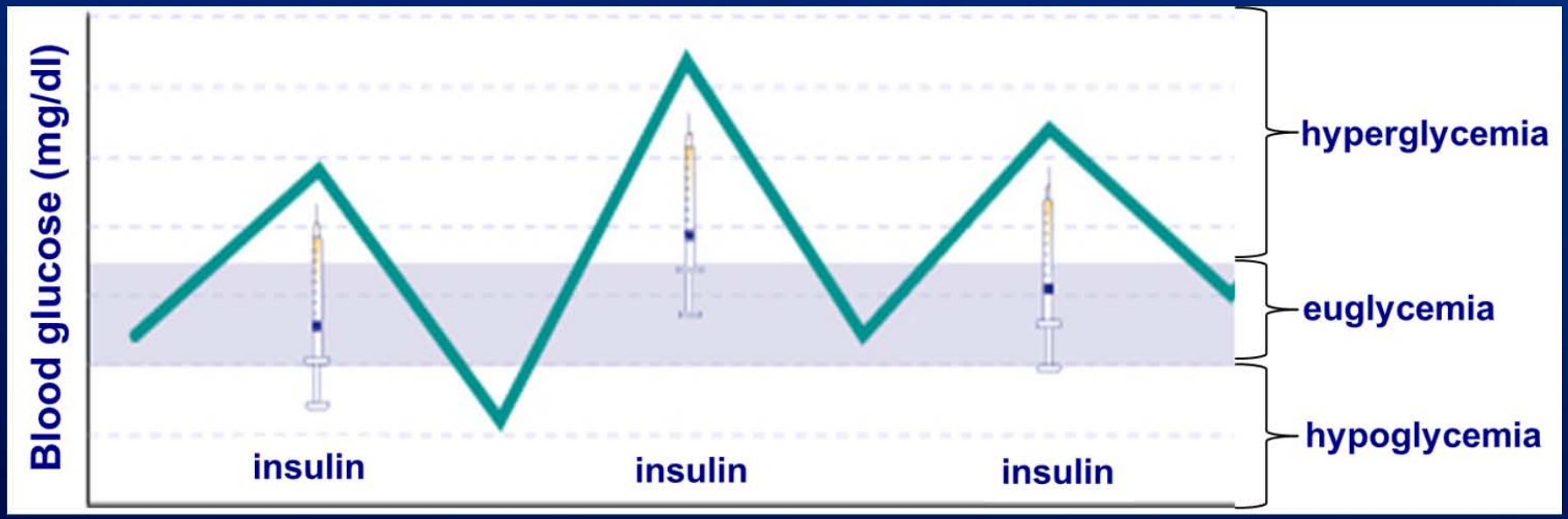

Rapid acting:
Insulin lispro, aspart or glulisine
Short acting:
Regular Insulin
Intermediate acting:
NPH
Long acting:
Insulin detemir
Insulin glargine
Adapted from Nolte (2009)
Insulin Effect
0
5
10
15
20
25
Time (hours)

The Basal/Bolus insulin therapy mimics physiologic insulin secretion



SSI monotherapy is ineffective[1-4]

"chasing" of blood sugar
widely fluctuating BG



1. Queale, WS et al. Arch Intern Med. 1997;157:545-552.
2. Gearhart JG, et al. *Fam Pract Res J.* 1994;14:313-322.
3. Sawin CT. *Arch Intern Med.* 1997;157:489.
4. Umpierrez, et al. Am J of Medicine. 2007;120,563-567

Inpatient Diabetes Management

- POC glucose checks -Q AC (before each meal) and QHS (bedtime)
- A1c testing on all patients with diabetes or hyperglycemia if not performed in the prior 3 months
- Consistent carbohydrate diet
- Basal insulin
- Prandial insulin
- Correction insulin - If the blood sugar is high ***prior*** to the patient eating the meal, they are given an ***additional amount of insulin*** (determined by the degree of hyperglycemia) ***in addition*** to the insulin to cover the meal.

Basal

Prandial

Correction

45 Y F admitted with cellulitis to medical floor. Glucose on admission 300. No prior history of diabetes. Weight 73 kg.

You have decided on using basal/bolus and correctional insulin for your hospitalized patient.

Which of the following values will help you determine what the initial total daily insulin dose (TDD) should be initially prescribed to your patient who ***was not on insulin*** prior to the hospitalization?

A. Hemoglobin A1c%
B. Creatinine
C. Body Mass Index (BMI)
D. A and C
E. All of the above

Step 1: Calculate Total Daily Dose

1. Home dose

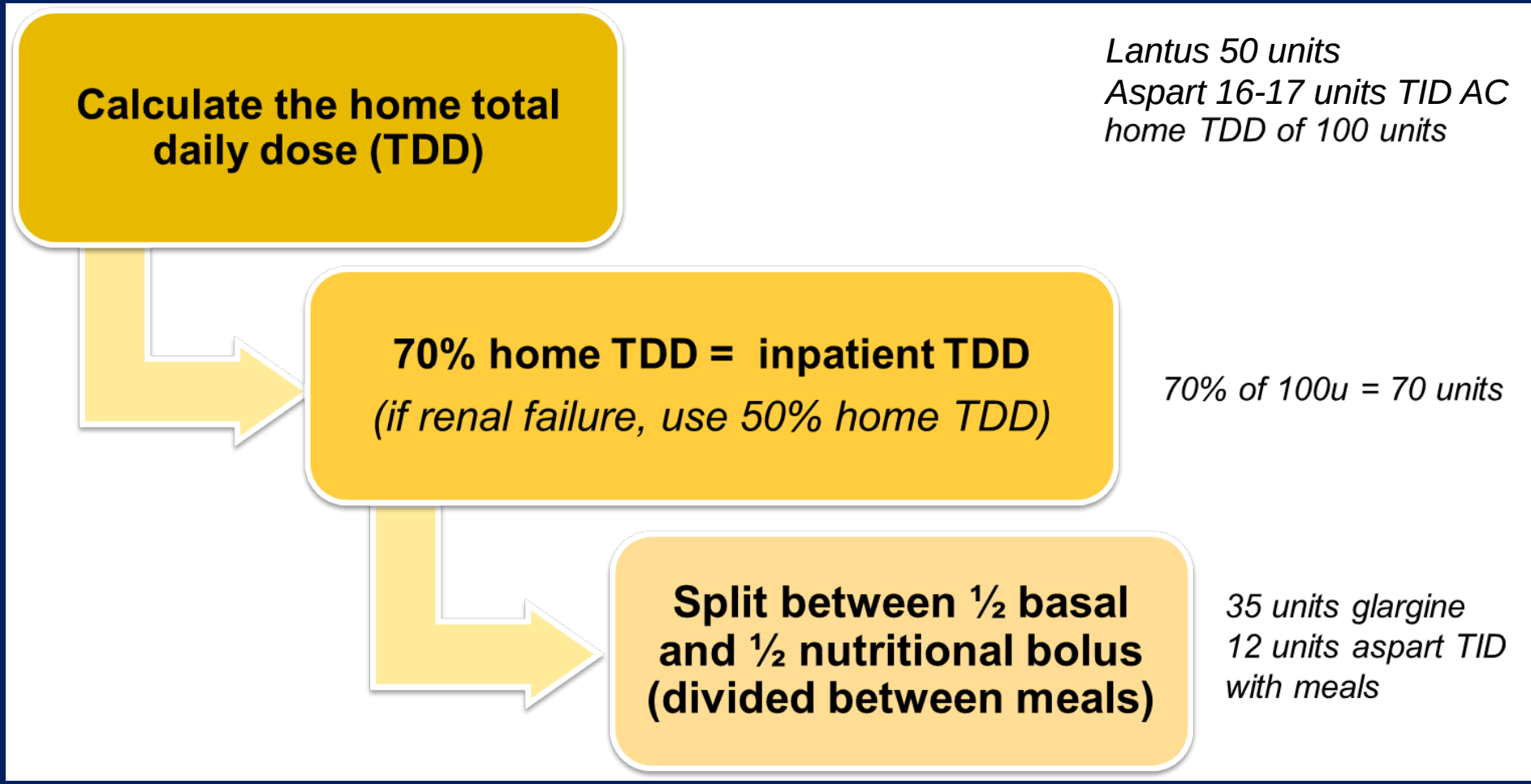
70-80% of home dose

2. IV requirements

last 6-8 hours of insulin drip rate can be used to estimate total daily dose

3. Weight based

Converting a home insulin regimen to an inpatient insulin regimen



Weight based insulin dose calculation

- Starting total daily dose (TDD):
  - 0.4 U/kg/d for BG between 140-200 mg/dL
  - 0.5 U/kg/d for BG between 201-400 mg/dL
  - 0.2- 0.3 U/ kg/day day if age > 70 and CKD

➢ Consider risk factors for hypoglycemia- elderly, low BMI, kidney disease, no history of insulin use

Divide into scheduled Basal and Nutritional Insulin

- Basal – 50%
- Prandial – 50%

- Scheduled Insulin therapy should be initiated for treatment of persistent hyperglycemia starting at a threshold ≥180 mg/dL
- Good oral intake
  - Basal
  - Prandial
  - Correction
- Poor oral intake or NPO- Basal plus correction

45 Y F admitted with cellulitis. Glucose on admission 300. No prior history of diabetes. Weight 73 kg. height 5’ 1” , BMI 30.

This is the insulin order based on your calculations:

A. 18 units glargine insulin Q HS and 6 units of lispro insulin Q AC plus correctional sliding scale
B. 36 units glargine insulin Q HS and 12 units of lispro insulin Q AC plus correctional insulin sliding scale
C. 45 units glargine insulin Q HS and 15 units of lispro insulin Q AC plus correctional sliding scale
D. 60 units glargine insulin q HS and 20 units of lispro insulin Q AC plus correctional sliding scale

Step 1:
73 kg x 0.5 units/kg =
36.4 units = TDD

Step 2:
36 / 2 = 18 glargine (basal)
18 nutritional / 3 meals =
6 units lispro q AC

18 units glargine q HS (basal) and 6 units q AC (bolus/nutritional) + correctional insulin

Prandial Insulin- Insulin to carb ratio

- Allows adjustment of insulin dose to the amount of carbohydrates and gives flexibility with eating.
- Insulin-to-carb ratio (ICR) is a calculation used to determine how many grams of carbs are covered by one unit of rapid-acting insulin.
- ICR = 450/ total daily dose
- ICR 1:10→ 1 unit of insulin for 10 grams of carbs

  So for 60 gram carbs→ 6 units prandial insulin.
- Especially useful in type 1 diabetes

Matching Prandial Insulin Dose to Food Intake

- If patient is a reliable eater (i.e. good appetite, has been eating more than 50% of tray), give Humalog within 15 minutes of START of meal.

- If the patient is not a reliable eater (i.e, appetite questionable, history of eating less than HALF of tray), give Humalog AFTER the meal, but no more than 30 minutes after the start of the meal.

-Eats > 50% of tray→ full dose of meal time Humalog.
-Eats 25 - 50% of tray→ half dose of meal time Humalog.
- Eats 0 - 25% of tray, hold the meal time Humalog.

Banner Insulin Order Set Correction Scales

Low resistance correction
(Sensitivity factor- 50)

151 - 200 mg/dL= 1 unit
201 - 250 mg/dL= 2 units
251 - 300 mg/dL= 3 units
301 - 350 mg/dL= 4 units
351 - 400 mg/dL= 5 units
Greater than 400 mg/dL = 6 units and notify provider

High resistance correction
(Sensitivity factor – 25)

151 - 175 mg/dL= 1 unit
176 - 200 mg/dL= 2 units
201 - 225 mg/dL= 3 units
226 - 250 mg/dL= 4 units
251 - 275 mg/dL= 5 units
276 - 300 mg/dL= 6 units
301 - 325 mg/dL= 7 units
326 - 350 mg/dL= 8 units
351 - 375 mg/dL= 9 units
376 - 400 mg/dL= 10 units
Greater than 400 mg/dL = 12 units and notify provider

Aggressive resistance correction
(Sensitivity factor -15)

151 - 165 mg/dL= 1 unit
166 - 180 mg/dL= 2 units
181 - 210 mg/dL= 3 units
211 - 225 mg/dL= 4 units
226 - 240 mg/dL= 5 units
241 - 270 mg/dL= 7 units
271 - 300 mg/dL= 9 units
301 - 330 mg/dL= 11 units
331 - 360 mg/dL= 13 units
361 - 400 mg/dL= 15 units
Greater than 400 mg/dL = 18 units and notify provider

Lower Resistance	Higher Resistance	Aggressive Resistance
- Type 1 diabetic - Renally insufficient - Insulin naive - On dialysis - Not known to have diabetes in the past, or newly diagnosed	- Type 2 diabetic - Acutely ill	- Obese - Receiving steroids and with blood sugar over 300 mg/dL - Do not use as initial dosing
0.4-0.5 units/kg/day total daily dose	0.5-0.6 units/kg/day total daily dose	0.7-1 units/kg/day total daily dose

Bedtime correction scale

201 - 250 mg/dL= 1 unit

251 - 300 mg/dL= 2 units

301 - 350 mg/dL= 3 units

351 - 400 mg/dL= 4 units

Greater than 400 mg/dL = 5 units and notify provider

Dose to be given if blood glucose is above 200 mg/dL at bedtime, even if patient NPO after midnight. Check blood glucose at 0200 if dose given.

A 45-year-old man with no significant past medical history (because he never saw the doctor) is admitted with pneumonia.

His blood sugar on admission is 320 mg/dL and his creatinine is 0.9 mg/dL. His BMI is 33 and his weight is 110 kg. Hgb A1c is 10.3%.

You start the patient on 28 units of glargine q HS and 9 units of lispro q AC + correction (weight based).

	7/12/2021 2200	7/12/2021 1800	7/12/2021 1200	7/12/2021 0800	7/11/2021 2200
BS-POC		300	240	202	220
Glargine (Basal)					28
Lispro (Nutritional)		9	9	9	
Lispro (Correctional)		12	8	4	

Which of the following is the most appropriate adjustment to be made to the patients insulin dosage now?

A.Glargine 30 q HS, Lispro 10 q AC, + correction
B.Glargine 35 q HS, Lispro 15 q AC + correction
C.Glargine 40 q HS, Lispro 20 Q AC + correction
D.Glargine 48 q HS, Lispro 16 q AC + correction

Daily Adjustments in Insulin Dose Based on Past 24 hour Blood Sugar Values

Step 1.

- Look at Blood Sugars for past 24 hours
- Notice any < 100 or > 180
- Calculate 24 hour insulin given (TDD)
- Any inappropriate insulin doses given or withheld?
- Adjust TDD up or down based on blood sugars, renal function, steroids, etc. (10-20% up or down)

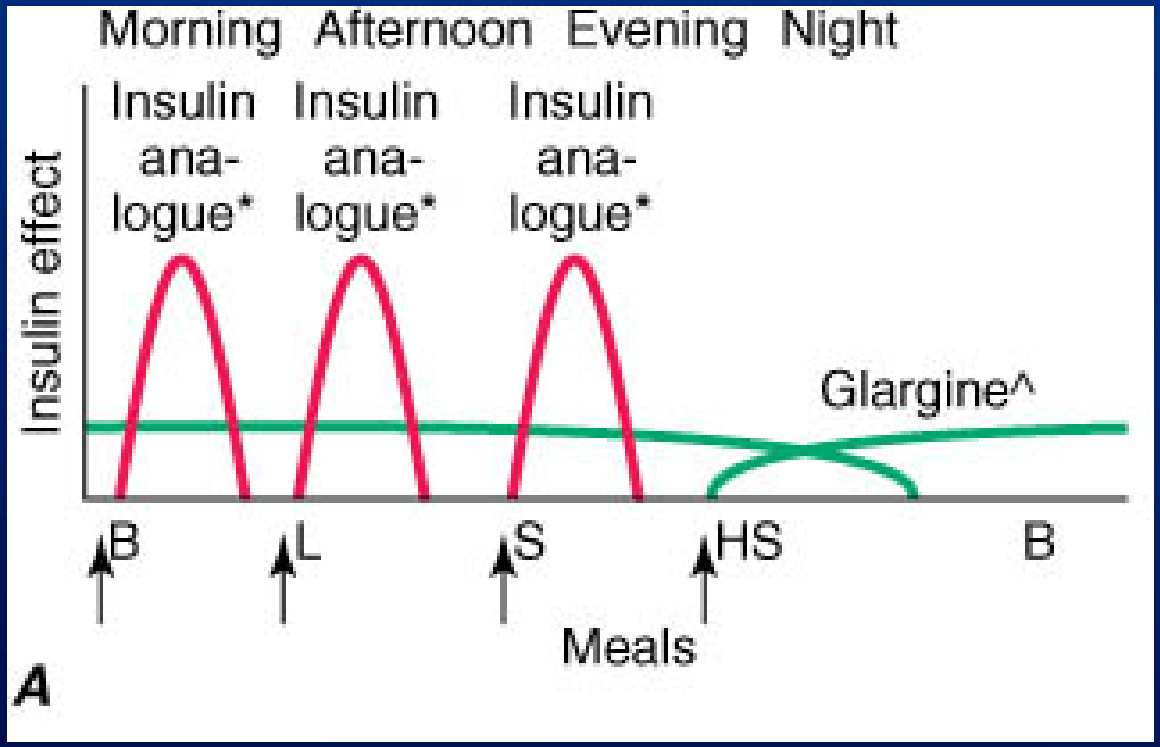
Step 2.

- Separate new TDD into Basal and Bolus (50/50)
- Separate Bolus into 3 doses (QAC)
- Continue Correctional Sliding Scale
- Place new order

180-200→ Increase by 10%
200-300→ Increase by 20%
> 300→ Increase by 30%

70-99→ Decrease by 10%
< 70 → Decrease by 20%

- TDD = 79 units
- All blood sugars > 200 therefore increase by 20%
- 79 x 1.20 = 94.8
- 95 / 2 = 47.5 = 48 glargine (basal)
- 48 / 3 = 16 units lispro (bolus)
- PLUS correctional sliding scale



Conservative insulin titration based on glucose trends

- Hyperglycemia despite insulin titration?
  - Medications increase insulin resistance (eg glucocorticoids)?
  - Illness worsening? (New infection, etc)
  - Nutritional intake increased? (sneaking food)

Why did my patient have hypoglycemia?

- Decreases in nutritional intake?
  - Nausea? Sudden discontinuation of parenteral or enteral nutrition?
- Iatrogenic Risk Factors?
  - Insulin sliding scale; poor regimens; disconnect between BG monitoring, insulin, meals
- Have hyperglycemia-inducing meds been decreased or d/c'd? (glucocorticoids, octreotide gtt)

Notes on being NPO

- NPO status is not a reason to withhold basal insulin (especially in a type I diabetic)
- If glargine is the basal and is dosed at 50% of total daily dose, then do not need to decrease the dose

A 66-year-old woman was admitted to the hospital 24 hours ago with community-acquired pneumonia. Since admission, she has been confused and her oral intake has been poor. Laboratory studies show glucose values of 185 to 215 mg/dL (10.3-11.9 mmol/L) and a hemoglobin A_{1c} level is 5.5%. A chest radiograph demonstrates a right lower lobe infiltrate.

Which of the following is the most appropriate management of this patient's hyperglycemia?

A Empagliflozin and sliding-scale insulin
B Metformin and sliding-scale insulin
C Scheduled basal insulin and correction insulin
D Sliding scale insulin only

HYPOGLYCEMIA PROTOCOL

HYPOGLYCEMIA treatment for patient CONSCIOUS and ABLE to swallow

- Glucose 50 to 69 mg/dL →15 Grams glucose gel / 4 oz apple juice
- Glucose <50 mg/dL→ 30 Grams glucose gel /8 oz apple juice

RULE OF 15

Recheck blood glucose in 15 minutes:

1. If glucose still < 70 mg/dL, repeat initial treatment until blood glucose greater than 70 mg/dL.

2. Provide meal or snack containing fat and complex carbohydrates within 1 hour to stabilize blood glucose. If applicable, dose insulin for carbohydrates according to physician orders.

3. Once blood glucose 70 mg/dL or greater, repeat blood glucose check Q1 hour X 1 to monitor for recurrence.

Unconcious/NPO/or unable to swallow

- IV established

1. 50 mL of D50W slow IV push
2. Recheck blood glucose within 15 minutes

- No IV established

1. Glucagon 1 mg intramuscular (IM)
2. Obtain IV access →if patient continues to be semi-conscious/unconscious/NPO/or unable to swallow→ follow glucose (Dextrose) protocol

Banner Subcutaneous Insulin Order Sets

Long Acting Basal Insulin	
Choose appropriate dosing scale (low, high, aggressive)	
insulin glargine	0.1 unit/kg, SubCutaneous, Soln-Inj, Q24h-interval
Patients Who are Eating	
1. Select Mealtime Insulin by dosing scale (fixed dose or carb count) 2. Select Correctional (Supplemental) Insulin by dosing scale	
insulin lispro	0.1 unit/kg, SubCutaneous, Soln-Inj, TID with meals
insulin lispro (insulin lispro carb count (HumaLOG))	carbo count insulin 1:15, SubCutaneous, Soln-Inj, TID with meals
insulin lispro (insulin lispro correction dose (HumaLO...	Low resistance correction scale, SubCutaneous, Soln-Inj, TID before meals, PRN, Blood Glucose
POCT by Nursing Glucose (Cont)	T;N, QIDACHS, (Additional check at 0200 if correction insulin dose given at HS.) When patient tolerating greater than 50% of diet
Patients Who are Not Eating (NPO)	
Select Correctional (Supplemental) Insulin by dosing scale and POCT order	
insulin lispro (insulin lispro correction dose (HumaLO...	Low resistance correction scale, SubCutaneous, Soln-Inj, Q4h-interval, PRN, Blood Glucose
POCT by Nursing Glucose (Cont)	T;N, Q4H (int), When patient NPO
Diet Order Adult	T;N, Diet: NPO (except medications)
Bedtime Insulin	
insulin lispro (insulin lispro correction dose (HumaLO...	Bedtime correction scale, SubCutaneous, Soln-Inj, QBedtime, PRN, Blood Glucose
Hypoglycemia Management	
glucose	15 Gm, Oral, On Call, PRN Blood Glucose
glucose	30 Gm, Oral, On Call, PRN Blood Glucose
glucose (Dextrose 50%)	25 Gm, IV Push, Soln-IV, On Call, PRN Blood Glucose
glucagon	1 mg, IntraMuscular, Powder-Inj, On Call, PRN Blood Glucose

DIABETIC FLOWSHEET IN CERNER

DIABETIC FLOWSHEET	07/11/2021 20:59 MST	07/11/2021 20:10 MST	07/11/2021 18:00 MST	07/11/2021 17:25 MST	07/11/2021 16:09 MST	07/11/2021 13:00 MST	07/11/2021 12:42 MST	07/11/2021 11:23 MST	07/11/2021 11:00 MST	07/11/2021 8:02 MST	07/11/2021 7:37 MST	07/11/2021 7:00 MST
Glucose POC	156 mg/dL ' H				167 mg/dL ' H			189 mg/dL ' H			134 mg/dL ' H	
Nutrition ADLs												
Diet Type												
Breakfast Percent												76-100%
Lunch Percent						51-75%						
Dinner Percent			51-75%									
Insulin Administered												
Humalog				2 units; 1 units *			2 units; 2 units *			2 units		
Lantus		12 units										

Enteral Nutrition

- Continuous Tube feeds

- Basal insulin (40% total daily dose)
- Prandial (60% total daily insulin dose) - Rapid acting insulin Q4H/ Regular insulin Q6H
- Correction Q4H (lispro, aspart or glulisine) , Q6H for regular insulin
- If tube feeds interrupted for prolonged time, consider D10 gtt at the same rate as the tube feeds can be used to prevent hypoglycemia

- Cycled Feeds

- NPH with rapid/ short acting insulin at the start of tube feeds

- Bolus feeds

- Rapid acting insulin before each bolus (60% of TDD)

TPN

- Regular insulin can be added to TPN bag, particularly if > 20 units of correctional insulin have been used in the past 24 hours

Steroid Induced Hyperglycemia

Exaggerated postprandial insulin needs

Discharge Insulin Algorithm

	A1c < 7%	A1c 7-9%	A1c > 9%
Hospital Discharge Regimen	Pre-admission therapy (oral or insulin therapy)	Pre-admission therapy + 50% TDD as glargine insulin	Pre-admission therapy + 80% glargine or basal bolus at 80% hospital TDD

Take Away Points

- Hyperglycemia in hospitalized patients is common, serious costly
- Hyperglycemia and hypoglycemia are both associated with adverse outcomes among inpatients
- Glycemic management lowers rates of hospital complications
- A standardized subcutaneous insulin order set that includes the use of scheduled basal and nutritional insulin is a key intervention for hospital management of diabetes
- Minimizing hypoglycemia is a priority for safety
- Special considerations to insulin administration are needed for patients on enteral and parenteral nutrition depending on the type and frequency.


Thank
You