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OPTIMIZING INSULIN THERAPY FOR DIABETIC PATIENTS: PRACTICAL ADJUSTMENTS, SLIDING SCALE, CORRECTION DOSES, AND BASAL–BOLUS REGIMENS.

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Abstract:
Optimizing insulin therapy for diabetic patients involves a multifaceted approach that includes practical adjustments, the use of sliding scale insulin, correction doses, and the implementation of basal-bolus regimens. Each of these components plays a crucial role in achieving effective glycemic control. Practical adjustments in insulin therapy are essential for tailoring treatment to individual patient needs. This includes understanding the indications for insulin therapy, which are particularly relevant for patients with type 2 diabetes who are not achieving target glucose levels after one year of diagnosis.

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INTRODUCTION:

Foundation Of Insulin Therapy

Insulin therapy serves as the cornerstone for managing diabetes, particularly for individuals with type 1 diabetes, where insulin deficiency is a primary concern. The Diabetes Control and Complications Trial established that intensive insulin treatment is crucial for achieving optimal metabolic control, thereby preventing chronic complications associated with poor glucose management.[1] Effective insulin therapy relies on understanding the timing of insulin delivery and the methods of injection, which are essential for mimicking normal physiological insulin secretion. This knowledge enables healthcare providers to tailor treatment plans that optimize blood glucose levels. Furthermore, home glucose monitoring plays a vital role in this process, allowing patients to track their blood glucose concentrations and assess the effectiveness of their insulin regimen. [2]

Insulin therapy can be categorized into long-acting and short-acting formulations, each serving distinct roles in glycemic control. Long-acting insulin analogues, such as insulin glargine and insulin detemir, are designed to provide a steady basal insulin level over 24 hours. Insulin glargine, for instance, exhibits a flat plasma insulin profile, which minimizes the risk of hypoglycemia, particularly at night. This characteristic is crucial for patients who require consistent insulin delivery to maintain stable blood glucose levels throughout the day and night. Insulin detemir also helps reduce nocturnal hypoglycemia and glycemic variability, making it a reliable option for long-term management. However, despite their benefits, long-acting insulins can exhibit significant pharmacokinetic variability, complicating optimal metabolic control for some patients.[3] In contrast, short-acting insulin analogues, including insulin lispro, insulin aspart, and insulin glulisine, are formulated for rapid absorption and onset of action, making them suitable for controlling postprandial blood glucose levels. These analogues can be administered immediately before meals, allowing synchronization with food intake and enhancing postprandial glycemic control without significantly increasing the risk of hypoglycemia. [4] The faster absorption rates of these short-acting insulins compared to regular human insulin facilitate improved management of blood glucose spikes after meals. [3] Despite the advancements in both long-acting and short-acting insulin therapies, achieving good metabolic control remains a challenge for many insulin-dependent diabetics. Issues such as the slower rate of uptake of conventional short-acting preparations and the variability in pharmacokinetics of intermediate- and long-acting insulins can hinder effective management. [5] Therefore, while both types of insulin play critical roles in diabetes management, their effectiveness can vary based on individual patient needs and responses.

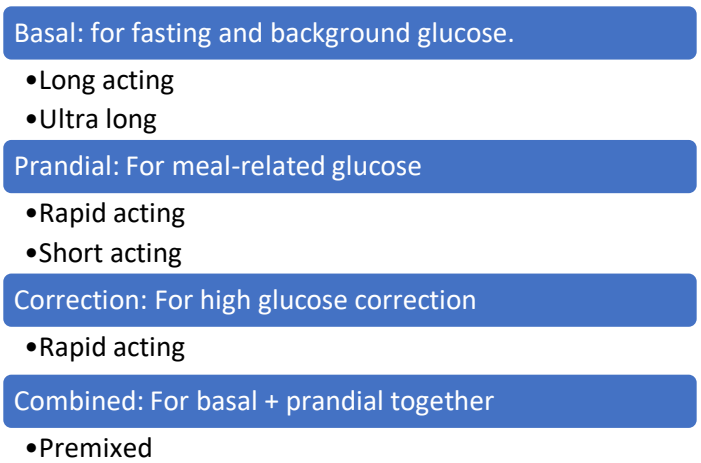
- **Insulin Class**

Insulin is classified into several types based on their onset and duration of action, which is crucial for managing blood glucose levels in diabetes. The primary classes include rapid-acting, short-acting, intermediate-acting, and long-acting insulins. Each type serves a specific purpose in insulin therapy, allowing for tailored treatment plans for individuals with type 1 and type 2 diabetes mellitus [Table1]. Rapid-acting insulin, such as insulin lispro, begins to work within 15 minutes and lasts for about 2 to 4 hours, making it ideal for controlling postprandial blood sugar levels when administered before meals. In contrast, short-acting insulin, or regular insulin, takes approximately 30 minutes to start working and has a duration of 3 to 6 hours, also typically used before meals. Intermediate-acting insulin has a slower onset, taking 1 to 2 hours to begin working and lasting for 12 to 18 hours, which helps cover insulin needs for half a day or overnight. The mechanism of action for all insulin types involves binding to insulin receptors on target cells, initiating a signaling cascade that promotes glucose uptake and metabolism in tissues such as muscle and fat. In clinical practice, classified into four main functional categories: basal, prandial, correction, and combined insulin therapy, each serving distinct roles in glycemic management. Basal insulin, such as insulin glargine, provides a steady level of insulin to manage blood glucose throughout the day and night, crucial for maintaining baseline metabolic needs. This type of insulin is typically administered once daily and is essential for both type 1 and type 2 diabetes patients, as it helps prevent nocturnal hypoglycemia and supports overall glycemic control. Prandial insulin, like insulin aspart, is used at mealtimes to control postprandial glucose spikes. It acts rapidly to mimic the physiological insulin response to food intake, making it vital for managing blood glucose levels after meals. Correction insulin is utilized to address acute hyperglycemia, allowing for adjustments based on real-time blood glucose monitoring. This type of insulin is administered as needed to correct high blood sugar levels. Combined insulin therapy integrates both basal and prandial insulins to achieve optimal glycemic control. This approach allows for a more tailored treatment regimen that effectively addresses both fasting and postprandial glucose levels [6]

Insulin class by onset	Onset	Peak	Duration	Purpose	Clinical use
Rapid-Acting Insulin (Prandial / Bolus)					
Insulin lispro	10-15 min	1-2 h	3-5 h	Control post-prandial glucose	• immediately before meals • Used for correction dosing • Part of basal–bolus regimens
Insulin aspart	10-15 min	1-3 h	3-5 h		
Insulin glulisine	10-20 min	1-2 h	3-4 h		
Short-Acting Insulin (older generation)					
Regular insulin	30-60 min	2-4 h	5-8 h	Prandial control	• 30 min before meals. • IV use in DKA, HHS
Intermediate-Acting Insulin (older basal insulin)					
NPH Insulin	1-2 h	4-12 h	12-18 h	Basal coverage	
Long-Acting (Basal) Insulin					
Insulin glargine U100			24 h		
Insulin detemir			18 -24 h		
Ultra-Long-Acting Insulin					
Insulin degludec			> 42 h		
Insulin glargine U300			~ 36 h		
Premixed Insulin					
NPH + Regular insulin					
Lispro protamine/lispro					
Aspart protamine/aspart					

Table (1): Clinical classification of insulin by onset

Figure (1): Clinical classification of insulin by function



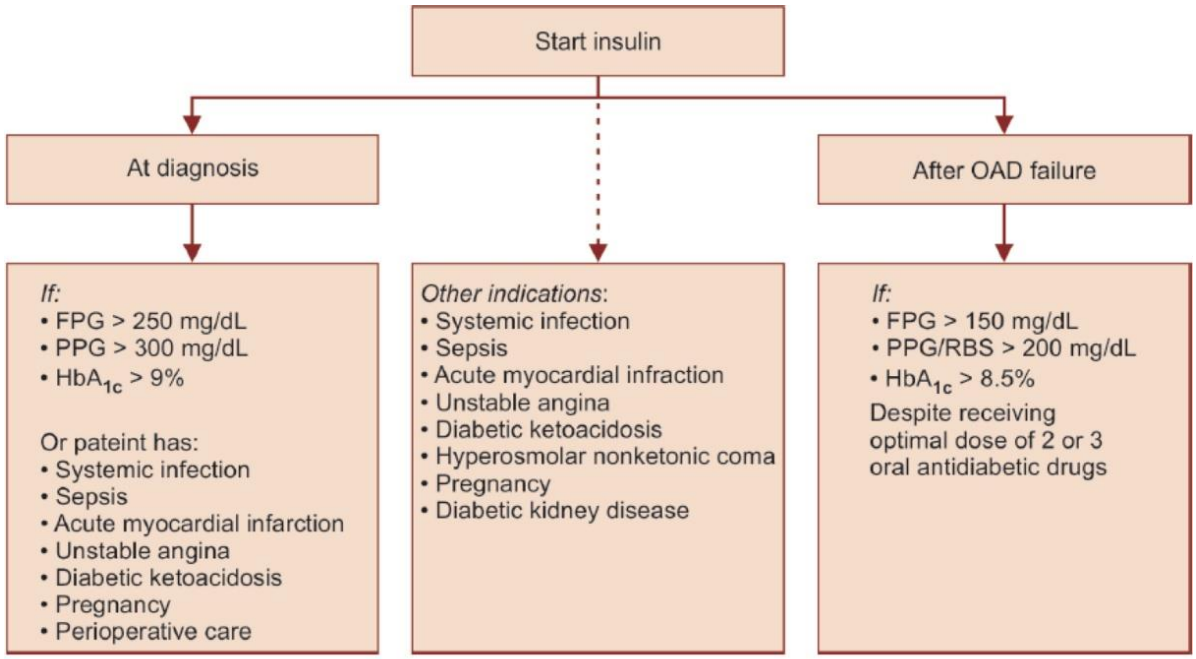
- **Initiation of Insulin Therapy for Diabetics**

Initiating insulin therapy for diabetics is a critical step in managing type 2 diabetes (T2D), particularly when glycemic targets are not achieved with oral

medications. Initiating insulin therapy is essential, as T2D is characterized by progressive beta-cell dysfunction, necessitating periodic evaluation and potential intensification of therapy.

The initiation of insulin when the glycosylated hemoglobin (A1C) level exceeds 9.0% and is accompanied by symptomatic hyperglycemia or metabolic decompensation. In such cases, insulin therapy can be started with or without oral antihyperglycemic agents (OHAs). Following this initiation, if the A1C target is not achieved with a basal insulin regimen, the next step is intensification of treatment. This may involve adding a glucagon-like peptide 1 receptor agonist (GLP-1RA), introducing prandial insulin, or switching to a premixed insulin regimen. For adult patients with T2DM who have not met glycemic targets despite adequate treatment with OHAs, the recommendation is to transition to basal insulin, which can be combined with OHAs. Depending on the clinical situation, adding a GLP-1RA or switching to a premixed insulin regimen may be appropriate alternatives [Figure 2]. [7]

Figure (2): When to initiate insulin therapy.



Source: Adapted from the INCG Guidelines 2009[10]
Abbreviations: OAD, Oral antidiabetes drug; FPG, Fasting plasma glucose; HbA_{1c}, Glycosylated hemoglobin; PPG, Postprandial plasma glucose; RBS, Random blood sugar

- **Practical Adjustments in Insulin Dosing**

Insulin adjustment in clinical practice is based on identifying patterns rather than relying solely on a single reading taken at a single point in time. The overarching objective is to pinpoint which specific glucose time period exhibits abnormal values and subsequently modify the insulin component associated with that abnormality. [6]

- Step 1: Total daily dose (TDD)

For individuals diagnosed with Type 2 Diabetes Mellitus (T2DM), the advised initial total daily insulin dosage varies between 0.3 to 0.6 units per kilogram of body weight each day, whereas for those with Type 1 Diabetes Mellitus (T1DM), the recommended range is marginally higher, falling between 0.4 to 0.7 units per kilogram of body weight daily. The distribution of insulin should be roughly 40 to 50% for basal insulin, with the remaining 50 to 60% reserved for bolus insulin, which encompasses both meal coverage and correction doses.

- Step 2: Identify the Pattern (Not One Value)

An elevation in fasting blood glucose levels signifies inadequate basal insulin and necessitates an adjustment in basal insulin. Elevated post-meal readings indicate insufficient mealtime coverage from the Prandial (bolus). Random spikes generally imply they are linked to stress, illness, or underdosing and require an insulin correction. Nighttime hypoglycemia results from excess basal insulin, suggesting that basal insulin should be reduced. Additionally, it is essential to examine a thorough set of glucose readings over 3 to 4 days prior to making any adjustments.

- Step 3: Adjust Basal InsulinAdjust Basal Insulin

If fasting glucose levels are consistently observed to be either above or below the designated target range, adjustments should be made by increasing or decreasing the insulin dosage by 10 to 20 percent, or alternatively by 2 to 4 units, as required every 3 to 4

days to ensure adequate monitoring and effectiveness until the optimal fasting glucose range for the majority of adults is between 80 and 130 mg/dL. No dose adjustment is necessary if fasting glucose levels are well-regulated, but post-meal readings are elevated.

Fasting Glucose the past 3 Days	Increase in Basal Insulin (units)
80-130	0
130-159	2
160-189	4
190-220	6
Over 220	8
any glucose level < 80	Decrease dose by 2-4 units

Table (2): Adjust Basal Insulin

- Step 4: Adjust Prandial (Bolus) Insulin

Rapid-acting insulin should be given 0 to 15 minutes before meals to enhance its effectiveness. The adjustment is needed when post-meal glucose levels exceed 180 mg/dL. There are two approaches: the fixed-dose method, which increases the meal dose by 1 to 2 units, or the carbohydrate ratio method, which usually starts at 1 unit per 10 to 15 grams of carbohydrates.

- Step 5: Use Insulin Correction (Fixes unexpected hyperglycemia)

This correction insulin should be used alongside prandial insulin, not as an independent treatment for prolonged periods. To determine the correction factor, apply the formula of Correction Factor (Rule of 1800); 1800 divided by the total daily insulin dose, which results in the anticipated decrease in mg/dL for each unit of insulin administered. For example, if the total daily dose (TDD) is 60 units, then using the formula results in 1800 divided by 60, which equals a drop of 30 mg/dL per unit of insulin used to reach the target glucose.

$$Correction\ Factor\ (Rule\ of\ 1800): \\ 1800 \div Total\ Daily\ Insulin\ Dose \\ = mg/dL\ drop\ per\ 1\ unit$$

- Fixed Correction Scale

Used when TDD is unknown (e.g., insulin-naïve patients).

Blood glucose (mg/dl)	Insulin (units)
150-200	2
201-250	4
251-300	6
301-350	8
351-400	10
>400	12

Table (3): Fixed Correction Scale

- Sliding Scale (SSI)

It is a method of insulin administration designed to manage blood glucose levels in diabetic patients, particularly in hospital settings, and aims to correct hyperglycemia after it occurs, rather than prevent it. The rationale for using SSI lies in its simplicity and standardized approach, making it easy for healthcare providers to implement. However, this method has significant limitations. It is often criticized for being reactive, which can lead to prolonged hyperglycemia and inadequate glycemic control because it lacks basal insulin. Dosing for SSI is typically calculated based on pre-meal blood glucose levels, with specific insulin units assigned to different glucose ranges. [8]

Blood glucose (mg/dl)	Insulin (units)
61-150	0
151-200	3
201-250	5
251-300	8
301-350	10
351-400	12
>400	15*

Standard Sliding Scale Insulin Protocol for Patients with Diabetes Mellitus
***The physician should be notified.**

Table (4): Sliding Scale.

- **Monitoring, Outcome, and Safety**

Effective monitoring, outcomes, and safety of insulin use are critical components of diabetes management, particularly for patients requiring intensive insulin therapy. Insulin infusion therapy is recognized as the best available mechanism for achieving glucose control in selected patients, which is essential for preventing complications associated with insulin-dependent diabetes. The concept of euglycemic management is supported by substantial evidence, emphasizing its role in minimizing complications and enhancing safety outcomes during insulin therapy. Continuous Glucose Monitoring (CGM) systems play a pivotal role in this context by providing real-time glucose data, which significantly enhances diabetes management and reduces the risks associated with insulin therapy. Furthermore, automated insulin delivery systems have been shown to improve glucose control and decrease the incidence of severe hypoglycemic events, thereby contributing to safer insulin use. The findings from the Diabetes Control and Complications Trial underscore the effectiveness of intensive insulin treatment in achieving optimal diabetes control and preventing chronic complications related to poor metabolic management. Collectively, these approaches highlight the importance of comprehensive monitoring and management strategies in ensuring the safety and efficacy of insulin therapy, ultimately leading to better health outcomes for patients with diabetes.

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