Diabetes Management and the Transplant Patient

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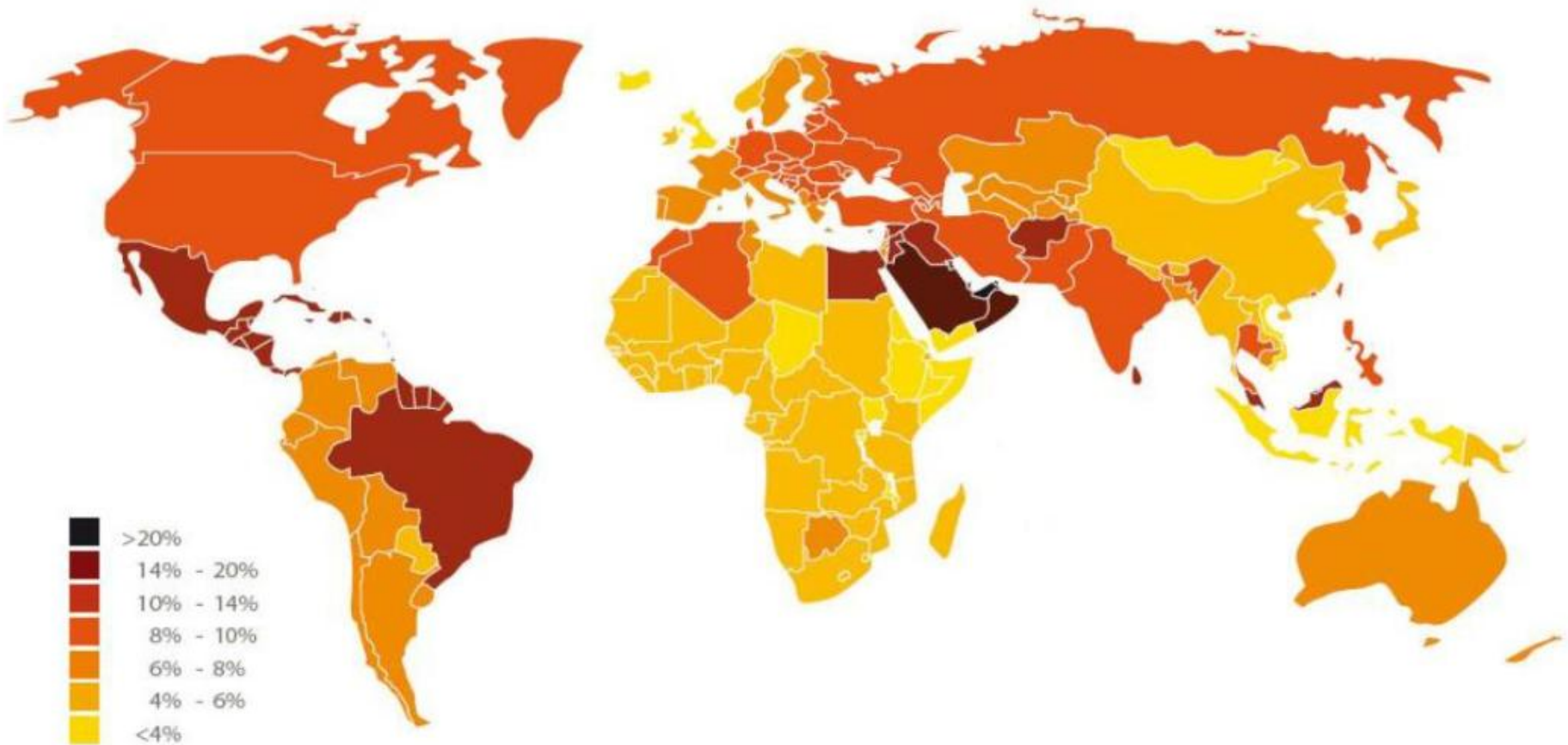
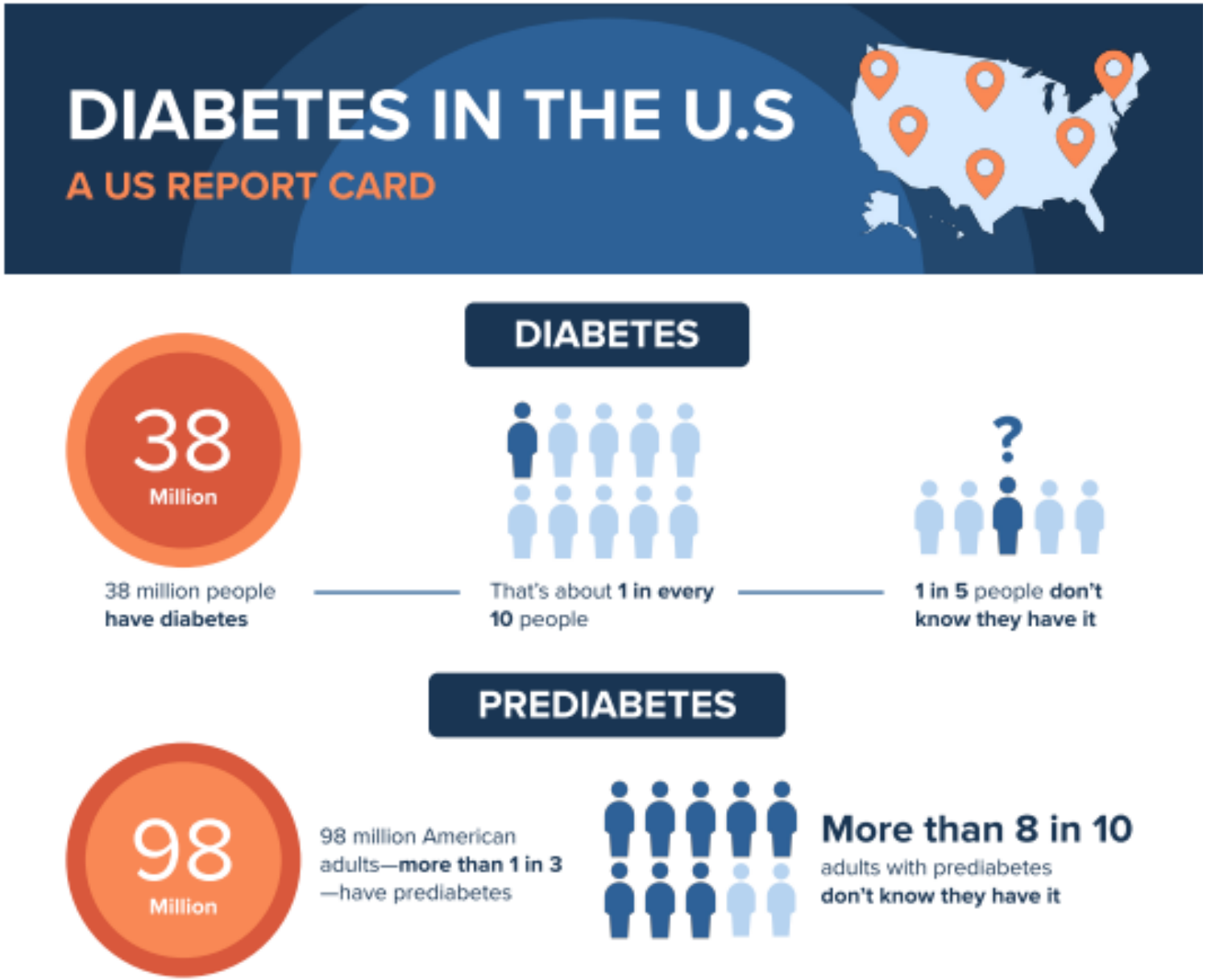
Estimated World Prevalence of Diabetes: 2025

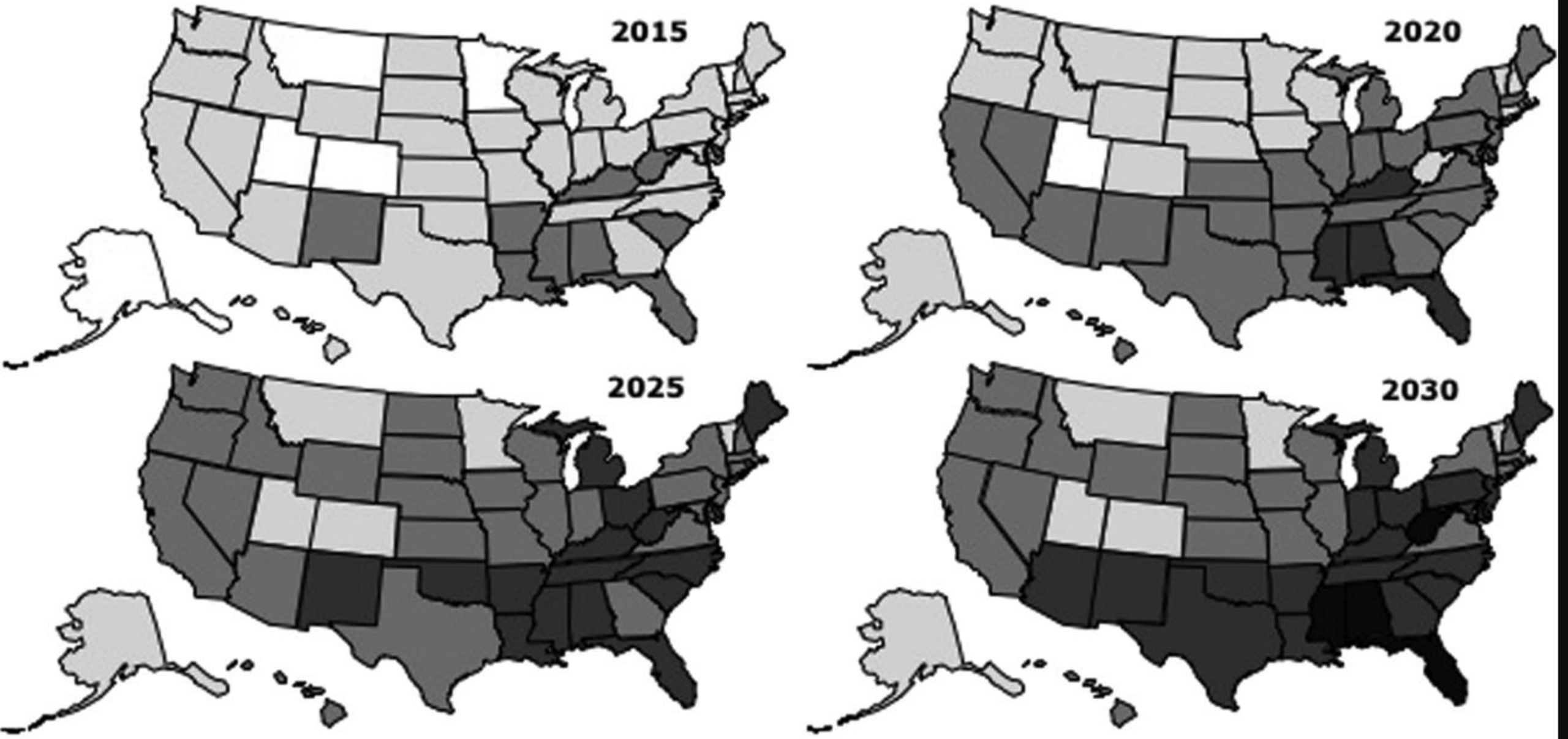
Prevalence estimates of diabetes, 2025





DiabetesInTheUS_Thumbnail-min - Taking Control Of Your Diabetes®

Increasing Prevalence of Diabetes



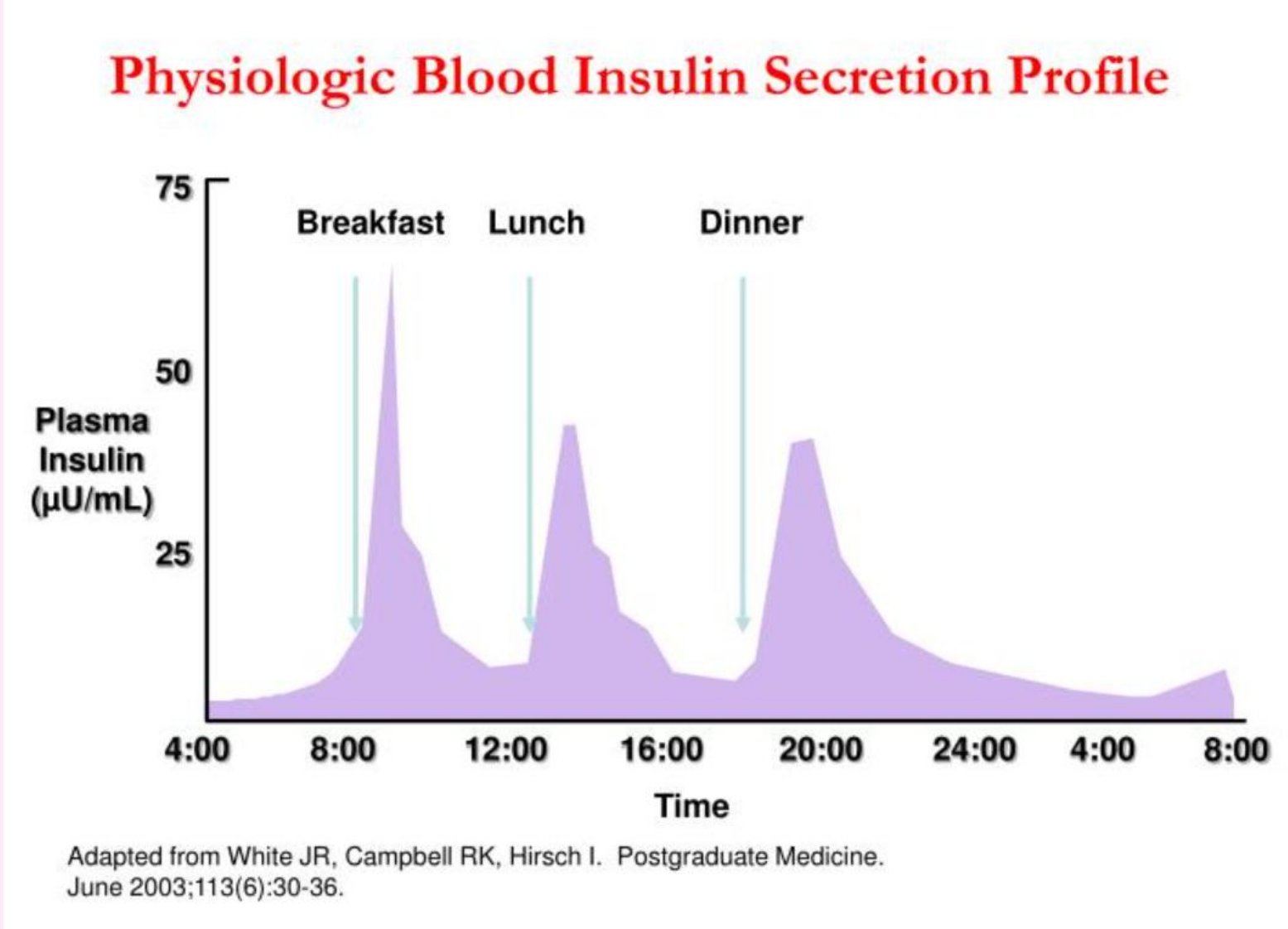
Endocrinology

16,181 licensed Endocrinologists in the US

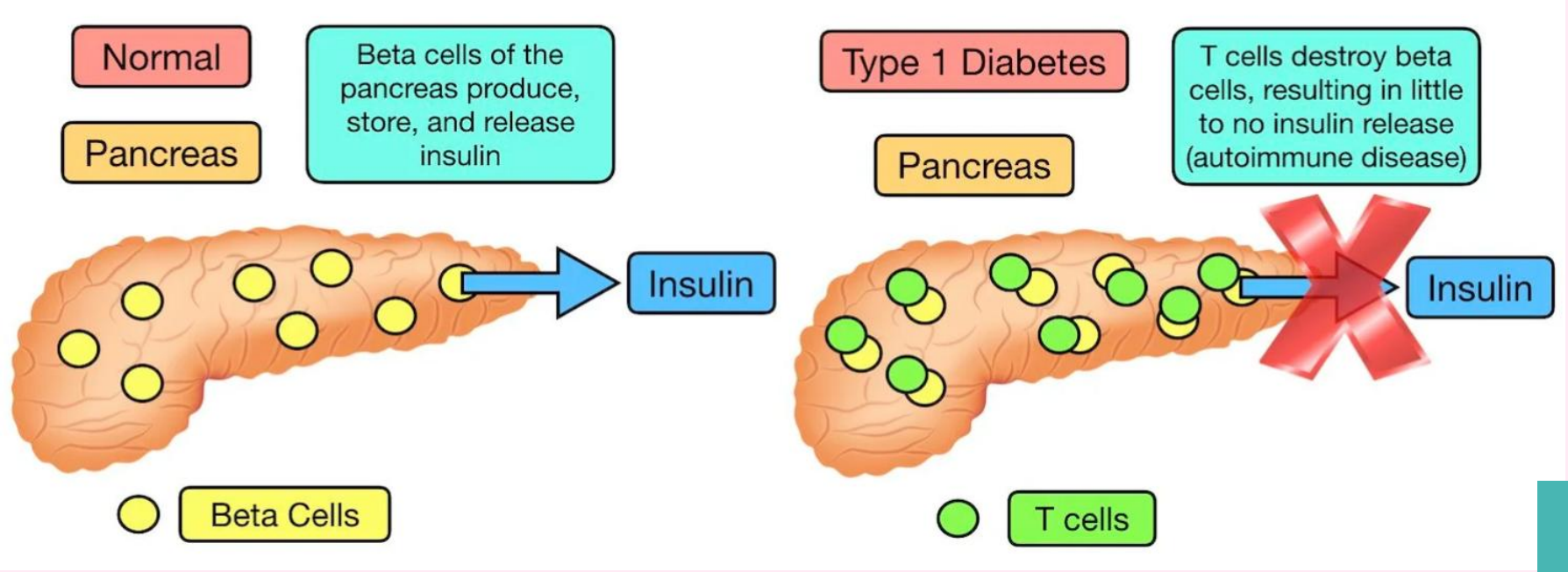
Vanderbilt University Medical Center: Division of Endocrinology

- 24 clinical Endocrinologists
- 24 APPs

Normal Insulin Physiology



Type 1 Diabetes

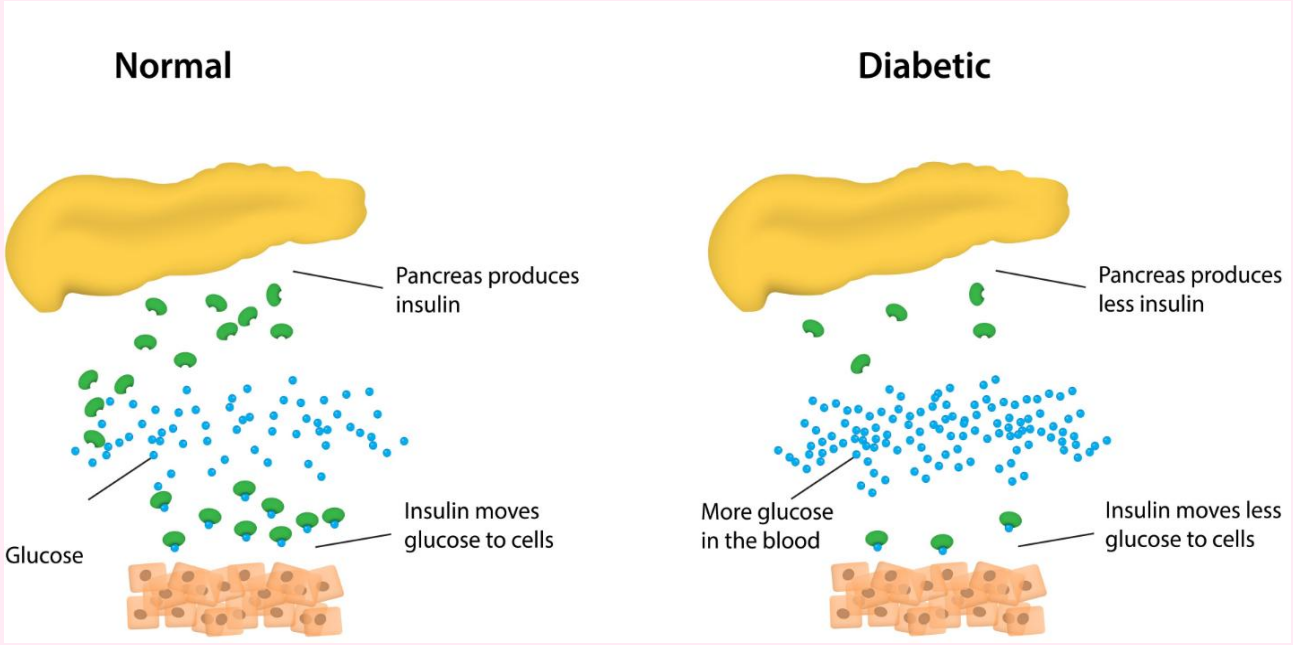


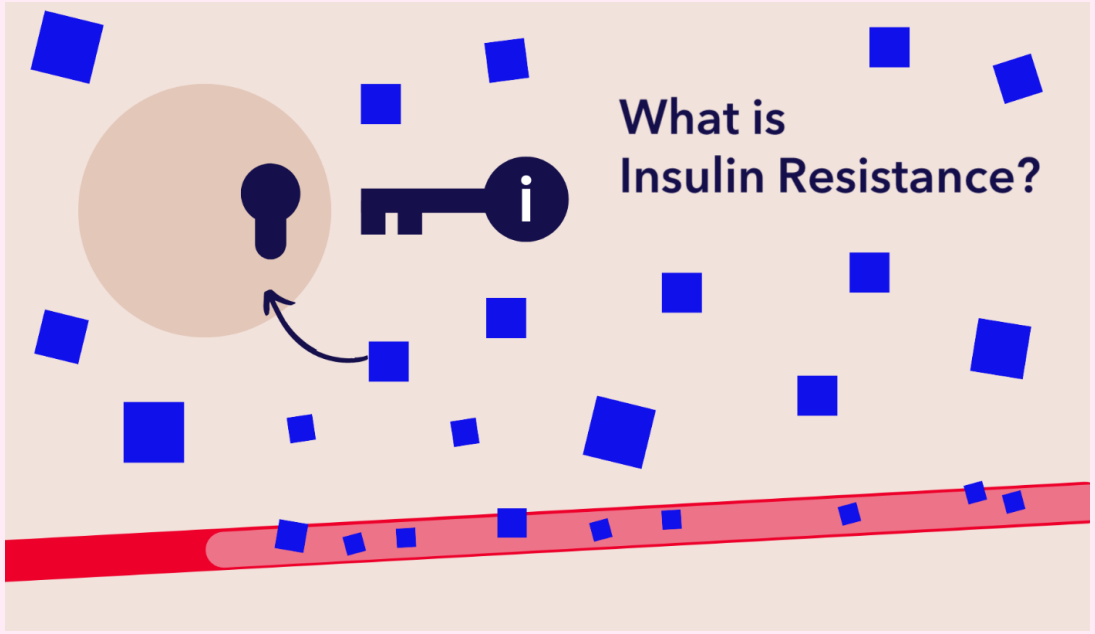
Autoimmune

Lifelong insulin treatment

Type 2 Diabetes

Insulin resistance + deficiency





Risk Factors:

- Family history
- Overweight/ Obesity
- African American, Hispanic, Asian, Native American, Pacific Islanders

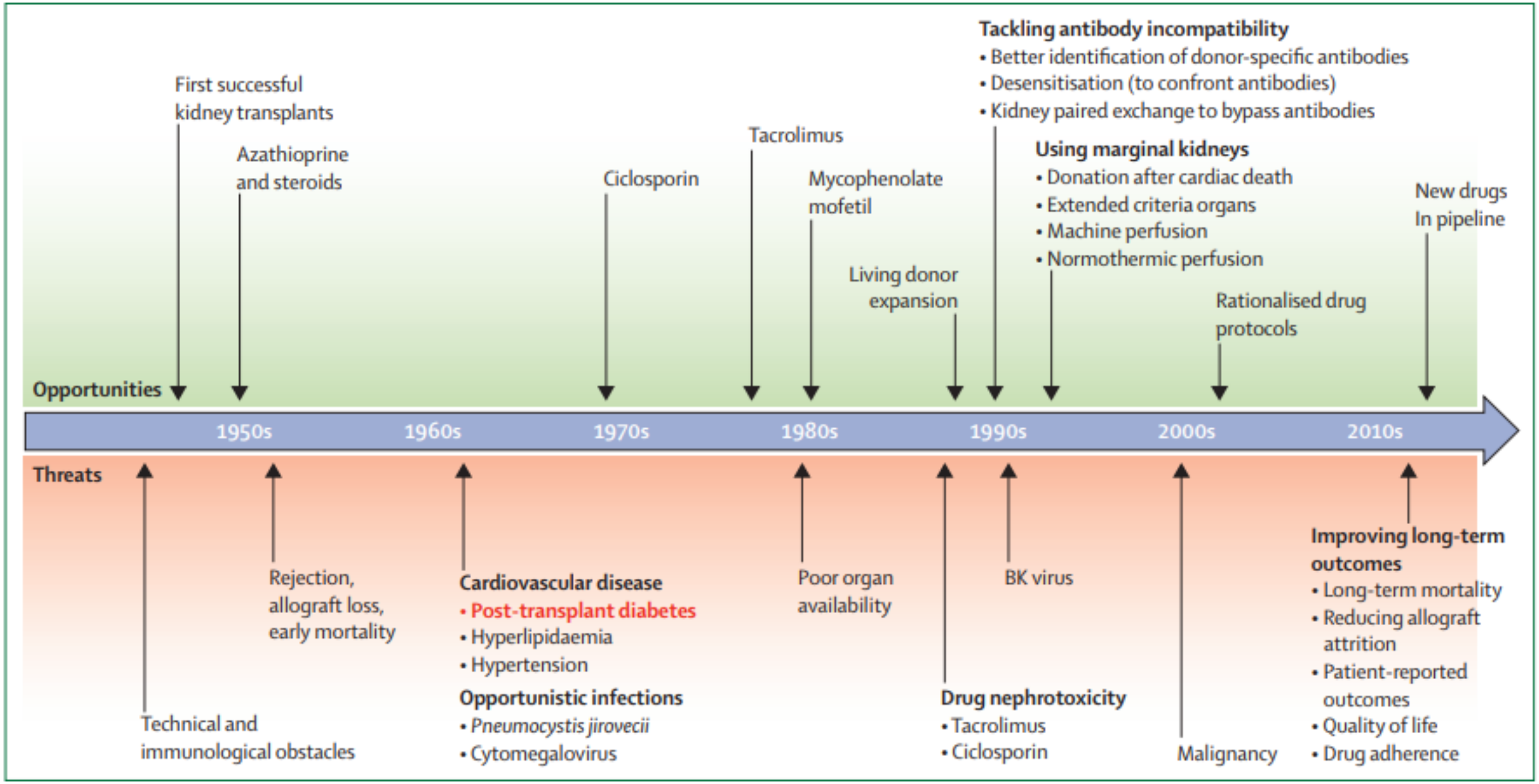


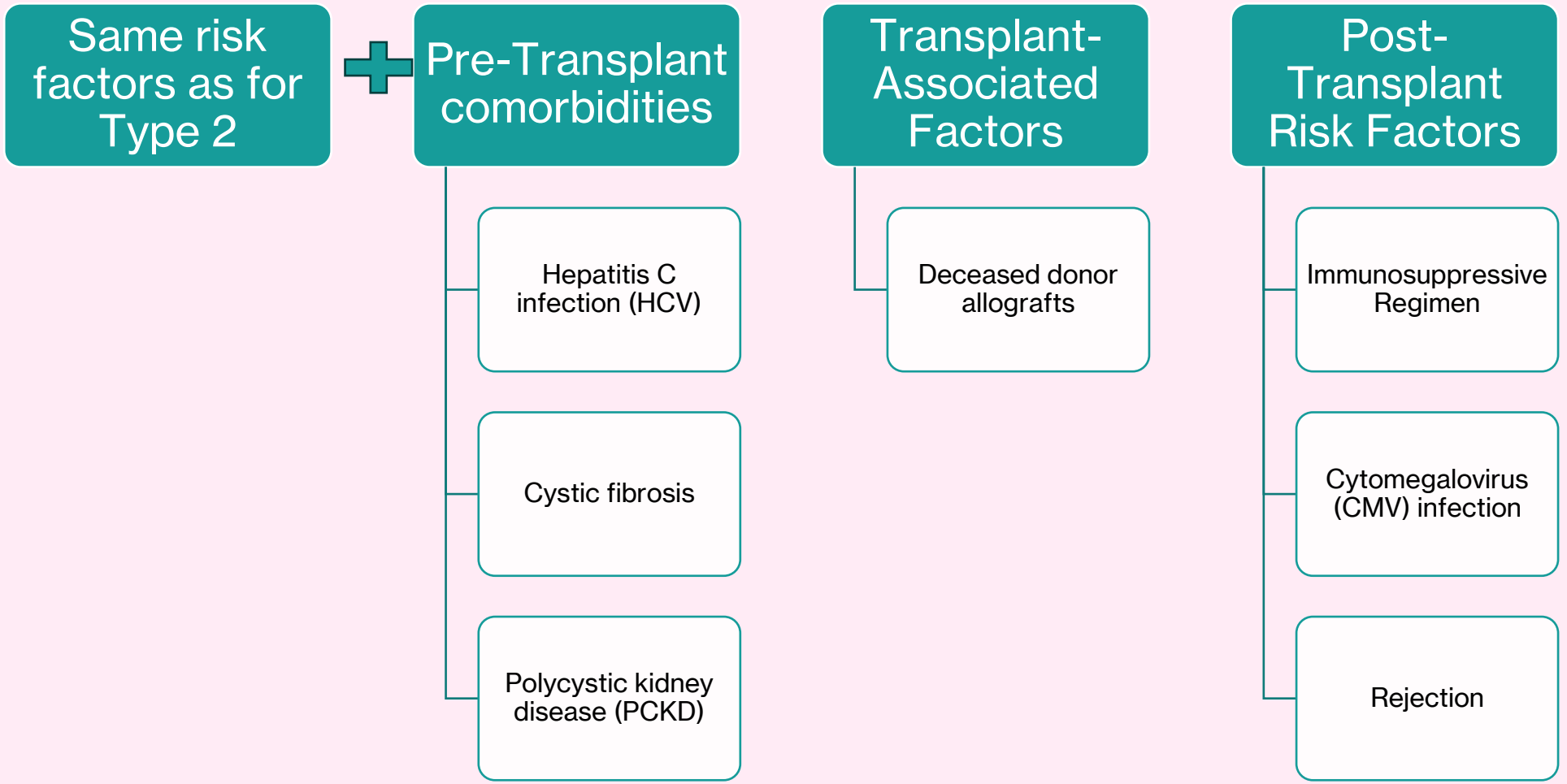
Figure 1: **Timeline of kidney transplantation, threats, and opportunities that have contributed to changes in practice**

The important take home message from this timeline is the need to understand the importance of post-transplant diabetes in view of competing risks and changes in clinical practice over time.

Organ	Incidence
Kidney	10-20%
Liver	30-40%
Heart	20-30%
Lung	20-40%

Incidence of PTDM

Post Transplant Diabetes Mellitus (PTDM)



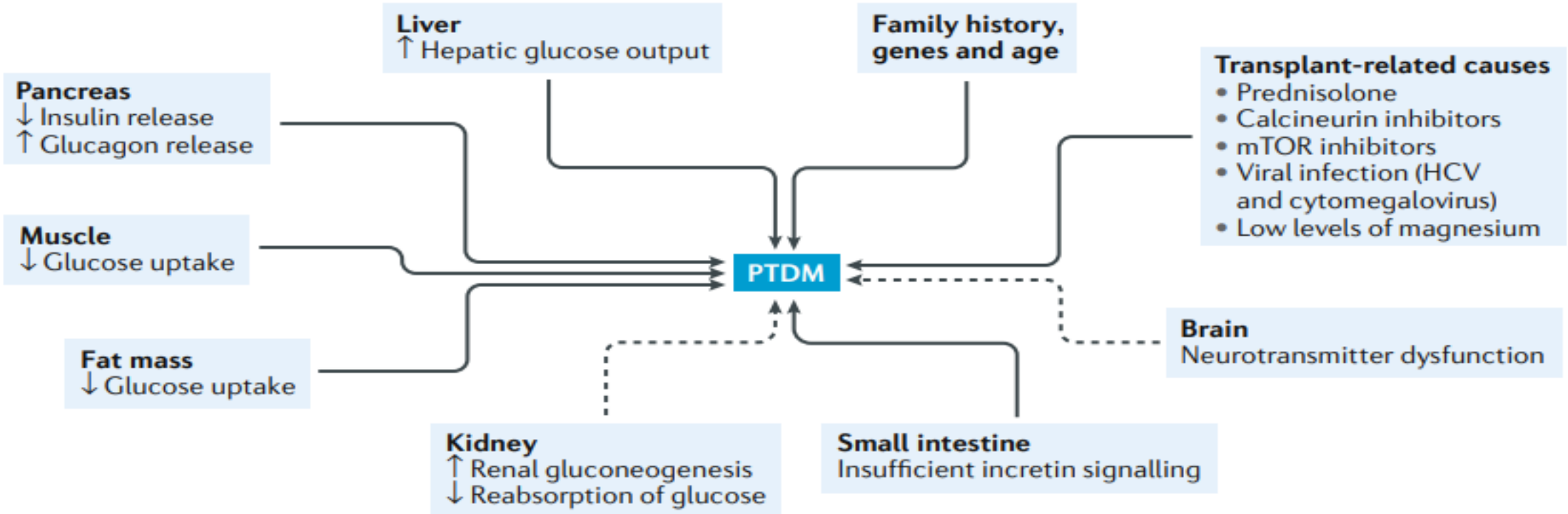


Fig. 1 | **Acknowledged contributors of hyperglycaemia in PTDM.** Common pathways in type 2 diabetes mellitus and post-transplant diabetes mellitus (PTDM) are impaired insulin release and impaired suppression of glucagon release. These effects are not fully compensated by glucagon-like peptide 1 (GLP1) release from the intestinal tract. Insulin-stimulated glucose uptake is reduced in muscle cells and adipocytes, and insulin-mediated suppression of hepatic glucose output is also reduced. In type 2 diabetes mellitus, it is documented that both renal gluconeogenesis and tubular reabsorption of glucose are increased, and crosstalk between insulin, the brain and systemic metabolism is also present. These mechanisms might also be operative in PTDM, but this has not yet been documented. Known contributors of hyperglycaemia in PTDM are shown with bold arrows. Broken arrows depict contributing organs in type 2 diabetes mellitus that have not yet been examined in PTDM. HCV, hepatitis C virus; mTOR, mechanistic target of rapamycin.

Dolly

- 56-year-old female
- Type 2 DM x 15 years
- HTN, HLD
- Diabetic nephropathy -> ESRD on HD x 3 years
- DDKT- received Methylprednisolone 500mg in OR
- Steroid taper:
  - POD 1: Methylpred 250mg
  - POD 2: Methylpred 125mg
  - POD 3: Prednisone 20mg daily

Johnny

- 65-year-old male
- Type 2 DM
- NICM, HErEF (on home Milrinone), HTN, CAD, CKD III, OSA, MDD, GERD, Iron Deficiency Anemia, Glaucoma, Prostate Cancer (now in remission)
- OHT
- Steroid Course
  - Methylprednisolone 125mg q8hours x 2 doses
  - Methylpred 100mg x 1
  - Methylpred 80mg x 1
  - Methylpred 60mg x 1
  - Methylpred 40mg x 4
  - Prednisone 30mg daily until biopsy

Insulin drip for the first 5 days after transplant

Pre-Transplant

Diagnosing PTDM

- Day 0-45: do not diagnose PTDM
- Day 46-365:
  - Oral Glucose Tolerance Test (OGTT)
    - Fasting glucose 126mg/dl or > **and/or**
    - 2-hour plasma glucose 200mg/dl or >
  - Fasting glucose 126mg/dl or >
  - Random glucose 200 or > WITH SYMPTOMS
  - Hemoglobin A1C 6.5% or > (may underestimate PTDM if used <1 year post-transplant)
- Greater than 1-year post-transplant
  - OGTT
  - Hemoglobin A1C
  - Fasting glucose/ Random glucose

What Alters A1C

- Hematologic conditions
  - Anemia
  - Accelerated erythrocyte turnover
  - Thalassemia
  - Sickle cell disease
  - Reticulocytosis
  - Hemolysis
- Physiologic States
  - Aging
  - Pregnancy
- Drugs/Medications
  - Alcohol
  - Opioids
  - Vitamin C
  - Vitamin E
  - Aspirin
  - Erythropoetin
  - Dapsone
  - Ribavirin
- Disease States
  - HIV infection
  - Uremia
  - Hyperbilirubinemia
  - Dyslipidemia
  - Cirrhosis
  - Hypothyroidism
- Medical Therapies
  - Blood transfusion
  - Hemodialysis
- Miscellaneous
  - Glycation rate
  - Protein turnover
  - Race and ethnicity*
  - Laboratory assay
  - Glycemic Variability
  - Smoking
  - Mechanical heart valves
  - Exogenous testosterone?

Fructosamine

- Glycated albumin; reflects average glucose levels over the preceding 2-3 weeks

- A1C= 0.017 x fructosamine + 1.61

Table 1.

Correlations Between Estimated Average Glucose, A1c, and Fructosamine[1,9,4]

Glucose (mg/dl)	A1c (%)	A1c (mmol/mol)	Fructosamine (µmol)
97	5	31	131
126	6	42	203
154	7	53	273
183	8	64	345
212	9	75	417
240	10	86	487
269	11	97	559
298	12	108	631

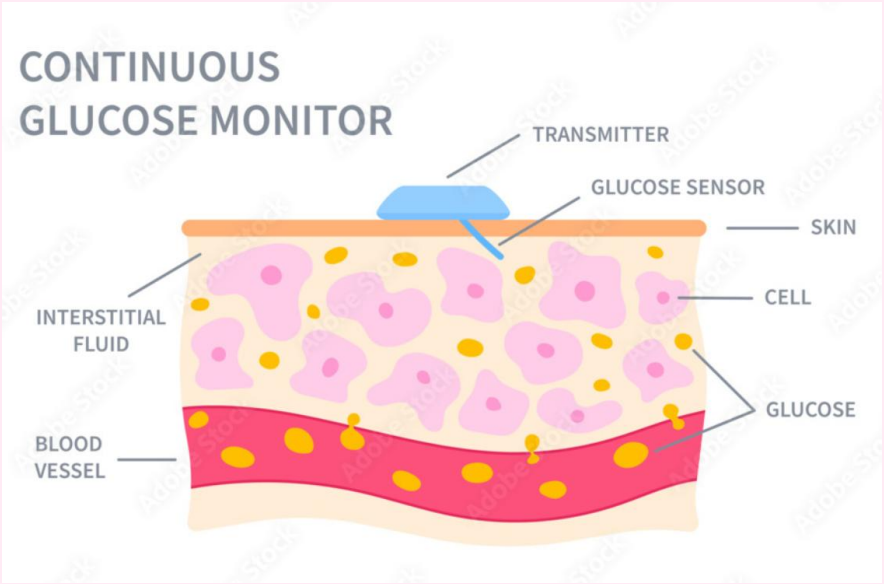
A1c hemoglobin A1c

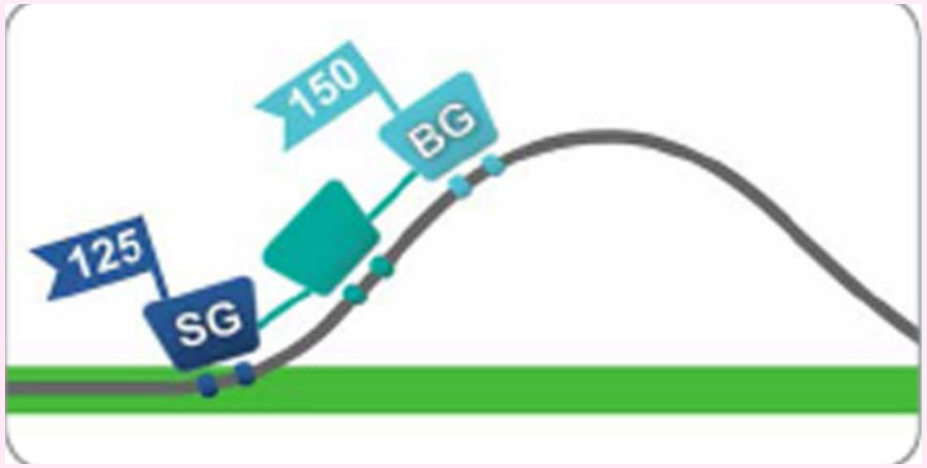
Table 7.2—Some of the more common interfering substances and/or conditions that affect blood glucose meters (for inpatient and outpatient use)

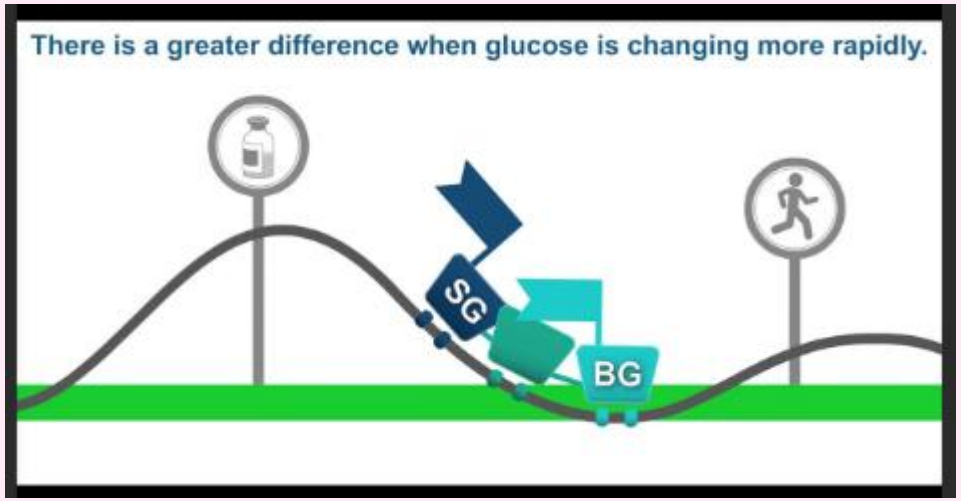
Substance or condition	Potential effects on glucose readings measured by BGMs*
Maltose†	Falsely higher blood glucose readings
Galactose	Falsely higher blood glucose readings
Xylose	Falsely higher blood glucose readings
N-Acetylcysteine	Falsely higher or lower blood glucose readings (depending on BGM design)
Acetaminophen	Falsely higher or lower blood glucose readings (depending on BGM design)
Dopamine	Falsely higher or lower blood glucose readings (depending on BGM design)
Pralidoxime (2-PAM)	Falsely higher or lower blood glucose readings (depending on BGM design)
Hydroxyurea	Falsely higher or lower blood glucose readings (depending on BGM design)
Vitamin C	Falsely higher or lower blood glucose readings (depending on BGM design)
Hematocrit (high)	Falsely lower blood glucose readings
Hematocrit (low)	Falsely higher blood glucose readings

*These are potential effects. There are blood glucose monitors (BGMs) that behave differently than listed in this table. Refer to product labeling for product-specific information. †Unmodified glucose dehydrogenase pyrroloquinoline quinone (GDH/PQQ) enzyme method only. Modern BGM designs do not incorporate unmodified GDH-PQQ enzyme.

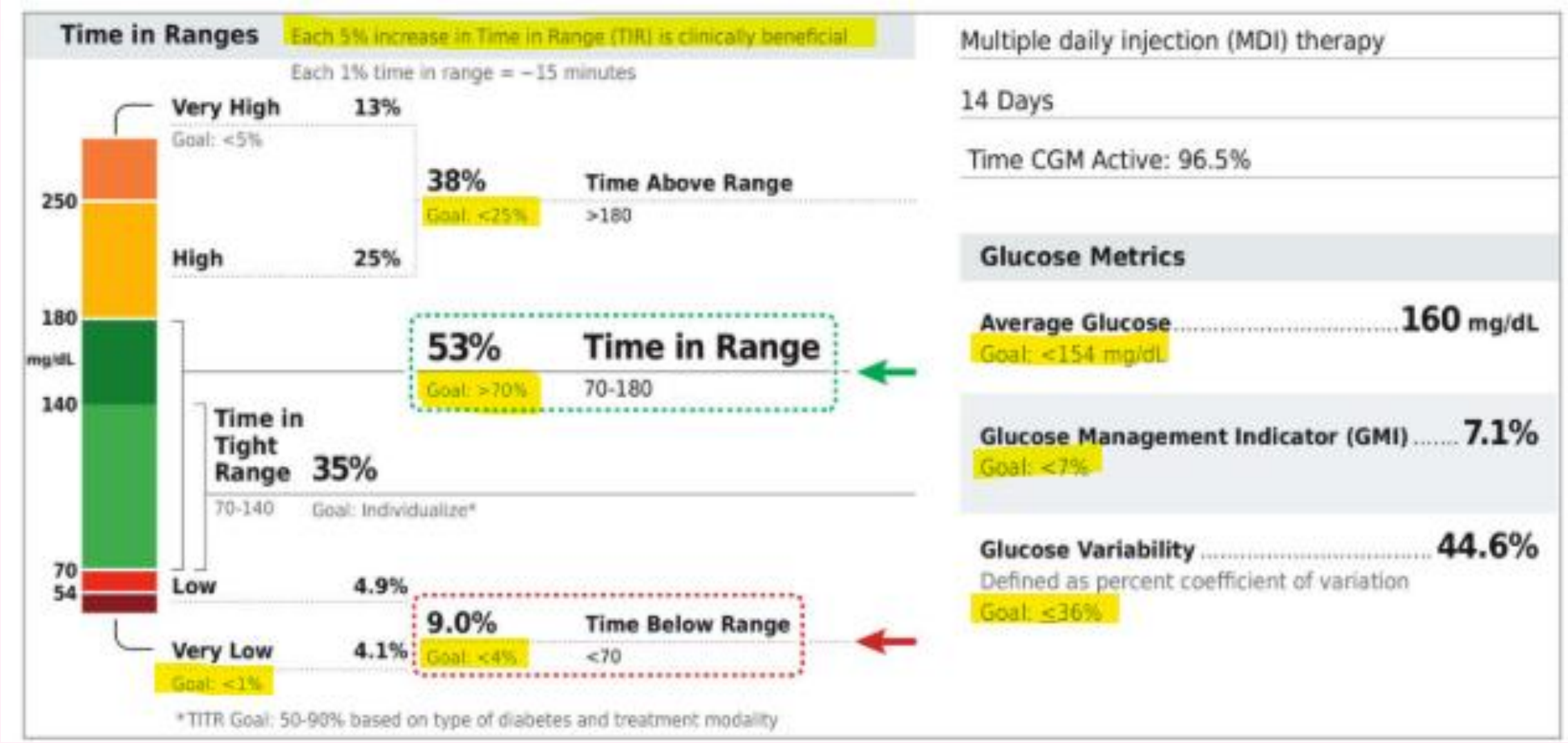
Continuous Glucose Monitors (CGMs)



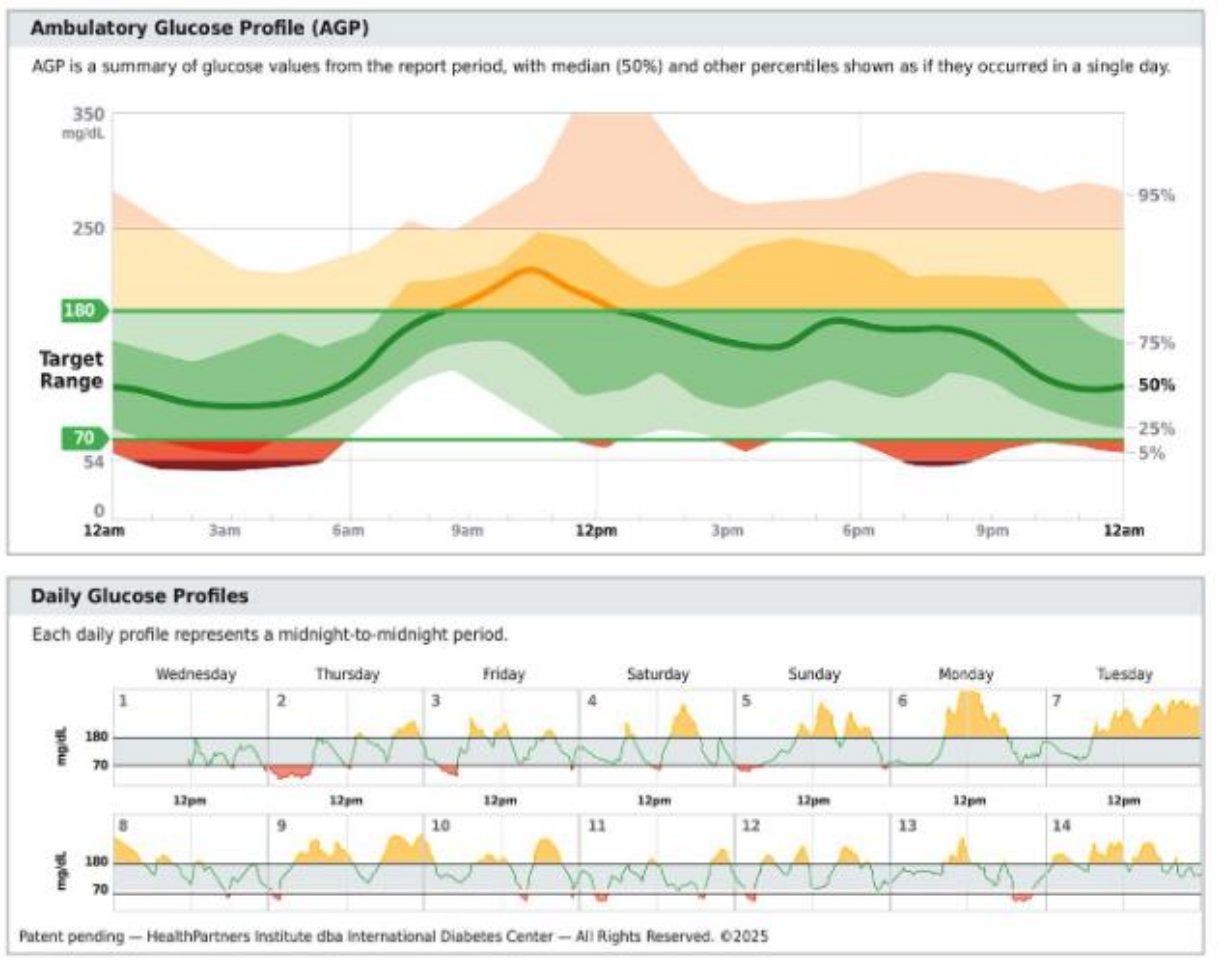




CGM Data


Time in Ranges
Each 5% increase in Time in Range (TIR) is clinically beneficial
Each 1% time in range = ~15 minutes
Very High 13%
Goal: <5%
High 25%
38%
Goal: <25%
Time Above Range
>180
250
180
mg/dL
140
70
54
53%
Goal: >70%
Time in Range
70-180
Time in Tight Range 35%
70-140
Goal: Individualize*
Low 4.9%
Very Low 4.1%
Goal: <1%
9.0%
Goal: <4%
Time Below Range
<70
*TITR Goal: 50-90% based on type of diabetes and treatment modality
Multiple daily injection (MDI) therapy
14 Days
Time CGM Active: 96.5%
Glucose Metrics
Average Glucose 160 mg/dL
Goal: <154 mg/dL
Glucose Management Indicator (GMI) 7.1%
Goal: <7%
Glucose Variability 44.6%
Defined as percent coefficient of variation
Goal: ≤36%

CGM Data



1. Address hypOglycemia

2. Address hyperglycemia

FreeStyle Libre

More affordable CGM at half the cost of other CGMs*1

Present this copay card to save money on your FreeStyle Libre CGM systems prescription each month.†

Get a more affordable price right at the register‡1

Copay savings for all eligible users, including non-insulin and GLP-1

BIN: 610020 | GROUP: 99992546
STATIC ID: ERXCONSUMERWEBLIBRE

FreeStyle Libre

Present this **COPAY CARD** to your pharmacist each time you fill your prescription.

Abbott

Copay savings for commercially insured or uninsured patients.

FOR PATIENTS: Present this FreeStyle Libre CGM systems copay card to your pharmacist.

FOR HCPs: Print and give this copay card to your patients to present at the pharmacy.

FOR PHARMACISTS: Important—DO NOT combine with other prescription sensor fill transactions. For insured patients, submit the SECONDARY Claim to PDMI under BIN 610020. For uninsured patients, submit PRIMARY/Cash Claim to PDMI under BIN 610020.

A PCN code is not required to process the copay card.

For questions about the product or about using your copay card, please call 1-855-632-8658.
(Monday–Friday 8 AM–8 PM ET, excluding holidays.)

Steroids

1. Decrease insulin sensitivity
2. Increase hepatic gluconeogenesis
3. Increase appetite -> weight gain
4. Effect on glucose is dose dependent

Calcineurin Inhibitors (CNIs)

Tacrolimus > Cyclosporin

Increased islet cell apoptosis

Decreased beta cell mass

Mammalian Target of Rapamycin Inhibitors (mTORI)

- Sirolimus
  - Impaired insulin secretion
  - Reduction in insulin signaling

Goals

- Optimize long-term outcomes
- Prevent microvascular and macrovascular complications
- Lessen premature mortality
- Decrease risk of graft loss
- Lower glucose by targeting cause of hyperglycemia
- Avoid interaction with immunosuppression meds

Glucose targets

- During hospitalization: 140-180mg/dl
- At home:
  - Fasting: 80-130mg/dl
  - Post-prandial: <180mg/dl
- Continuous Glucose monitor (CGM):
  - > 70% time in range (TIR)
    - Target range is 70-180mg/dl
- Hemoglobin A1C <7%

Treatment of PTDM

Continue education

Nutritional counseling

Exercise

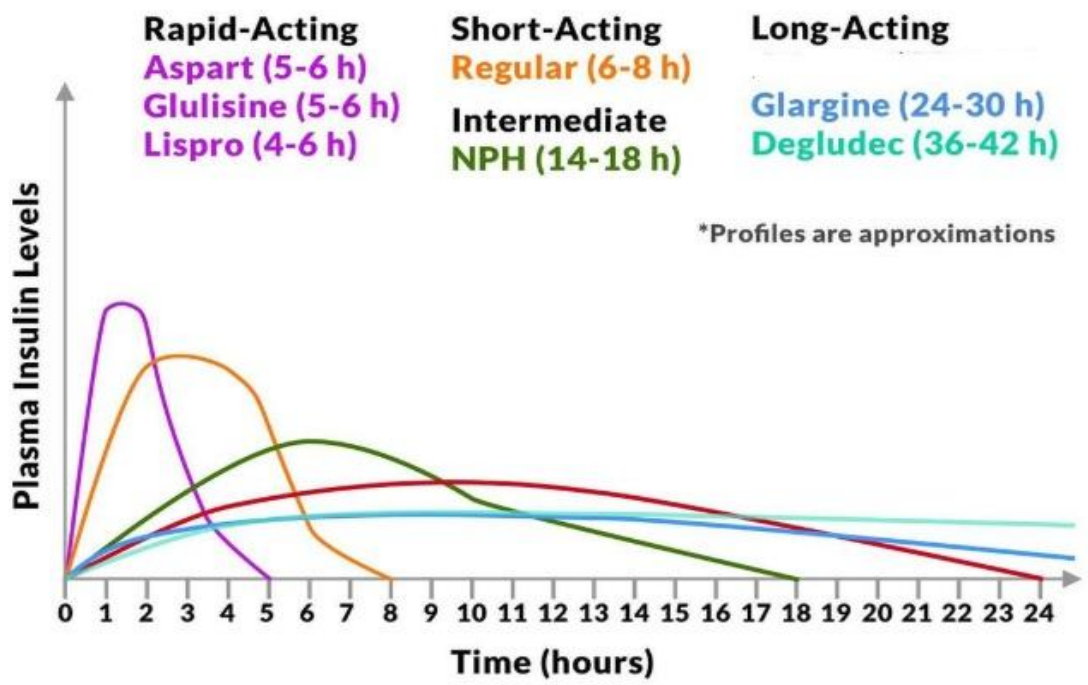
Insulin

Consider other medications

Doses of immunosuppression medications are stable

Less than 20 units of insulin/day

Insulin Action Profiles



Adapted and referenced from: Hirsch IB. Insulin analogues. N Engl J Med. 2005 Jan 13;352(2):174-83. https://www.ncbi.nlm.nih.gov/pubmed/15647580 and individual product labels.

Insulin	Onset	Peak	Duration
Ultra-Rapid Acting			
Insulin lispro (Lyumjev™)	10-15 mins	1-2 hrs	4-6 hrs
Insulin aspart (Fiasp®)	10-15 mins	1-2 hrs	4-6 hrs
Rapid-Acting			
Insulin lispro (Admelog®, Humalog®)	15 mins	1-2 hrs	4-6 hrs
Insulin aspart (Novolog®)	15 mins	1-2 hrs	4-6 hrs
Insulin glulisine (Apidra®)	15 mins	1-2 hrs	4-6 hrs
Short-Acting			
Regular (Humulin R, Novolin R)	30 mins	3 hrs	8 hrs
Intermediate-Acting			
NPH (Humulin N, Novolin N)	1-2 hrs	4-8 hrs	12 hrs
Long-Acting			
Insulin degludec (Tresiba®)	1 hr	9 hrs	42 hrs
Insulin detemir (Levemir®)	2 hrs	3-9 hrs	20-22 hrs
Insulin glargine (Basaglar®, Lantus®, Toujeo®, Semglee®)	2 hrs	--	24 hrs

Initiating Insulin

- 0.3 units/kg: BMI <18.5 or high risk for hypoglycemia
- 0.4 units/kg: Normal (BMI 18.5-24.9)
- 0.5 units/kg: Overweight (BMI 25-29.9)
- 0.6 units/kg: Obesity (BMI >30) or highly insulin resistant

TDD= Total Daily Dose

Initiating Insulin Part 2

Basal insulin: 50% of TDD

Bolus insulin: divide remaining 50% into 3 equal doses before meals

Correction scale:

- Low-dose: Insulin naïve, AKI, ESRD, Type 1 DM
- Moderate-dose: steroids, tube feeds, obesity, or requiring high insulin doses

Dolly- POD 1

- Methlypred 250mg
- Weight: 107.4kg/ BMI 33.69
- Insulin regimen: start 0.6 units/kg TDD
  - 107.4 x 0.6 = 64 units
  - 64/ 2 = 32 units
  - Glargine: 32 units qhs
  - Lispro 32/3 meals= 10 units
  - **Double prandial insulin for steroids
  - Lispro 20 units with meals
  - Correction scale 4 units:50mg/dl for BG >150mg/dl ACHS

Dolly- POD 2&3

Glucose	Lispro
B- 118	20
L- 218	28
D- 186	24
HS- 145	0

POD 2
Methylpred 125mg

No change in insulin

POD 3
Prednisone 20mg daily

Decrease Lispro to 16 units with meals

Decrease correction scale to 3 units:50mg/dl for BG >150mg/dl

Glucose	Lispro
B- 124	20
L- 165	24
D- 82	20
HS- 110	0

Johnny

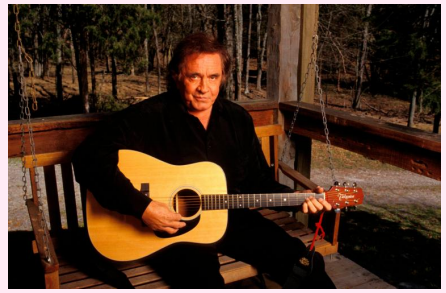
- Transitioned off insulin drip
  - **give basal insulin at least 2 hours before stopping insulin drip
- Methylpred 40mg daily
- Weight: 84.2kg
- BMI 27.81
- Start weight-based insulin dosing
  - 0.3 units/kg TDD
  - Basal: 12 units
  - Prandial: 8 units with each meal
  - Correction scale: 2 units:50mg/dl for BG >160mg/dl ACHS

Johnny

	10/07 0700 - 10/08 0659						10/08 0700 - 10/09 0659								
Time:	1804	2115	2118	2119	0607	0617	0735	0736	1141	1211	1212	1634	1800	2111	
Glucose (mg/dl)	Graphs cannot display in the current view														
Glucose															
POC glucose		233				197			273			225		249	POC glucose
Blood glucose					172										Blood glucose
Medication Dosing															
insulin glargine,hum.r...			12												insulin glargi...
insulin lispro SUBQ (...	14			4				10		9	12		18		insulin lispro ...
methylprednisolone s...							40								methylpredni...

- Increase Lantus to 15 units
- Increase Lispro to 12 units with meals
- Continue correction scale 3 units: 50mg/dl for BG >150mg/dl
- Diabetes education- including insulin teaching

Johnny



	10/08 0700 - 10/09 0659				10/09 0700 - 10/10 0659									
Time:	2220	2221	0607	0611	0841	1015	1136	1156	1636	1820	2121	2232	2257	0506
Glucose (mg/dl)	Graphs cannot display in the current view													
Glucose														
POC glucose				192			139		190		195			
Blood glucose			173											122
Medication Dosing														
insulin glargine,hum.r...	15												16	
insulin lispro SUBQ (...		6			21			18		21		3		
PredniSONE ORAL (...						30		10						

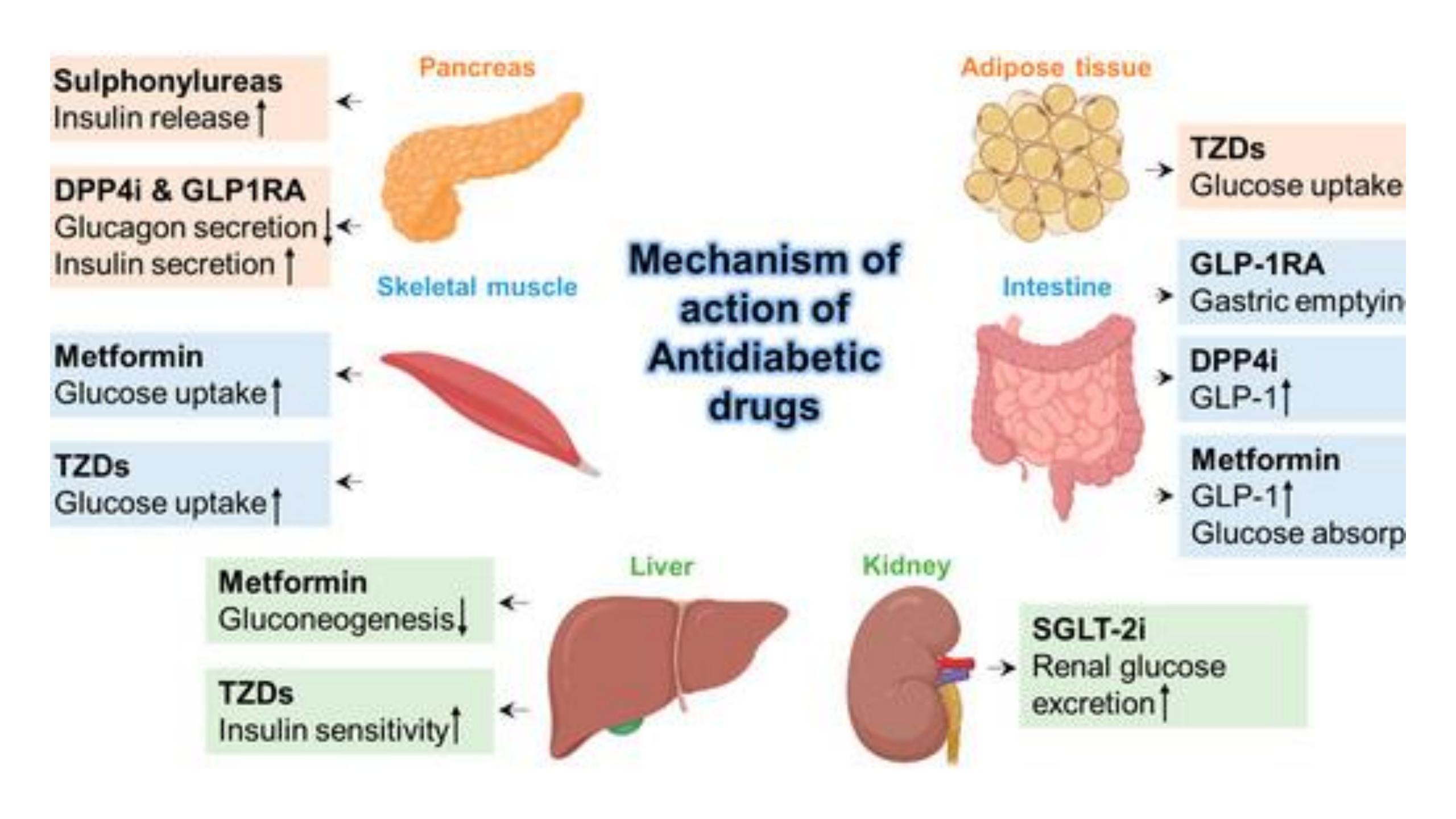
- Prednisone 40mg daily
- Increase Lantus to 16 units
- Increase Lispro to 18 units with meals
- Continue correction scale 3 units: 50mg/dl for BG >150mg/dl
- Diabetes education- including insulin teaching

Johnny

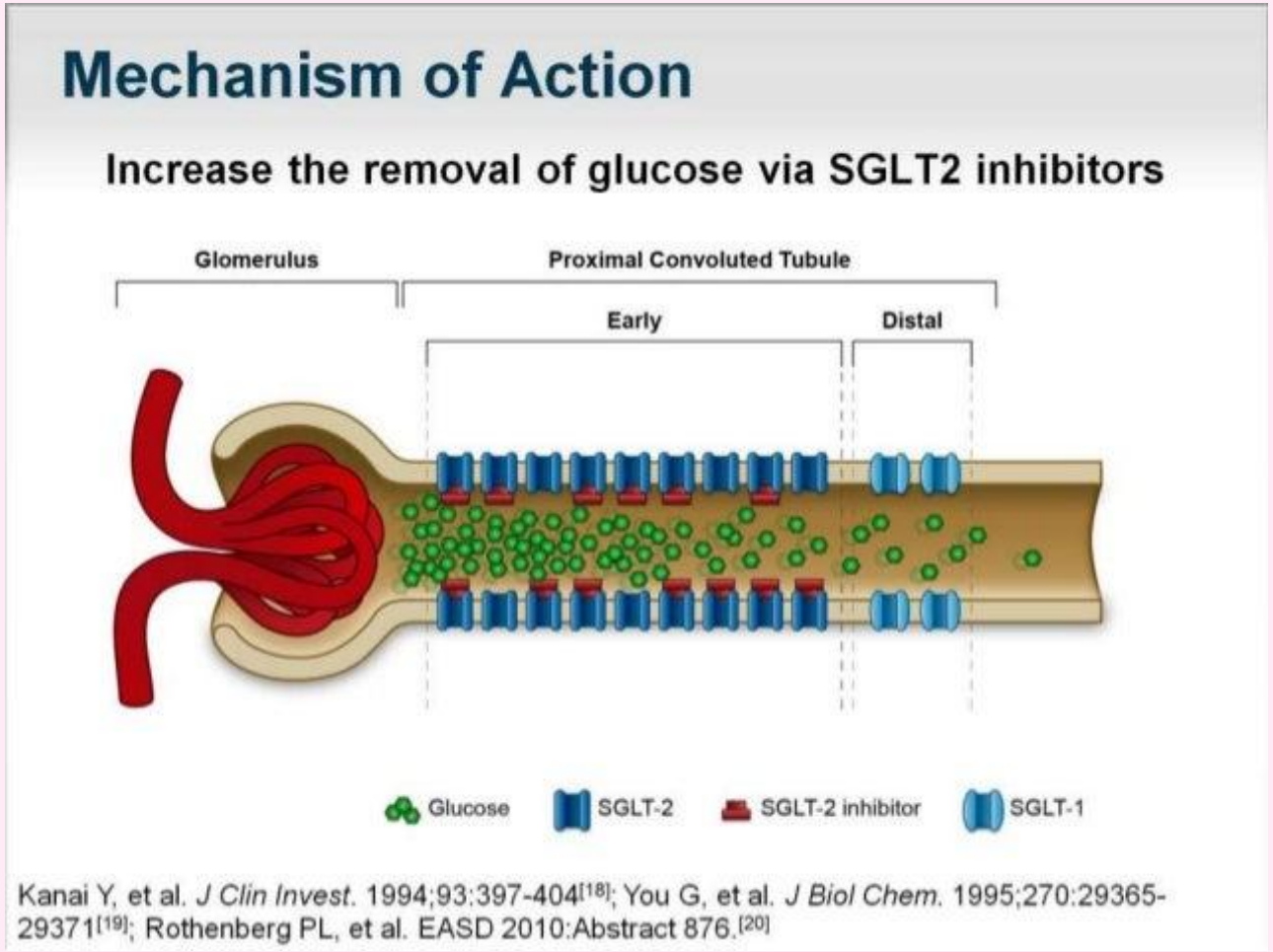
	10/09 0700 - 10/10 0659											10/10 0700 - 10/11 0659			
Time:	0841	1015	1136	1156	1636	1820	2121	2232	2257	0506	0620	0834	1025	1120	
Glucose (mg/dl)	Graphs cannot display in the current view														
Glucose															
POC glucose			139		190		195				134			284	POC glucose
Blood glucose										122					Blood glucose
Medication Dosing															
insulin glargine,hum.r...									16						insulin glargi...
insulin lispro SUBQ (...	21			18		21		3				18			insulin lispro ...
PredniSONE ORAL (...		30		10									40		PredniSONE...

- Continue Lantus 16 units
- Increase Lispro to 24 units with meals
- Increase correction scale to 5 units: 50mg/dl for BG >150mg/dl

Mechanism of action of Antidiabetic drugs



Sodium Glucose Transport 2 Inhibitors (SGLT2)



Kanai Y, et al. *J Clin Invest*. 1994;93:397-404[18]; You G, et al. *J Biol Chem*. 1995;270:29365-29371[19]; Rothenberg PL, et al. EASD 2010:Abstract 876.[20]

Glucagon-Like Peptide

- **Tablet**: Ozempic
- **Daily**: Victoza
- **Weekly**:
- Ozempic
- Trulicity
- Mounjaro (+ GIP)

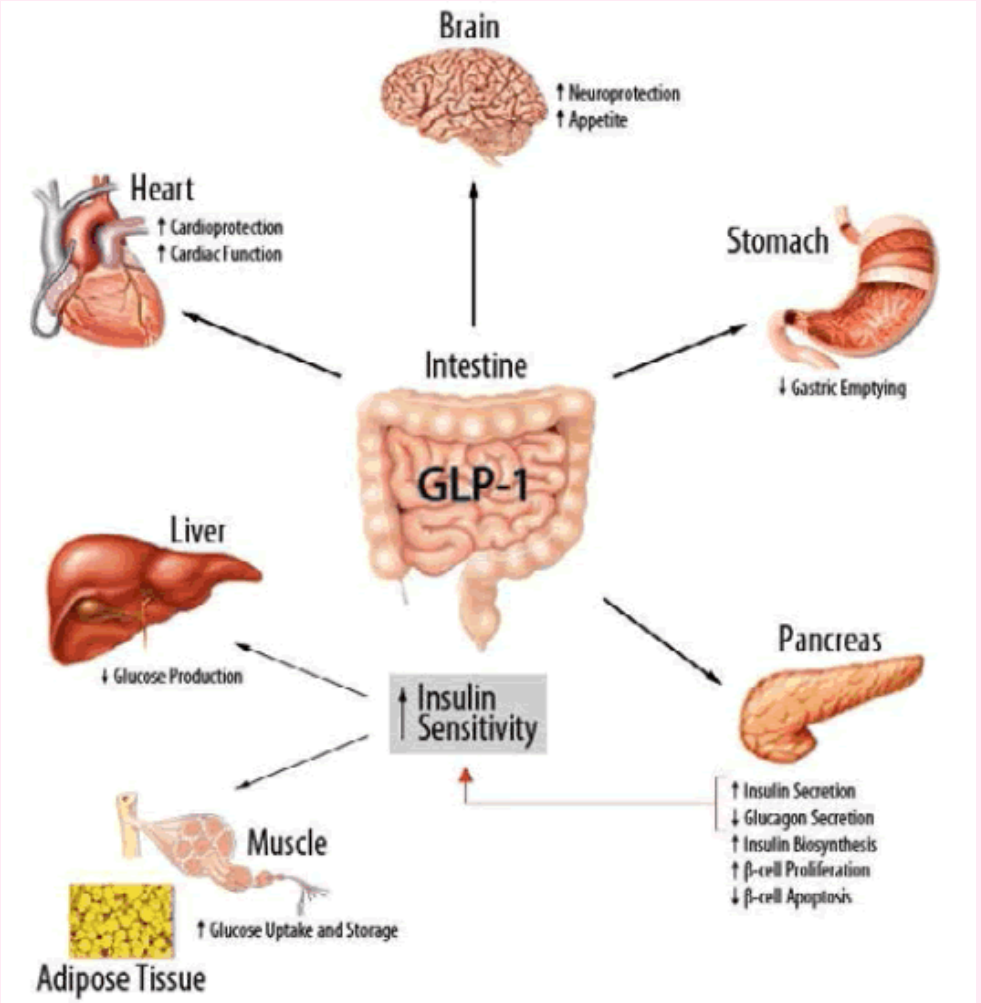


Figure 4: Biological Activities of GLP-1. The main action of GLP-1 occurs at the pancreas where GLP-1 stimulates insulin secretion and inhibits glucagon secretion in a glucose dependent manner. In addition, GLP-1 also decreases appetite, slows gastric emptying, increases β-cell proliferation, increases cardiac function as well as other physiological actions as indicated in the diagram. Redrawn from [91].

Dolly

- 8 months post-transplant
- Immunosuppression regimen stable
- Prednisone 5mg daily
- Weight up 28 pounds since transplant
- Hemoglobin A1C 7.2%
- Insulin regimen
  - Lantus 28 units qhs
  - Lispro 10 units with meals
  - Lispro correction scale 2 units:50mg/dl for BG >150mg/dl

Dolly

- Next steps
  - Continue Lantus 28 units qhs
  - Decrease Lispro to 8 units with meals
  - Decrease Lispro correction scale to 1 unit:50mg/dl for BG >150mg/dl
  - Start Mounjaro 2.5mg weekly
  - Nutrition counseling
  - Encourage physical activity/ exercise

Johnny

- 6 months post-transplant
- Immunosuppression regimen is stable
- Prednisone stopped
- Hemoglobin A1C 5.8%
- Fructosamine 250umol/L
- Insulin regimen:
  - Lantus 12 units qhs
  - Lispro correction scale: 1 unit:50mg/dl for BG >150mg/dl ACHS
- Adjustments?
  - Jardiance 25mg daily
  - Stop Lantus
  - Continue Lispro correction scale

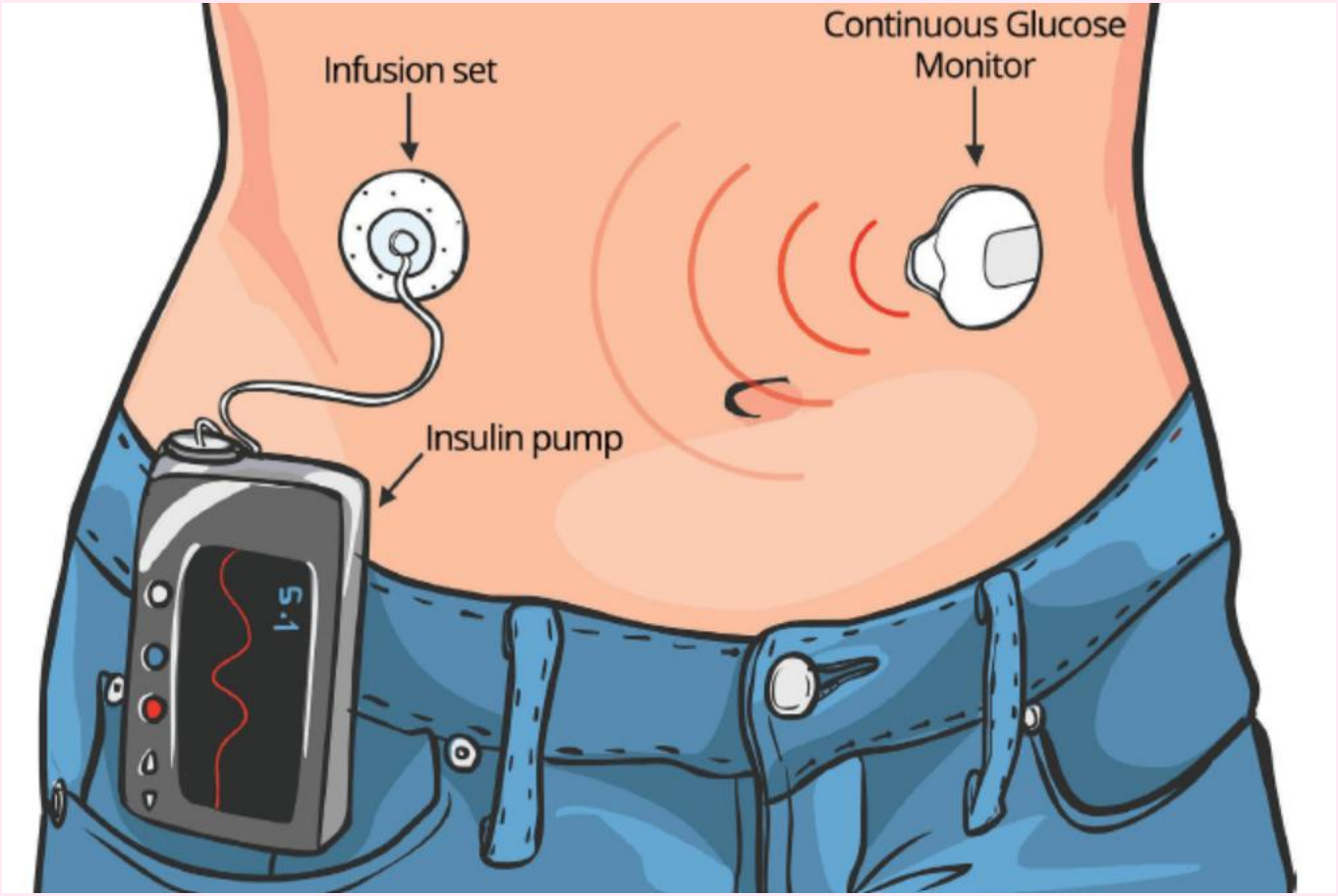
Hypoglycemia

Glucose <70mg/dl

Treatment:

- **Alert**: 15 grams of fast-acting carbohydrates
  - 4 ounces of fruit juice or REGULAR soda (NOT diet or zero)
  - 4 glucose tablets
- **Altered/ Unable to take PO**
  - Glucagon: glucagon, Gvoke, Zegalogue, Baqsimi nasal spray

Automated Insulin Pumps



Long Term Follow-Up

Monitor for microvascular complications

- Annual eye exam
- Annual foot exam
- Annual microalbumin/ BMP

Cardiovascular risk reduction

- Lipids
- Blood pressure

Summary

- Patients with diabetes > diabetes providers
- Treat hyperglycemia with insulin in the hospital
- When immunosuppression regimen is stable, can consider changing to oral meds/ GLP-1 to treat hyperglycemia
- Persistent PTDM should be treated as Type 2 DM, including monitoring for micro and macrovascular complications

References

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