Insulin Pumps and Continuous Glucose Monitoring

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Disclosures

I have no conflicts of interest, financial or otherwise, with the commercial concerns that will be mentioned in this presentation.

Because there are very few manufacturers of insulin pumps and CGM devices, and because no such generic products are available, trade names will be mentioned during this presentation for clarity and in order to increase the quality of the presentation.

Every effort will be made to present commercial products in a non-biased fashion.
Insulin Pump vs Insulin Injections

• More predictable insulin absorption and precise delivery

• Programmable insulin delivery allows closest match with physiologic insulin requirements
Physiologic insulin secretion

- **Insulin**
  - Basal insulin
  - Time of Day: 7 a.m. to 9 p.m.

- **Glucose**
  - Basal glucose
  - Time of Day: 7 a.m. to 9 p.m.
Idealized Basal Insulin Replacement

B’fast  Lunch  Dinner  Bed  Overnight  B

Insulin Activity

MEAL BOLUS  MEAL BOLUS  MEAL BOLUS  BASAL INFUSION

NPH  Glargine
Basal insulin requirements are variable!

- Decreasing insulin requirement
- Exercise
- Dawn phenomenon

B’fast  Lunch  Dinner  Bed  Overnight
Meal Bolus: Square Wave Function

Standard Bolus

Square wave

Basal rate
Who Needs an Insulin Pump?

• Sensitive to small changes in insulin levels in basal insulin supply
• Sensitive to changes in physical activity – increased risk of hypoglycemia
• Day to day activities vary
• Excellent self-mgmt skills, realistic expectations
Precise Delivery

- Patient Data
Matching Physiologic Needs

• Patient Data
Interstital Fluid Glucose Measurement
CGM: Snapshot vs. Continuous

288 readings/24 hours
CGM: Dexcom G5
Freestyle Libre CGM
Pump-CGM systems

- Medtronic 670G
- Accu-Chek Spirit
- Tandem t:slimX2
Patients can make treatment decisions, including insulin dosing, directly from the CGM data without the need for confirmatory fingerstick testing.

The Medtronic Guardian Sensor 3 does not yet have this claim, so fingerstick glucose readings are required both for calibration and insulin dosing.

The Libre, also has a non-adjunctive indication, although fingerstick glucose levels are required to confirm hypoglycemia or impending hypoglycemia because the system does not alarm for hypoglycemia.
Infusion Sites

- Infusion set: cannula, tubing and insulin reservoir.
- Usually placed in the abdomen, thigh, buttock.
- Changed every 72 hours.
- Several types available.
For more information on pumps, CGM:
Initiating Pump Therapy

- 70-75% of Pre-pump basal dose ÷ 24
- Bolus dose based on insulin to carb ratio (e.g. 1U/15g)
Mealtime dosing considerations

<table>
<thead>
<tr>
<th>Carb content of meal</th>
<th>Current blood glucose</th>
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**Carb content of meal**

Use Insulin to Carb Ratio (1U:12g)

**Pre-meal blood glucose – use Target and ISF**

1800 ÷ Total Daily Dose (60) ⇒ 1U lowers BG 30

For 60g CHO meal with BG 180: 5U for CHO

(180-120) ÷ 30 = +2 units for correction ⇒ 7U
Fine Tuning: Basal Rate

- Monitor BG pre-meal, post-meal, bedtime, 3 am
- Adjust nighttime basal based on 3 am and pre-breakfast BG; may need coverage for dawn phenomenon
- Adjust daytime basal based on pre-meal BG (after correcting postprandial hyperglycemia)
- Adjust basal by 0.1 u/hr or less to avoid over-correction
- Start higher rate ~2 hours before glucose becomes elevated
Fine Tuning: Bolus Doses

- Individualized insulin to carbohydrate ratio
- Adjust bolus based on 2 hour post-meal BGs
- Can use different ICRs for different meals
- Correction doses use ISF and BG targets.
- Avoid insulin “stacking” by setting “active insulin time” at 3-4 hours (5-6 for regular)
- Full coverage for frequent carb intake
Preventing DKA During Pump Use

- Monitor BG every 6 hours.
- Change infusion set every 2-3 days.
- Treat “incidental hyperglycemia” per algorithm.
- DO NOT go to bed or anywhere else with a high BG without confirming that it’s coming down.
Pump Stoppage in Type 1 DM

- N = 7 type 1, pump discontinued at time 0
- Mean plasma glucose increased 200 mg/dL from baseline at 7 hours (some sources say BG increases by 50 mg/dL per hour)
- Mean capillary pH fell from 7.40 to 7.34 at 7 hours

Reichel et al., Exp Clin Endocrinol Diabetes 106 :186-172, 1998
Hyperglycemia Treatment Guidelines

1st BG over 250 mg/dl:
- Take correction bolus via pump, check BG in 1 hour

2nd BG over 250 mg/dl:
- *Take correction bolus by syringe* and *change infusion set*, check BG and ketones again in 1 hour
- Check urine ketones
- Call physician immediately if nausea and vomiting are present or if hyperglycemia, ketonuria persist
- “Twice in doubt, take it out.”
Exercise and the Pump

- Insulin levels fall during exercise to permit hepatic glucose production.
- In diabetes, exercise usually lowers glucose, but brief intense exercise can raise glucose.
- Suspend pump for activities lasting less than 1 hour.
- Use temporary basal for prolonged activity; start 50%.
- Carb intake is required for prolonged activity in addition to reduced pump rate.
- May need prolonged reduction in basal rates and even bolus after long-duration exercise
Insulin pump adjustments for physical activity

- Suspend for short duration (<1h) activity (30-min run)
- Temp Basal for long duration (home project)
Combined Insulin Pump-CGM

- **Sensor Augmented insulin pump** – CSII in conjunction with CGM

- **Bihormonal, closed-loop system** – uses two commercially available pumps, with one delivering insulin and the other glucagon.

- **Insulin-only, hybrid closed-loop system** – uses one pump to deliver insulin. A hybrid system (not fully automated), in that only the basal insulin is automatically adjusted based on CGM results. Users need to use conventional bolus calculations to dose insulin prior to meals.
HOW DOES THE SUSPEND BEFORE LOW FEATURE WORK?

Suspend before low suspends insulin delivery before glucose levels reach a pre-set low, without alerting the user.

Suspend before low suspends insulin delivery when sensor glucose is approaching a pre-set low limit.

SmartGuard suspends insulin when sensor glucose is approaching a pre-set low limit.

SmartGuard resumes basal insulin delivery will automatically resume if sensor glucose recovers.

Suspended insulin delivery when glucose is within 70 mg/dL above the low limit and predicted to reach within 20 mg/dL above the low limit in 30 minutes. Automatically resumes when glucose reaches 20 mg/dL above the low limit and predicted to reach 40 mg/dL above the low limit in 30 minutes and has been suspended for 30 minutes.
Each patient’s daily insulin requirements are unique  
4 NIGHTS IN A SINGLE WEEK OF A PATIENT

Data on file, Medtronic
Each patient’s daily insulin requirements are unique
THERE IS SIGNIFICANT INTRA-PATIENT VARIABILITY

Data on file, Medtronic
Automated basal delivery compensates for under or overestimates in carb intake

1. Good overnight control
2. Accurately counts carb intake
3. Under-estimates carb intake
4. Over-estimates carb intake

Basal stops & resumes automatically
Pivotal trial for the Minimed 670G System

• Non-Randomized study design

**Study Design**
- Multicenter: 9 sites in US & 1 site in Israel
- Single-arm (no control group)
- Non-randomized

**Patients**
- N=124
- Type 1 ≥ 2 years
- A1C < 10%
- Ages 14-75 yr
- Pump therapy ≥ 6 months, with or without CGM

**Study Protocol**

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<tr>
<th>RUN-IN PERIOD</th>
<th>STUDY PERIOD: Auto Mode</th>
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<tbody>
<tr>
<td>Pump + CGM</td>
<td>3 months</td>
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<tr>
<td>2 weeks</td>
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Medtronic 670G Pivotal Trial Results

- A1C fell by 0.5% run-in versus study period
- Time spent in range 24h: 72.2% vs 66.7% study vs run-in
  Nocturnal: 75.3% vs 66.8
- No DKA or severe hypo

Bergenstal R, et al. Poster presented at the 76th Scientific Sessions of
the American Diabetes Association, June 10-14, 2016,
New Orleans. LA. P-99.

My 670G patient
Summary

• Pump therapy, CGM, and pump-CGM therapy facilitate the treatment of type 1 diabetes and can improve glycemic control and reduce hypoglycemia.

• New automated closed-loop systems promise better control with less “mental burden”.

• Simpler and less costly CGM systems may broaden the utility of CGM to those with type 2 diabetes.