SingHealth DukeNUS
ACADEMIC MEDICAL CENTRE

Diabetes Centre

Insulin Pump Essentials

Success in insulin pump therapy

Singapore General Hospital
SingHealth

Singapore General Hospital
SingHealth

The Singapore General Hospital (SGH) Department of Endocrinology is a tertiary referral centre which serves the needs of people with a wide range of conditions involving endocrine glands, including diabetes mellitus.

The Young Adults with Diabetes (YAD) & Intensive Insulin clinic at SGH is a specialised multidisciplinary clinic focused on providing comprehensive care to people with type 1 diabetes (T1D) and young people with diabetes (≥ 15 years old). It provides one-stop access to the endocrinologist, diabetes specialist nurse, dietitian, medical social worker and psychologist.

Self-management of T1D is founded in knowledge and skills. To this purpose, SGH has been running the Singapore Dose Adjustment for Normal Eating programme (SgDAFNE) since 2011. This provides group education over five days in self-management and advanced carbohydrate counting. To date, SGH remains the only centre in Asia providing the DAFNE education programme. Building upon this foundation, we equip people with skill sets and knowledge for the effective incorporation of diabetes technology including insulin pump therapy and continuous glucose monitoring into their daily living to optimise outcomes.

We are committed to providing individualised and holistic care to all with diabetes, and continuously work closely with multiple stakeholders to increase access to, and reduce the burden of diabetes care.

Our diabetes and metabolism-related services include:

- Personalised consultation for diabetes
- Dietary counselling
- Diabetes Nurse Educator counselling
- Dedicated podiatry service
- On-site laboratory testing
- Fundal photography for early detection of diabetic retinopathy
- Insulin pump therapy including advanced hybrid closed-loop pumps
- Continuous glucose monitoring
- Regular self-management courses for type 1 diabetes (SgDAFNE)

To find out more about insulin intensification or the use of insulin pump therapy, email sgdafne@sgh.com.sg.

SGH is a clinical site of the SingHealth Duke-NUS Diabetes Centre. The SingHealth Duke-NUS Diabetes Centre is located at:

1. **Singapore General Hospital Diabetes and Metabolism Centre (DMC)**
2. **Changi General Hospital**
3. **Sengkang General Hospital**
4. **KK Women's and Children's Hospital Obstetric Day Assessment Centre**
5. **Singapore National Eye Centre**
6. **SingHealth Polyclinics**

Find out more about the Centre at **www.singhealth.com.sg/diabetescentre**

Welcome to insulin pump therapy!

This guide aims to support your transition to insulin pump therapy and is designed for use by both healthcare providers and people with diabetes.

Beginning insulin pump therapy may feel challenging, however, with the right knowledge and skills you can reduce your diabetes self-care burden and improve your glucose control. In this guide, we cover the essential components of successful insulin pump therapy.

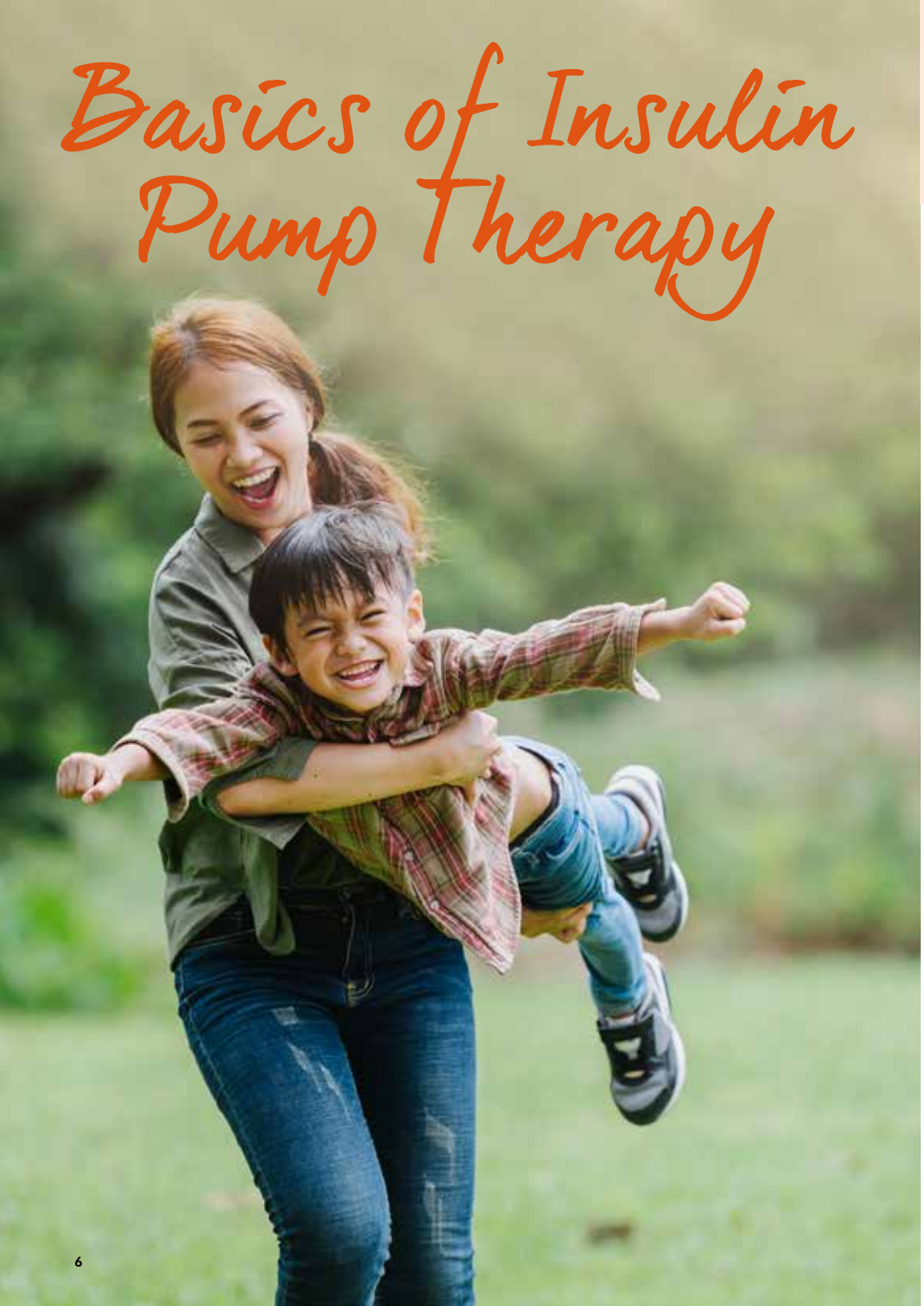
Insulin pump users should have the following skill sets and knowledge after reading this guide.

1. Understand the concepts of basal insulin and bolus insulin delivery
2. The ability to do carbohydrate counting
3. Understand the relationship between insulin action, food, exercise, alcohol, illness and blood glucose levels (BGL)
4. Record-keeping and analysis
5. Understand the mechanics and functions of the insulin pump
6. Troubleshoot in the event of unexpected low or high BGL

This guide, together with continued education from your intensive insulin therapy team, should provide you with a complete working knowledge of insulin pump therapy.

Contents

Basics of Insulin Pump Therapy



The Link Between Glucose & Insulin

GLUCOSE (THE BODY'S FUEL)

What is it?

Glucose is a type of sugar that the body uses for energy required to perform bodily functions. An optimal level of blood glucose is needed in our body at all times, even while sleeping, since all cells need glucose for energy.

How does it work?

Glucose comes largely from carbohydrates (simple sugars and starches). Upon absorption from the digestive tract into the blood stream, it moves into the interstitial fluid and eventually into cells. Glucose that is not used immediately for energy is stored in the liver.

Importantly, for glucose to move into the cells, insulin is required.

How is it affected by diabetes?

Without diabetes, glucose levels are kept very tight between 4-7.8 mmol/L. This is achieved by a complex hormonal system that senses changes to blood glucose and uses the appropriate hormones to increase or decrease the blood glucose level.

Once diabetes develops, it becomes very difficult to keep glucose levels within this range without medications.

INSULIN

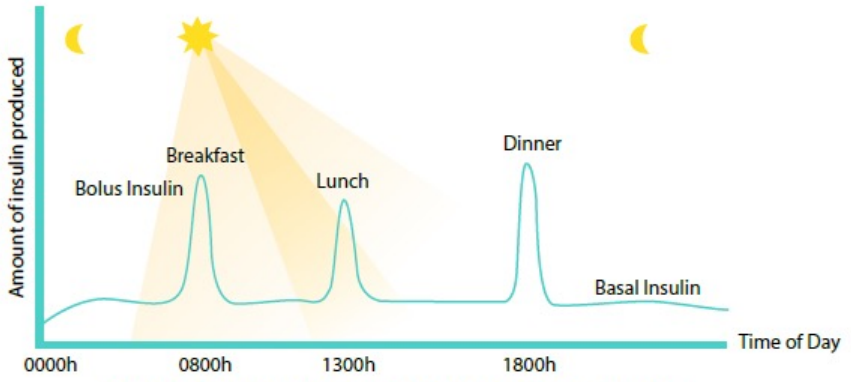
What is it?

Insulin is a hormone produced by the pancreas. Even in those without diabetes, there is a constant supply of insulin so that glucose may enter into the cells. When insulin is not available, glucose stays in the blood and interstitial fluid.

How is it affected by diabetes?

Without diabetes, the pancreas produces insulin almost continuously and in response to the amount of glucose in the blood. This is so precise that exactly the right amount of insulin is produced to keep the blood glucose level within a tight range.

- **During sleep or in between meals.** Small amounts of insulin are produced every few minutes for small amounts of glucose (basal insulin) 24 hours of the day.
- **During mealtimes.** Larger amounts of insulin are produced in response to larger amounts of glucose (bolus insulin). See figure below.



Insulin production over 24 hours, during the fasting state (basal insulin) and in response to food intake (bolus insulin)

When diabetes develops, the pancreas is unable to produce sufficient basal and bolus insulin properly. This must be replaced with insulin by injection or with an insulin pump.

Going on the Pump

WHY YOU MAY CHOOSE INSULIN PUMP THERAPY

Insulin pump therapy may be recommended if you:

1. Have recurrent episodes of hypoglycaemia despite a high level of self-management
2. Experience a rise in blood glucose level (BGL) early in the mornings (the dawn phenomenon)
3. Have wide fluctuations in BGL (high glucose variability) despite multiple daily injections of insulin
4. Have suboptimal HbA1c levels despite a high level of self-management
5. Require very small amounts of insulin, or have high insulin sensitivity
6. Are planning for pregnancy or during pregnancy
7. Experience significant diabetes distress related to the need for multiple daily insulin injections

It is important to note that insulin pump therapy will not remove the need for:

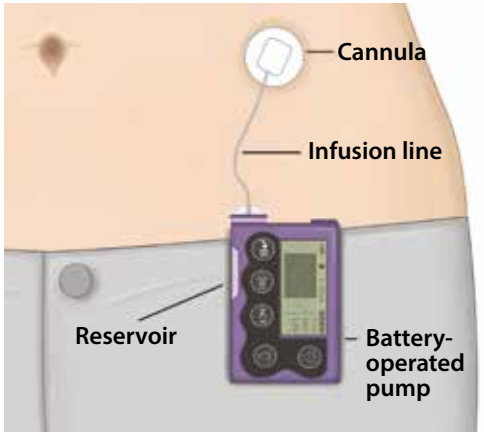
1. Regular blood glucose measurements
2. Accurate carbohydrate counting
3. Administering appropriate insulin boluses via pump before meals or snacks

How Does
Insulin Pump Therapy Work?

AN INSULIN PUMP CAN DELIVER INSULIN LIKE A PANCREAS

Whilst the insulin pump can deliver more precise doses of insulin, and in a manner more similar to a pancreas, the end user is still in ultimate control over insulin delivery.

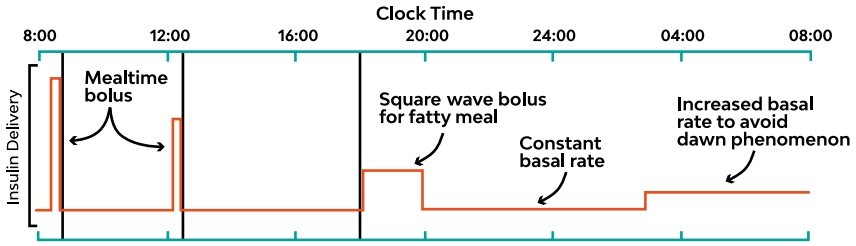
The pump uses quick-acting U100 (100 units of insulin in 1 ml) insulin that delivers both basal insulin 24 hours of the day, and bolus insulin before each meal or snack.



*Insulin is delivered via an **infusion set and cannula** into the subcutaneous layer of the abdomen.**

**For illustration purposes only. Actual device may differ.*

A schematic showing the insulin delivery from an insulin pump



- Basal insulin is continuously infused at pre-set rates
- User-initiated boluses for meals are delivered quickly
- Boluses can be delivered in various ways

BASAL INSULIN

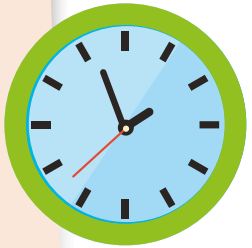
Basal insulin covers insulin requirements between meals and throughout the night.

The insulin pump uses only quick-acting insulin to deliver both basal and bolus insulin.

For basal insulin, it delivers this as small amounts throughout the day to meet basal insulin requirements, unlike a depot of basal insulin injected once or twice a day during multiple daily insulin (MDI) injection regimens.

Hence, any interruption to insulin delivery from an insulin pump for more than two hours will result in insulin deficiency and the risk of diabetic ketoacidosis.

Fine-tuning basal insulin levels for your needs



The amount delivered can be adjusted by the hour to deliver varying amounts of basal insulin throughout the day.

For example, you may require greater amounts of basal insulin in the early morning hours than the rest of the day; hence your pump can be programmed to deliver basal insulin at different rates at different time blocks to match your needs.

Once programmed (see example on page 22), these rates continue every day unless basal rates are changed.

! Insulin infusion should not be suspended or stopped for more than one hour without checking your blood glucose level.

BOLUS INSULIN

Bolus insulin may be given to:

1. Cover mealtime glucose rise from carbohydrate consumption (meal bolus)
2. Correct high glucose levels (correction bolus)

Quick-acting U100 insulin delivered by the pump:

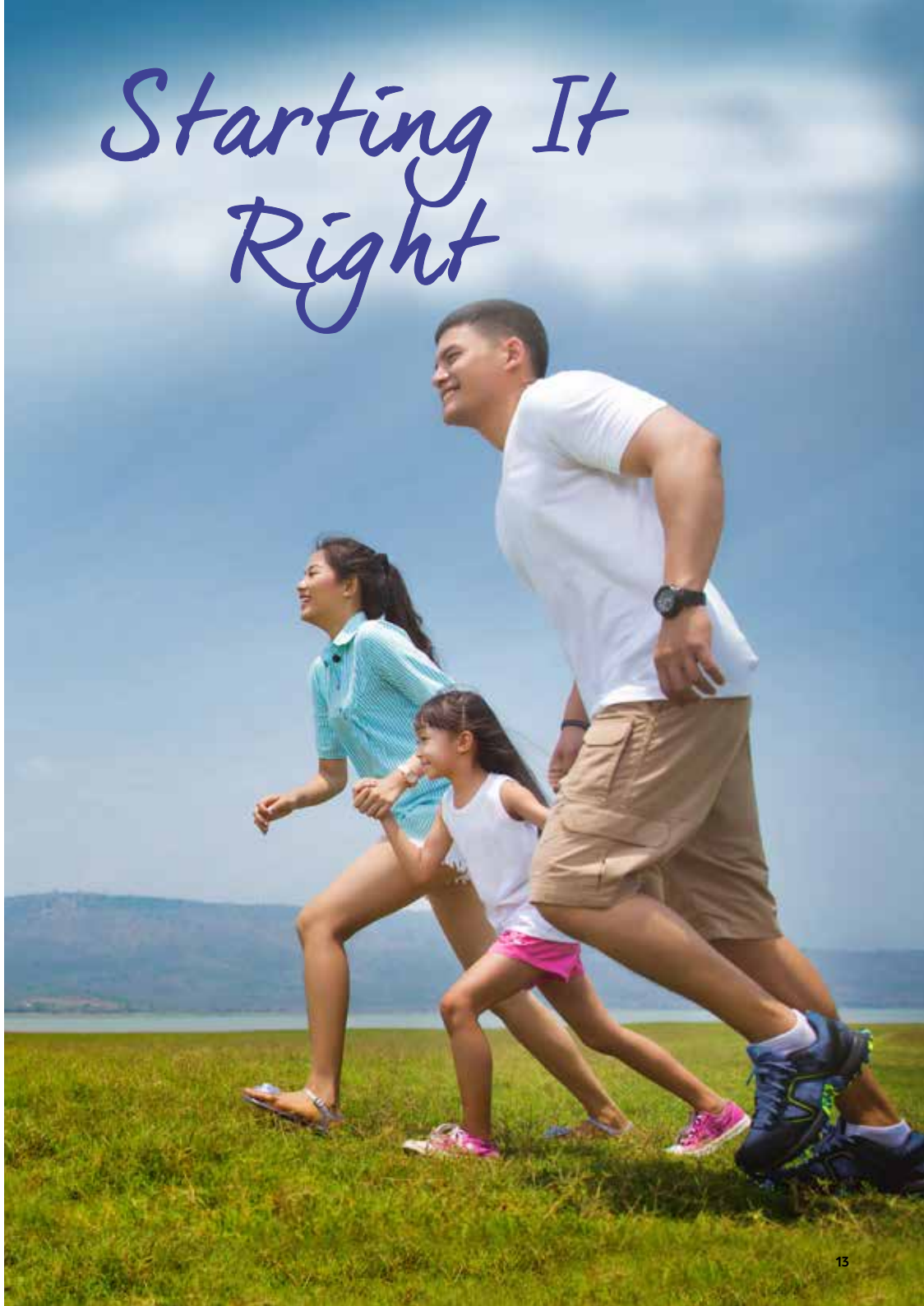
1. Enters the bloodstream within 10-15 minutes
2. Has the greatest glucose-lowering effect for 1-1.5 hours
3. Stops lowering glucose levels after 4-5 hours

You are in charge!

Good safety practices will allow you to pre-empt and resolve potential problems promptly. These include:

- Measuring your blood glucose regularly (minimum 3-4 times daily)
- Never ignoring a low glucose level (< 4 mmol/L) and taking appropriate food/drinks to treat hypoglycaemia
- Never ignoring a high glucose level (> 13 mmol/L) and taking a correction bolus, if appropriate
- **Rechecking a blood glucose level after a low or high glucose reading to ensure it is moving in the correct direction**

Starting It Right



Getting Started on the Pump

EQUIPMENT YOU WILL NEED

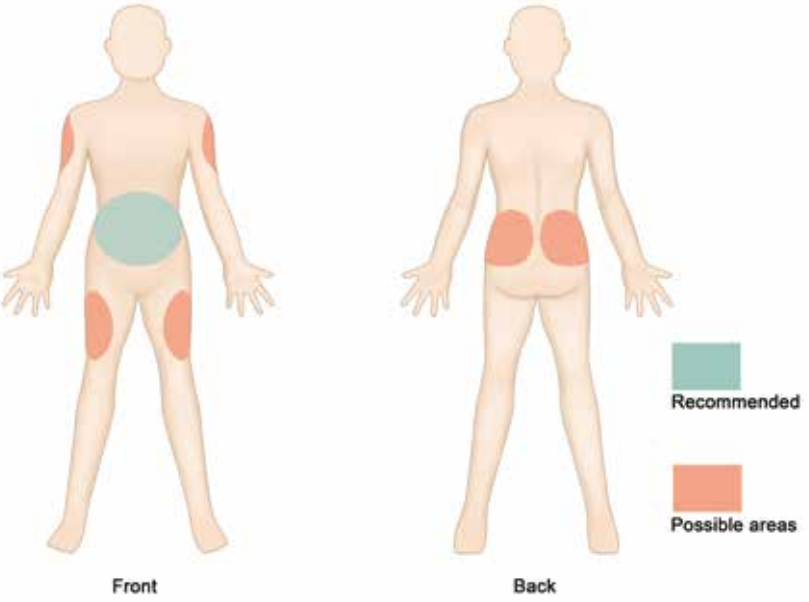
- [ ] Your pump
- [ ] Quick-acting insulin: 1 new cartridge or insulin pen
- [ ] Reservoir
- [ ] 1 cannula set and inserter
- [ ] Blood glucose monitor

LEARN THE SETTINGS

You will be shown how to:

- [ ] Set up basal rates
- [ ] Set a temporary basal rate
- [ ] Give a bolus
- [ ] Set up bolus calculator settings
- [ ] Programme maximum bolus and basal rates
- [ ] Set reminders for infusion set change
- [ ] Programme auto-off limits
- [ ] Fill up a reservoir and prime your infusion set
- [ ] Insert your cannula
- [ ] Fill your cannula

KNOW THE INSERTION SITES



Best spots are on your abdomen, two fingers away from your navel

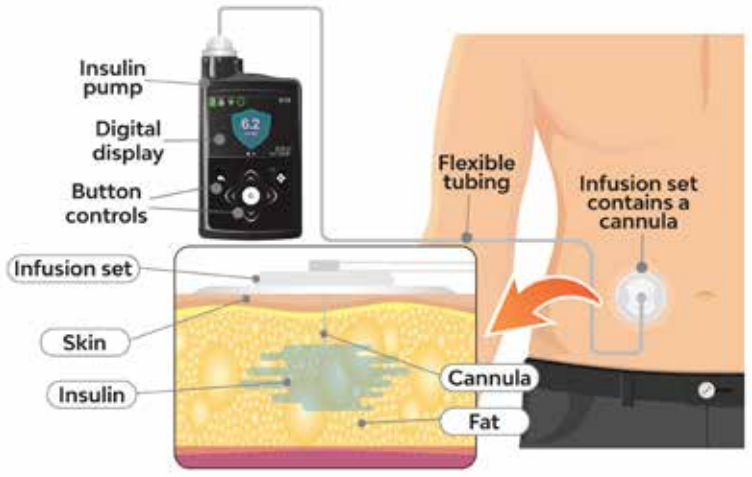
- ✓ If you insert in the **upper arm**, use only the **outer back** area (where there is more fat) and use a shorter cannula.
- ✓ If you insert in the thigh, use a shorter cannula and **avoid using the inner thighs.**

Areas to avoid

- ✗ Do not insert too close to the **navel**, as insulin absorption will not be as consistent.
- ✗ Also do not insert close to **moles, scars or hardened areas.**
- ✗ Do not insert in an **area that will be exercised** soon. Exercising increases blood flow, which causes insulin to be absorbed at a rate that is faster than usual.

Infusion Site Management

Selecting proper infusion sites and caring for your skin appropriately are important parts of successful insulin pump therapy.



The figure above shows the placement of an insulin infusion cannula. The cannula is a plastic tube that is inserted under the skin using an insertion device. The tip of the cannula rests under the skin in the fat layer.

GUIDELINES FOR HEALTHY INFUSION SET AND CANNULA MANAGEMENT

1 Choose the correct site

- Avoid sites that are 'lumpy' or heavily used before.
- Avoid your waistline, belt and underwear line.
- Rotate your infusion sites.
- Your new site should be at least 5 cm (about three fingers) away from the old site.

2 Take care of your infusion sets

- Change infusion sets at least every 3 days.
- An ideal time for a set change is after a shower or before a meal so that the meal bolus ensures the clearing of tissue or blood left in the cannula.
- Wash your hands before you open any package and after touching the old site.
- Use a no-touch technique for ends of tubes.
- Cleanse your skin with an isopropyl alcohol 70% swab and wait for it to dry before insertion.
- Leave the old infusion set in place for up to 8 hours and only remove it after ensuring that the new cannula is working. The old cannula may work as a temporary back-up if the new cannula is not working.

Example of a bent cannula seen after removal

- Sometimes, your healthcare provider may recommend using a metal needle rather than a plastic cannula for insulin infusion. This may be because of challenges with frequent kinking of cannula or non-delivery of insulin.

3 Look out for signs of infections

Be on the lookout for these signs and symptoms of infections:

- High blood glucose
- Redness, swelling
- Warmth
- Discomfort / tenderness
- Fever
- Discharge / drainage
- Abscess formation

! For any of the above symptoms, immediately change the infusion set and site. Contact your pump healthcare team if there is no improvement within 24 hours.

Evaluating Basal Rates

How to Calculate the Basal Rate: Day 1

You will usually need **15-30% less insulin on an insulin pump** than on an insulin pen device. This is related to the manner in which insulin is delivered on a pump.

1 Calculate the total daily dose

The total daily dose (TDD) on a multiple dose injection regimen is calculated from the average total of the basal (or background) insulin and bolus injections given in a day (24 hours).

For example, if you are usually using 22 units of background insulin a day, and 4 units of quick-acting insulin at breakfast, 8 units at lunch and 9 units at dinner, the TDD will be:

$$22 + 4 + 8 + 9 = 43$$

Taking away 30% of this dose, the **new TDD** on an insulin pump will be:

$$\frac{7}{10} \times 43 = 30$$

The **new TDD** of insulin for the insulin pump is 30.

2 Calculate the total daily basal insulin dose

Basal insulin usually provides for half (50%) of your total daily requirements of insulin. The **total daily basal insulin** dose on the pump will therefore be:

$$\frac{1}{2} \times 30 = 15$$

3 Calculate the basal insulin rate

Basal insulin is delivered ***per hour over 24 hours***. To calculate the rate of **basal insulin delivery per hour**, divide by 24:

15 ÷ 24 = 0.6

The basal insulin rate is 0.6 units/hour.

Points to note

- Importantly, although this rate gives a good estimation of your initial basal rate per hour, **basal insulin requirements vary over 24 hours**.
- The pump is able to deliver different basal rates over the 24-hour period.
- Fasting tests can help you with adjusting of your basal rates. The insulin pump healthcare team can help you with this assessment.
- Most people have between 1-6 different basal rates over 24 hours.

For day 1 of starting on the insulin pump, please check blood glucose:

Before each meal

At bedtime

At 3am

Anytime you feel unwell

How to Assess Basal Rates

WHY DO YOU NEED TO ASSESS BASAL RATES?

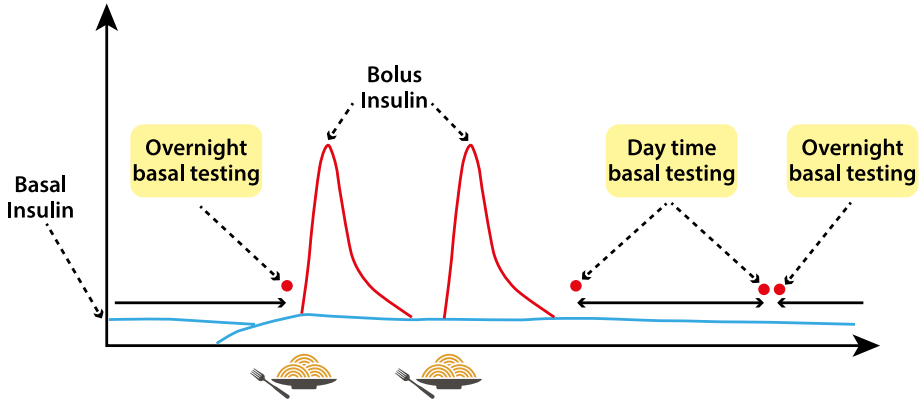
Basal rates should be assessed periodically to check if the programmed rates are meeting your body's background insulin requirements.

Studies have shown that the basal insulin requirements of a person can vary from day to day depending on multiple factors like the degree of physical activity, illness, alcohol intake, etc. The aim of the basal test is to identify an average basal rate that is suitable for most days.

Adjustments to your basal rates, up or down, may be needed for optimal glycaemia. Discuss this with your healthcare team.

HOW TO ASSESS BASAL RATES

Testing the basal rate involves fasting (going without carbohydrates for a period of time). Basal testing is done when only the basal insulin is in action. This is done at least 4 hours after the last dose of bolus insulin and meal.



When fasting, if your basal rate is optimal your blood glucose (BG) should remain relatively stable (BG change ± 2 mmol/L).

GENERAL RULES TO OBSERVE WHEN PERFORMING A FASTING TEST

1. Consume your last carbohydrates 4 hours before starting the fasting period, and avoid food types with a low glycaemic index or high fat meals before the test
2. Give your usual insulin bolus with your last meal
3. Do not eat any snacks during the fasting period
4. Check your blood glucose level (BGL) every 2 hours during the fast
5. If hypoglycaemia (low BG) occurs (BGL < 4 mmol/L), abort the test and treat hypoglycaemia
6. If hyperglycaemia (high BG) occurs (BGL > 13 mmol/L), abort the test and treat hyperglycaemia

WHAT TO DO WITH YOUR RESULTS

BGL results	Action
BGL stays within ± 2 mmol/L	**No change.** Your basal dose is optimal
BGL rises by more than 2 mmol/L	**Increase basal rate.** E.g., by 10-20% of your current basal rate, 2 hours prior to the rise in glucose
BGL falls by more than 2 mmol/L or hypoglycaemia	**Reduce basal rate.** E.g., by 10-20% of your current basal rate, 2 hours prior to the fall in glucose

Importantly, after implementing a change, recheck basal rates by repeating fasting periods.

Example

If your BGL rose from 5.3 mmol/L to 8.8 mmol/L during your fasting test, and the rise happened at 10am, an appropriate action would be to increase the current basal rate by 20% from 8am onwards.

If the existing basal rate at 8am is 0.55 units/hour, the new increased basal rate will be 0.55 x 1.2 = 0.66 units/hour.

Exercises

Exercise 1

From the BGL profile below during an evening basal fasting test, what changes would you make to the basal rate?

Time	BG	Basal rate	Comments
1600h	8.3	0.6	
1700h			
1800h	8.1	0.6	
1900h			
2000h	4.5	0.6	
2100h			
2200h	3.2	0.6	Tremors, felt hungry
2300h			

Exercise 2

From the BGL profile below during an afternoon basal fasting test, what changes would you make to the basal rate?

Time	BG	Basal rate	Comments
1000h	5.3	0.5	
1100h			
1200h	4.1	0.5	
1300h			
1400h	5.6	0.5	
1500h			
1600h	8.4	0.5	
1700h			
1800h	10.2	0.5	
1900h			
2000h	10.5	0.5	

FASTING TEST
MORNING BASAL

Date:

Time	BG	Basal rate	Carbohydrates	Food bolus	Correction bolus	Comments
0000h						
0100h						
0200h						
0300h						
0400h						
0500h						
0600h						
0700h						
0800h						
0900h						
1000h						
1100h						
1200h						
1300h						
1400h						
1500h						
1600h						
1700h						
1800h						
1900h						
2000h						
2100h						
2200h						
2300h						

- Keep all variables constant.
- No breakfast/food or calorie-containing drinks until after 1200h.
- Test blood glucose (BG) at:
  • **0600h** • **0800h** • **1000h** • **1200h**
- **Stop the test if BG < 4 mmol/L or > 13 mmol/L and treat accordingly.**

FASTING TEST
AFTERNOON BASAL

Date:

Time	BG	Basal rate	Carbohydrates	Food bolus	Correction bolus	Comments
0000h						
0100h						
0200h						
0300h						
0400h						
0500h						
0600h						
0700h						
0800h						
0900h						
1000h						
1100h						
1200h						
1300h						
1400h						
1500h						
1600h						
1700h						
1800h						
1900h						
2000h						
2100h						
2200h						
2300h						

- Keep all variables constant.
- No further food / calorie-containing drinks until after 1800h.
- Test blood glucose (BG) at:
  • **1000h** • **1200h** • **1400h** • **1600h** • **1800h**
- **Stop the test if BG < 4 mmol/L or > 13 mmol/L and treat accordingly.**

FASTING TEST
EVENING BASAL

Date:

Time	BG	Basal rate	Carbohydrates	Food bolus	Correction bolus	Comments
0000h						
0100h						
0200h						
0300h						
0400h						
0500h						
0600h						
0700h						
0800h						
0900h						
1000h						
1100h						
1200h						
1300h						
1400h						
1500h						
1600h						
1700h						
1800h						
1900h						
2000h						
2100h						
2200h						
2300h						

- Keep all variables constant.
- Lunch to be consumed before 1300h.
- No further food / calorie-containing drinks until after 2200h.
- Test blood glucose (BG) at:
  • **1600h** • **1800h** • **2000h** • **2200h**
- **Stop the test if BG < 4 mmol/L or > 13 mmol/L and treat accordingly.**

FASTING TEST
OVERNIGHT BASAL

Date:

Time	BG	Basal rate	Carbohydrates	Food bolus	Correction bolus	Comments
0000h						
0100h						
0200h						
0300h						
0400h						
0500h						
0600h						
0700h						
0800h						
0900h						
1000h						
1100h						
1200h						
1300h						
1400h						
1500h						
1600h						
1700h						
1800h						
1900h						
2000h						
2100h						
2200h						
2300h						

- Keep all variables constant.
- Dinner to be consumed before 1800h.
- No further food / calorie-containing drinks until after 0800h the next morning.
- Test blood glucose (BG) at:
  • **2200h (Bedtime)** • **0200 - 0300h** • **0700h - 0800h**
- **Stop the test if BG < 4 mmol/L or > 13 mmol/L and treat accordingly.**

Temporary Basal Rates

You may find that changes to your fixed basal rate may be necessary at times.

A temporary basal rate helps you alter the basal rate for a fixed period without changing your pre-programmed basal rates.

A temporary basal rate is programmed in percentages of the usual basal pattern.

The typical range of temporary basal rates available on most insulin pumps can be from 0-200% of the usual basal rate, programmable in 10% increments for up to 24 hours.

WHY WILL I NEED TO USE A TEMPORARY BASAL RATE?

Studies conducted in people without diabetes show that about 50% of the insulin secreted by the pancreas is basal insulin, and the rest is secreted in response to meals (bolus insulin).

However, **the amount of basal insulin required per day may change** based on factors like the degree of physical activity, presence of illness, stress, medications and hormonal changes during menstruation.

In a person without diabetes, the pancreas responds to these factors and auto-adjusts the amount of basal insulin required precisely.

When adjusting the temporary basal rate, it is important to understand that any change in basal rate takes 2 hours or longer to manifest as a change in blood insulin levels.

Temporary increased basal rate

Examples of people needing increased temporary basal rates are a **person who is ill** or a **student during the exam period.** They may be experiencing high blood glucose as a result of stress.

They may programme the pump to deliver 120% of the usual basal rate for 24 hours. This will translate to a 20% increase to their usual basal rate.

Temporary decreased basal rate

During **aerobic exercise**, there is a drastic reduction in insulin requirement. People with type 1 diabetes need very little or no insulin during prolonged moderate intensity aerobic exercise.

A person with type 1 diabetes planning to go for a 2-hour jog at 5pm, based on their personal experience, may set a temporary basal rate of 20% for 4 hours starting at 3pm. This equates to an 80% reduction in the preset basal rate for 4 hours. The temporary basal rate can be cancelled anytime if needed.

People who do **intermittent exercise** (only a few days a week or on weekends only) may need a lower overnight basal rate on the days of exercise.

A person with type 1 diabetes who did a bout of afternoon exercise may set a temporary basal rate of 80% (20% reduction) for 6-8 hours from bedtime. This reduces the risk of overnight hypoglycaemia on the night of exercise.

Why a temporary basal rate may be needed (increase or decrease) and/or alternate basal rate may be needed:

- Exercise (may range from a few hours before, to during or hours after the activity)
- Intimacy / sexual activity
- Illness (sickness/surgery)
- Pre-menstruation (hormonal surges)
- Stress (related to school, work, exams)
- Travelling (sitting for prolonged hours in a flight, changing time zones)
- Holidays (more activity than usual)
- Weekends (different exercise levels, sleeping patterns and reduced amounts of stress)

You may be required to use a temporary decreased basal rate during times when you experience unexplainable hypoglycaemia.

Note After a temporary basal rate ends, the pump resets itself to the user's usual basal rate.

Determining Bolus Doses

Bolus Insulin

WHAT IS A BOLUS CALCULATOR?

All insulin pumps have an inbuilt bolus calculator (sometimes called a bolus wizard or bolus advisor).

The bolus calculator can help you by doing the calculations and recommending the required bolus insulin. It can also keep track of your last bolus and estimate the active insulin remaining from your last bolus.

The accurate amount of bolus insulin required depends on the:

- Amount of carbohydrate taken
- Current blood glucose level (BGL)
- Active insulin remaining from a previous bolus

1 DETERMINING THE INSULIN TO CARBOHYDRATE RATIO

The insulin to carbohydrate ratio (ICR) is the amount of insulin given to cover the blood glucose (BG) rise that occurs after eating or drinking foods containing carbohydrate.

- You may have previously been calculating your ICR based on carbohydrate portions of 10 g (i.e., number of units of insulin per 10 g of carbohydrate).
- An insulin pump allows more precise doses of insulin to be delivered and it is therefore more accurate to use ratios that allow for the exact amount of carbohydrate taken (e.g., 1 unit of insulin per 8 g of carbohydrate). This ratio may be programmed into your bolus calculator settings and may vary throughout the day (i.e., different ratios from morning to evening).
- **All you need to do is enter the exact amount of carbohydrate taken, and the bolus calculator will do the math.**

2 DETERMINING THE CORRECTION FACTOR (INSULIN SENSITIVITY FACTOR)

The correction bolus is the insulin given to correct a higher-than-target BG. The correction bolus dose is influenced by the insulin sensitivity factor (ISF), that is, how much the BGL falls with 1 unit of insulin.

The ISF may be estimated using the formula:

(100 or 120) ÷ TDD insulin

For example, if the total daily dose (TDD) insulin on an insulin pump is 40 units/day:

120 ÷ 40 = 3

In someone who is using 40 units of insulin a day on an insulin pump, 1 unit of insulin will bring the BGL down by 3 mmol/L.

3 BOLUS CALCULATOR SETTINGS (PROGRAMMING YOUR BOLUS CALCULATOR)

The bolus calculator can be programmed to take into account your current BGL, and carbohydrate intake data which you enter into the pump, and advise you on the amount of bolus to give.

This is calculated based on:

$$\text{Bolus dose} = \frac{\text{Carbohydrates}}{\text{ICR}} + \frac{\text{Current BG} - \text{Target BG}}{\text{ISF}} - \text{Active insulin}$$

This calculation also takes into account your programmed **BG targets.**

4 ACTIVE INSULIN

The **active insulin** is the amount of insulin that is remaining in your body from previous boluses and will continue to lower your BG. The pump estimates this based on the duration of insulin action time programmed.

For quick-acting insulin, the recommended insulin action time is 4 hours. That is, 4 hours after a bolus dose, no further glucose lowering is expected from the bolus dose.

Importantly, whilst the bolus calculator can advise you on the amount of bolus insulin to deliver, the accuracy is entirely dependent on the entry of your current BG and accurate carbohydrate counting.

WHEN TO TAKE BG MEASUREMENTS

We recommend BG measurements:

When you wake up

Before each meal

At bedtime and occasionally overnight

During episodes of hypoglycaemia

Note

The bolus calculator does **NOT** consider any planned upcoming physical activity. You may need to modify the recommended bolus if required, based on exercise recommendations.

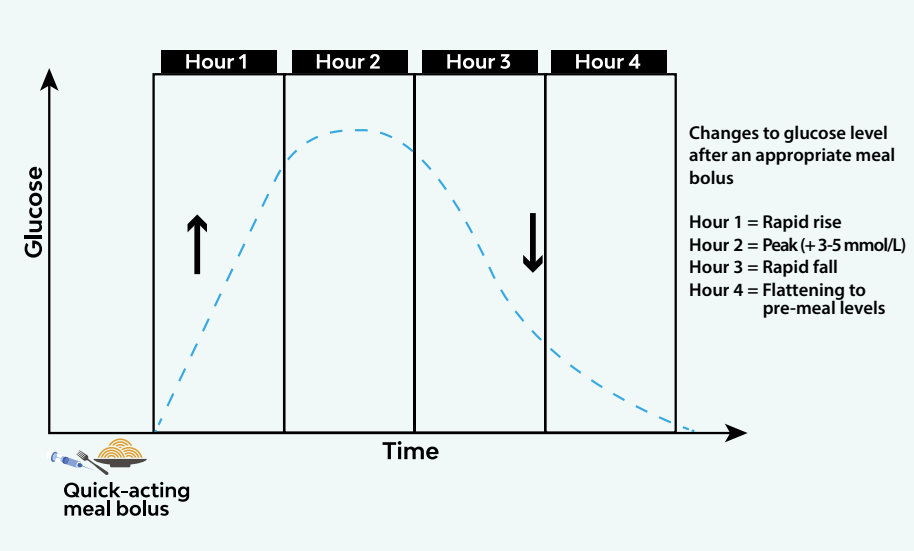
Assessing the Insulin to Carbohydrate Ratio

It is often important to ensure that your basal rates are optimal (see page 22) before assessing the insulin to carbohydrate ratio (ICR).

This is because a basal rate that is too high will result in hypoglycaemia. A basal rate that is too low will result in hyperglycaemia, requiring more doses of supplemental bolus insulin.

UNDERSTANDING HOW ACTIVE INSULIN WORKS

In assessing the ICR, it is helpful to understand how your active insulin works.



Upon consumption of carbohydrates, these are digested and appear in the blood stream as a raised blood glucose (BG) level within the first hour. However, quick-acting insulin is still at work, even for up to 4 hours.

For this reason, your glucose may still be above pre-meal target at 2 hours and will gradually drop to pre-meal target range by 4 hours if the bolus dose was correct.

TO TEST YOUR ICR, ENSURE:

- You have not had hypoglycaemia in the preceding 8 hours
- Your pre-meal readings are within the BG targets set by your healthcare team
- You can accurately count carbohydrates each meal

Steps for testing your ICR

1. Eat sufficient carbohydrates (30-50 g) in order to assess your ICR
2. Avoid foods with excess fat and/or protein
3. Accurately count carbohydrates and enter the amount of carbohydrates and BG reading into your pump, and take the bolus your pump recommends
4. Test your BG reading at the next meal (at least 4 hours after the last bolus)

Note

Do not take a snack after the meal when testing your ICR. Due to the duration of insulin action above, even if you were to cover a snack with insulin 2-3 hours before your meal, your pre-meal readings may still be above target.

In that scenario, the higher-than-target reading will not truly reflect a pre-meal reading and the ICR may not be assessed accurately.

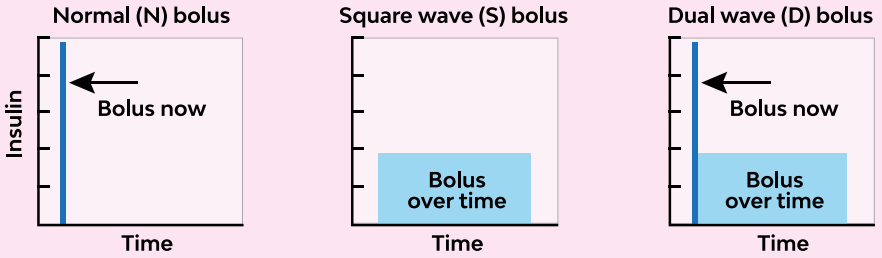
Bolus Options

WHAT TO THINK ABOUT BEFORE A BOLUS

1. How much carbohydrate do you plan to eat?
2. What is your current blood glucose level (BGL)?
3. Is a physical activity of higher intensity than usual planned within 3 hours?

TYPES OF BOLUS OPTIONS

The different bolus options on an insulin pump are:



Standard bolus

Your personalised insulin to carbohydrate ratio (ICR) may be programmed into the pump to enable easier and more accurate bolusing to cover your carbohydrate intake. You may require a different ICR with each meal throughout the day, and this could be programmed.

Example

If your ICR is 10, it means that you require 1 unit to cover 10 g of carbohydrates. For 60 g of carbohydrates, you will require 6 units to cover the meal.

If your ICR is 5, it means that you require 1 unit to cover 5 g of carbohydrates.

Advanced bolus options

Besides the standard bolus, there are two additional bolus types:

1. **Extended or square wave bolus**
2. **Combination or dual wave bolus**

These are used to match carbohydrates with varying digestion times, which may be related to:

- The nature of the carbohydrates consumed (e.g., low versus high glycaemic index foods)
- The combination of foods consumed (e.g., fat slows down carbohydrate digestion)

These bolus options are also helpful in conditions such as gastroparesis (delayed emptying of food from stomach).

Before exploring the different bolus options, it is important to firstly have a **good knowledge of the composition of your meals and robust carbohydrate counting skills.**

ACTIVE INSULIN ON BOARD

It is also important to note that because of the duration of action of insulin, if you were to give your bolus soon (e.g., 2 hours) after your last bolus, **you may risk insulin overlap (known as stacking)**.

Before giving a correction insulin bolus to bring down a high glucose reading, consider if the previous bolus is still active. Using the 'active insulin' feature on your bolus calculator should help avoid insulin stacking.

Note

The home screen of your pump will show you the amount of active insulin remaining at any time. If you have residual active insulin, it means that your current BG is expected to fall further without any additional insulin.

Troubleshooting

Hyperglycaemia
(High Blood Glucose)

WHAT IS HYPERGLYCAEMIA?

Hyperglycaemia (high blood glucose [BG]) means that there is too much glucose in the blood. High BG occurs when there is not enough insulin available to cover the amount of glucose that is in your blood.

WHY IS IT IMPORTANT TO MANAGE IT?

A major goal of managing diabetes is to avoid persistent high BG and maximise the time spent in target range (3.9-10 mmol/L).

> **!** A persistent high BG should never be ignored as this may be due to a lack of insulin, which can develop quickly into a serious life-threatening complication known as diabetic ketoacidosis.

REASONS FOR HYPERGLYCAEMIA

Increased insulin requirements	• Infection/illness • Stress • Hormonal (menstruation/pregnancy) • Steroids
Insufficient insulin delivery	• Inaccurate settings (basal and bolus) • Missed bolus • Underestimated carbohydrates • Rebound following hypoglycaemia
Infusion set / cannula	• Blocked/dislodged cannula • Cannula and infusion set used for too long • Leaking cannula • Air bubble inside infusion set / cannula • Lipodystrophy (thickening at site from repeated use)
Insulin pump	• Empty reservoir • Pump not working

TREATMENT FOR HYPERGLYCAEMIA

If your BG is high without any residual active insulin

1. Consider taking a correction bolus using your bolus calculator.
2. Recheck BG in 2 hours to ensure that BG is falling.
3. If your BG does not fall or rises 2 hours after a correction dose, consider cannula / infusion set issues and change the infusion set and cannula.

If there are 2 BG readings of more than 13 mmol/L

- ✓ Check for blood ketones
- ✓ Drink plenty of sugar-free fluids (about 100 ml [1/2 glass] per hour) and use the sick day management plan (see page 41)
- ✓ Contact your healthcare provider if your BG has not improved after two supplemental insulin doses

Sick Days on a Pump

It is important to know what to do when you are ill, as the body becomes more resistant to insulin. This means that your blood glucose levels (BGL) can rise. In addition, since the insulin pump delivers only quick-acting insulin and has a small depot of quick-acting insulin, there is a high risk of developing diabetic ketoacidosis if the BGL is not monitored closely or controlled. **Importantly, never stop taking insulin.**

WHAT IS CONSIDERED A SICK DAY?

Conditions that may be considered a 'sick day' and make your BGL increase include:

1. Common cold, influenza (flu)
2. Nausea, vomiting, diarrhoea
3. Infections
4. Surgery, injury, stress
5. Dental work

STEPS TO TAKE ON SICK DAYS

- Check your BGL every 3 hours and check for blood ketones (blood glucose [BG] and blood ketone testing is available on the Abbott FreeStyle Optium Neo meter)
- Drink sugar-free fluids (100 ml/hour)
- Use a bolus calculator to cover meals if eating
- Use a bolus calculator to correct for high BG, both at mealtimes and **even if not eating**
- Continue usual basal insulin rates. However, increase them by 10% (temporary basal rate of 110%) if you continue to be unwell for more than 1 day
- If your blood ketone level is > 1.5 mmol/L, check your BG every 2 hours and correct your BG using the bolus calculator, even if you are not eating

CONTACT YOUR HEALTHCARE PROVIDER OR GO TO THE HOSPITAL IF:

- You are unable to keep fluids down or if vomiting persists for > 2-4 hours
- Ketones are still > 1.5 mmol/L despite 2 correction boluses
- BG is < 10 mmol/L and ketones > 1.5 mmol/L, or BG is < 13 mmol/L and ketones > 3 mmol/L
- You cannot keep your BG above 4.5 mmol/L
- You feel unwell, drowsy or confused
- You develop fast/unusual breathing or experience abdominal pain
- You are not sure what is wrong with you or are too unwell to follow these guidelines

Pump Failure

You need to go back to insulin injections if your pump is not working properly.

HOW TO DETERMINE AN OFF-PUMP DOSE FOR PUMP FAILURE

If long-acting insulin is NOT available

Step 1 Identify your current total basal dose on the pump.

Step 2 Multiply this dose by 1.3, and this is your new basal dose off-pump.

Step 3 Take 1/6 of your new total basal dose on the pump every 4 hours using quick-acting insulin, until long-acting insulin is available.

Step 4 Use your usual insulin to carbohydrate ratio (ICR) and insulin sensitivity factor (ISF) on your pump to determine bolus doses for meals and corrections.

Using long-acting insulin

Step 1 Identify your current total basal dose on the pump.

Step 2 Multiply this dose by 1.3, and this is the total basal dose on a long-acting insulin pen device.

Step 3 Take the new total basal insulin dose once daily or take half the dose twice daily, 12 hours apart.

Step 4 Use your usual ICR and ISF on your pump to determine bolus doses for meals and corrections.

Note Contact the pump manufacturer immediately for supply of another pump for you. Contact your healthcare provider if you are uncertain about the insulin conversion doses.

Hypoglycaemia
(Low Blood Glucose)

WHAT IS HYPOGLYCAEMIA?

Occasional hypoglycaemia (low blood glucose [BG]) is not uncommon in people with type 1 diabetes, particularly when starting to use the pump for the first time. An insulin pump when used alone cannot predict hypoglycaemia, so it is **important that you check your blood glucose level (BGL) regularly**. This will help to fine-tune your insulin pump settings.

HOW OFTEN SHOULD YOU CHECK BGL?

For a start, you should be checking your BGL at least **4 times a day:** pre-meals and at bedtime. In addition, it is also wise to check your BGL whenever you feel unwell or recognise any hypoglycaemia symptoms.

It is important to carry hypoglycaemia treatment with you at all times.

WHAT CAUSES LOW BGL WHEN ON A PUMP?

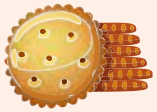
Hypoglycaemia at any time means that you have more insulin than is required for your body.

This could be due to:

- A basal rate that is set much higher than your background insulin needs
- Taking more insulin than is required for meals due to inaccurate bolus settings or inaccurate carbohydrate counting
- Physical activity (planned or unplanned) that reduces your insulin requirements
- Consumption of alcohol, especially without much carbohydrate intake
- 'Stacking of insulin' – multiple bolus doses taken within a few hours

HOW TO TREAT HYPOGLYCAEMIA

BG < 4 mmol/L	BG < 2.8 mmol/L
1. Consume 15 g of carbohydrate	1. Consume 30 g of carbohydrate
2. Recheck BG in 15 minutes	2. Recheck BG in 15 minutes
3. Repeat with another 15 g of carbohydrate if BG is still < 4 mmol/L, until BG returns to normal	



You may consider taking a small snack (10-15 g of carbohydrate) following a hypoglycaemia treatment,
OR
Apply a temporary basal rate of 70-80% of your usual basal rate overnight if you experience bedtime hypoglycaemia.

Do not overcompensate with snacks.

The next BG reading following treatment for hypoglycaemia may be high.

DO NOT use the bolus calculator to correct for this high glucose level. Cover your mealtime carbohydrates using your usual **ICR** for that meal.

DO NOT suspend your pump basal delivery because of hypoglycaemia.

As any change in basal rates takes 2 hours or longer to cause a change in your blood insulin levels, suspending your basal delivery when you are having hypoglycaemia cannot treat it. It will only result in rebound high BG much later.

Try to determine the cause of hypoglycaemia to prevent future similar episodes.

Severe Hypoglycaemia

Severe hypoglycaemia is defined as a low blood glucose level (BGL) that you are unable to self-treat. During an episode of severe hypoglycaemia, the person may become confused, lose consciousness or develop seizures.

HOW TO TREAT SEVERE HYPOGLYCAEMIA

When conscious

If you are conscious but confused and unable to treat yourself, someone will need to give you your hypoglycaemia treatment (15-20 g of rapid-acting carbohydrate).

When unconscious

When unconscious, **NO oral treatment** should be given as this could cause aspiration.

Administering Glucagon

Glucagon can be given by injection to help raise the BGL by signalling your liver to release stored glucose.

Glucagon kits are only available on prescription and should only be administered by someone who has been trained to do so. If the person helping you has not been trained to give you this injection or it is not available they must call the ambulance (995) so that a paramedic can assist you.

Important points to note

- Glucagon takes 10 minutes to work.
- When you regain consciousness, you should consume 20 g of rapid-acting carbohydrate immediately, followed by an additional 40 g of longer-acting carbohydrate.
- **The person administering Glucagon must call for an ambulance (995) if you do not regain consciousness.**
- Glucagon injection must not be used more than once in 24 hours. Glucagon releases stored glucose from the liver and if it has been used within 24 hours, there will not be much stored glucose in your liver.
- You should also check your BGL more frequently for at least 24 hours, as you may be at risk of further hypoglycaemia.

REDUCED AWARENESS OF HYPOGLYCAEMIA CAN LEAD TO SEVERE HYPOGLYCAEMIA

Anyone with diabetes can lose their warning signs of hypoglycaemia as the brain adapts to a low BGL and 'resets'.

Instead of the warning symptoms of hypoglycaemia coming on at the usual glucose threshold of 3.5 mmol/L, it only comes in at much lower glucose levels (e.g., 2.5 mmol/L).

This is dangerous, since at a lower glucose level, it may be too late to effect appropriate hypoglycaemia treatment due to confusion or decreased consciousness. This leads to increased incidences of severe hypoglycaemia.

The following measures will help you regain your awareness of hypoglycaemia.

1. Check your BGL more frequently and treat hypoglycaemia promptly
2. Minimise episodes of hypoglycaemia and aim to keep your BGL from falling below 4.5 mmol/L
3. Individuals on an insulin pump that also has real-time continuous glucose monitoring capabilities can set their monitor to alert them prior to the onset of hypoglycaemia, so that they can take appropriate pre-emptive action

Alcohol Consumption

CAN PEOPLE WITH DIABETES DRINK ALCOHOL?

People with diabetes can choose to drink alcohol.

Diabetes nutrition guidelines recommend that individuals who choose to drink should have:

- No more than 1 standard drink a day for women
- No more than 2 standard drinks a day for men

1 unit of alcohol is defined as any drink that provides 10 g of alcohol.

A standard alcoholic drink is defined as:

- 2/3 of a can (220 ml) of regular beer
- Half a glass (100 ml) of wine
- 1 nip (30 ml) of spirits

RISK OF HYPOGLYCAEMIA

Drinking alcohol decreases your awareness of symptoms of hypoglycaemia.

As the liver also needs to work to metabolise alcohol, it will not be efficient in releasing glucose to maintain glucose levels. This results in a greater risk of hypoglycaemia when alcohol is taken in large quantities.

This effect can last up to 12 hours after alcohol consumption.

TIPS TO MAINTAIN SAFE BLOOD GLUCOSE LEVELS

The following can help you work out what you should do to maintain a safe blood glucose (BG) level:

- Knowing the effects of different alcoholic beverages on your BG readings
- Knowing the amount of alcohol you have consumed
- Taking regular BG readings after alcohol consumption
- Trial and error may be necessary

Alcoholic drinks that contain carbohydrates	Alcoholic drinks that (if taken neat) do not contain carbohydrates
• Beer • Cider • Alcopops / pre-mixed drinks • Dessert wine • Sweet martini / sherry • Guinness • Port wine / Kahlua / Baileys	• Wine (red or white, dry or medium) • Sparkling wine / champagne • Dry martini / sherry • Spirits (e.g., vodka, rum, brandy, whisky, gin)

- It may be necessary to use a **temporary decreased basal rate** for up to 12 hours after alcohol intake, particularly for the prevention of nocturnal hypoglycaemia
- **Do not drink on an empty stomach**

Note

If you are dancing while drinking, remember to incorporate exercise guidelines since this will further increase the risk of delayed hypoglycaemia.

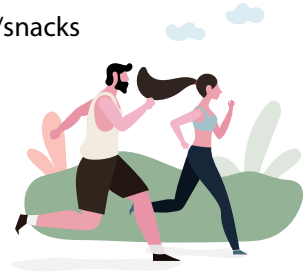
Exercise and Physical Activity

Your carbohydrate intake and insulin reductions have to be tailored to your training level and the intensity and duration of exercise.

WHAT AFFECTS BLOOD GLUCOSE LEVELS DURING EXERCISE?

The most important factors that affect blood glucose (BG) during exercise and activity are:

- Current active insulin levels (available on bolus calculators on the pump or bolus calculator apps)
- Timing of the exercise in relation to recent meals/snacks
- Current blood glucose level (BGL)
- Length and intensity of the exercise
- Training or fitness level of the individual
- Whether the exercise is aerobic or anaerobic
- Stress hormone release in competitive sports



FUEL SOURCES

Exercise requires fuel. The first fuel source available for exercise is the glucose that is already present in the blood. This limited supply is quickly followed by the release of glucose from muscle and liver glycogen stores.

In a person without diabetes, this is facilitated by a rapid decrease in insulin levels and a rise in glucagon levels.

In a person with diabetes, although glucose and glycogen are easily accessible and rapidly released, the supply of these fuels is limited due to the presence of exogenous insulin, which does not automatically decrease during exercise.

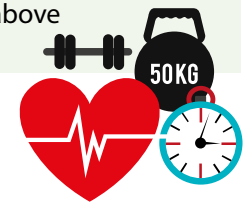
You may be at risk of hypoglycaemia during, immediately after, or for hours (12-18 hours) after exercise.

MANAGING INSULIN LEVELS

BG is directly affected by insulin levels, so it is not surprising that the insulin level is important to exercise and activity.

Prevent hypoglycaemia during exercise

- Reduce the dose of the insulin bolus at the mealtime just prior to exercise
- Use a temporary decreased basal rate during and hours after the exercise
- Top up 'exercise carbohydrates' during exercise
- Top up carbohydrates after the exercise
- You may need to do more than one or all of the above



PRE-EXERCISE TIPS

- **Ensure that BGL is > 7 mmol/L**

  If below 7 mmol/L, carbohydrates are required. The amount of carbohydrates required will be dependent on the activity, duration and intensity of exercise.

- **If BGL is 7 to 10 mmol/L**

  This is a safe range. The requirement for carbohydrates is dependent on the activity, duration and intensity of exercise.

- **If BGL is > 13 mmol/L**

  If this is unrelated to recent carbohydrate intake and is not readily explainable, consider delaying your exercise. This is important since insufficient insulin may worsen the high glucose levels and precipitate diabetes ketoacidosis.

EFFECTS DURING EXERCISE

There are two types of exercise: **aerobic** and **anaerobic.**

	Aerobic	Anaerobic
Fuel	Oxygen	No oxygen, hence activity is short term
Typical duration	Prolonged	Short
Activity level	Endurance	Intense
Examples	Walking/running/swimming	Weights / short sprint
Effect on glucose	Lowers during and/or immediately after exercise	Causes immediate/temporary rise in BG but typically falls later

Many activities will fall into both categories and consist of a combination of both aerobic and anaerobic activity (e.g., racquet sports, basketball, football).

Endurance activities tend to reduce glucose levels, and will need continual top-up of carbohydrates or a greater lowering of basal rates (applying a decreased temporary basal rate).

POST-EXERCISE

Both aerobic and anaerobic exercise **increase your risk of hypoglycaemia for up to 12-18 hours** afterwards.	A decreased temporary basal rate may be applied to reduce this risk.
A post-exercise rise in BG may occur particularly with high-intensity exercise or anaerobic exercise.	A phase of active cool-down (light aerobic exercise) instead of abrupt cessation of exercise may limit this rise.
Work out a pattern for yourself based on the nature, intensity, duration and timing of activity.	It will be helpful to keep a diary of your exercise to correlate with your pump download.

Note Before you embark on a new exercise regimen, discuss with your diabetes care team about strategies to safely do so.

Travelling

Travelling can be stressful as changes in time zones, schedules, activity levels, mealtimes and types of food can affect your diabetes control. However, with proper planning and preparation you can enjoy a stress-free holiday.

Measuring your blood glucose more frequently while you are travelling will provide you with the information to make necessary changes to your regimen.

BEFORE YOU GO

Discuss with your diabetes care team about your travel plans and any adjustments to your pump settings that may be needed.

TRAVELLING CHECKLIST

- [ ] Extra insulin supply (including long-acting basal insulin)
- [ ] Infusion sets
- [ ] Insulin pump reservoirs
- [ ] Batteries
- [ ] Blood glucose measuring kit
- [ ] Ketone strips
- [ ] Glucose tablets or fast-acting sugar
- [ ] Snacks
- [ ] Medical ID
- [ ] Prescription and document with current pump settings
- [ ] Insulin syringes and/or insulin pen needles for emergency injections and dosing instructions from your doctor

ON THE PLANE

✓ **Consider disconnecting the infusion set during take-off and landing before reconnecting again.**

At times, during take-off and landing, bubbles may be introduced into the infusion set, pushing through small amounts of insulin, potentially causing hypoglycaemia.

✓ **Always carry extra insulin supply as cabin baggage.** Storing insulin in check-in baggage may cause it to freeze and make it ineffective.

WHILE TRAVELLING

Pay extra attention to updating the time on your insulin pump if you:

- Have multiple basal rates that vary significantly throughout the day
- Experience the dawn phenomenon
- Experience low BG in the middle of the night
- Are travelling far distances (with a time zone change of more than three hours)

Admission to Hospital

WHAT DO YOU DO WITH YOUR PUMP IF YOU ARE ADMITTED TO THE HOSPITAL?

If it is an elective admission	Make sure you discuss it with your diabetes team beforehand.
If you are having a minor operation that does not require general anaesthesia	It may be possible to keep your pump on with the agreement of the anaesthetist and your diabetes team.
If you are having a major operation requiring general anaesthesia	You will need to take off your pump and be given insulin subcutaneously or intravenously.
If you are admitted with high blood glucose levels or ketones	You will be asked to take off your pump and given intravenous insulin until the problem has resolved.
If you are capable of looking after your insulin pump yourself	You should continue using your pump while in hospital with agreement of the medical team and nurses caring for you.
If you are incapable of looking after your insulin pump yourself	You will need to use other methods to give your insulin. Your medical team will advise you according to your condition.

Emergency Kit

The following equipment should be carried at all times for emergency use.

ESSENTIAL ITEMS

- ☐ Rapid-acting insulin pen / syringe / needle
- ☐ Hypoglycaemia treatment
- ☐ Blood glucose measurement kit

ADVISABLE ITEMS

- ☐ Spare infusion set
- ☐ Spare insulin pump reservoir
- ☐ Spare batteries
- ☐ Ketone strips

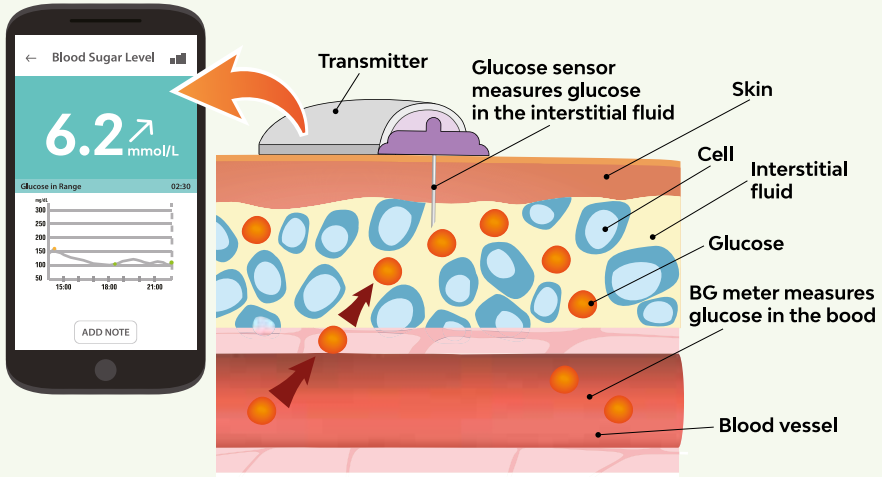
Advanced Diabetes Technology

Glucose Sensors

WHAT IS A GLUCOSE SENSOR?

Glucose sensors are small devices with an implantable sensor that sits under the skin to continuously measure glucose.

These devices measure the glucose in the tissue fluid and not blood. They then provide an estimated blood glucose level (BGL) using their proprietary software interface, usually downloadable on a smartphone. Currently available devices last from 7 to 14 days.



The figure above shows the position of a glucose sensor on the skin with a sensor resting under the skin.

The sensor detects glucose in the interstitial fluid as an electric current and converts it into a sensor glucose value. The transmitter transfers the sensor glucose to a viewing device (a handheld device or smartphone).

Diabetes technology is evolving at a rapid pace. The information provided in this booklet is accurate at the time of publication. You should discuss with your healthcare provider about your region-specific availability, regulatory approvals and indications of use for diabetes technology which may change from time to time.

HOW IS A GLUCOSE SENSOR INSERTED?

Most glucose sensors are easy to insert and can be done by people with diabetes themselves. Each sensor has a unique spring-loaded device to easily and painlessly insert the device into the skin. After the usage period, these sensors can be peeled off the skin and discarded.

DO I NEED AN INSULIN PUMP TO USE A GLUCOSE SENSOR OR VICE VERSA?

No, glucose sensors and insulin pumps are separate devices, and they can be used independently of each other. However, certain types of insulin pumps can communicate with the sensors. This provides the insulin pump with continuous information about your sensor glucose.

Predictive low glucose suspend

This enables the use of some features like 'predictive low glucose suspend', where the insulin pump automatically shuts off the basal insulin delivery if hypoglycaemia is predicted, and resumes basal insulin delivery when the glucose begins to rise.

Hybrid closed-loop system

Another insulin pump system that communicates with the sensor is a hybrid closed-loop (HCL) system.

The use of a compatible glucose sensor is a necessity if you wish to use an **artificial pancreas system** (a HCL system), as the insulin pump requires continuous information on your glucose levels to function as a closed loop. Such systems continuously and automatically modify the delivered insulin based on changes to your sensor glucose.

Advanced hybrid closed-loop (AHCL) systems are able to automatically adjust the basal insulin delivery as well as give correctional boluses based on changes in your sensor glucose. See page 64 for more information.

ARE GLUCOSE SENSORS ACCURATE?

All glucose measuring devices, including finger prick glucose meters, must pass a minimum accuracy standard before being approved for use.

- In general, a device is approved if it consistently reads **within 15% of your true blood glucose (BG) value** (as measured by a reference laboratory method).
- It must be noted that even the reading obtained by the finger prick glucose meter is only within 5-15% of your true BG reading.
- Hence, your glucose sensor readings and your finger prick glucose readings are unlikely to be exactly the same as each are only within 5-15% of your true glucose reading.
- Some glucose sensors require you to enter your capillary BG a few times a day to calibrate them. By doing this correctly, your sensor glucose readings will more closely match your capillary glucose readings.

In addition, glucose sensors are particularly liable to providing a falsely low or high reading when your BG is changing rapidly. An example of this is a rising BG soon after a meal or a dropping BG after a correction insulin dose.

Some medications you take when you are unwell can also interfere with your sensor readings and make them falsely high or low. High-dose paracetamol (> 1 g every 6 hours) may cause falsely high readings on Medtronic Guardian G3 and Dexcom G6 sensors. The Abbott FreeStyle Libre sensor is affected by aspirin (falsely low) and vitamin C (falsely high). Hydroxyurea causes falsely high readings on the Dexcom G6.

The value of glucose sensors

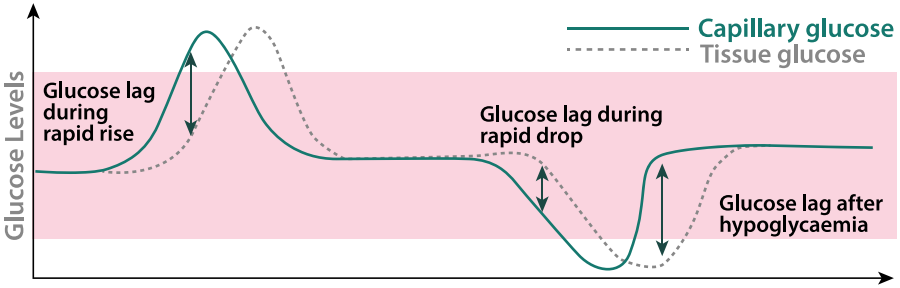
The accuracy of glucose sensors is continuously improving. Despite the above caveats, people with diabetes have found glucose sensors useful as they provide a lot more information including the direction of change of glucose.

Depending on the device used, glucose sensors measure glucose 96 to 288 times in 24 hours.

WHAT IS TISSUE GLUCOSE LAG TIME?

A glucometer measures capillary BG while a glucose sensor measures interstitial (tissue) glucose. It takes time for glucose to travel from the blood vessel to the interstitium.

- **If your BG is stable** and not changing, both the tissue glucose and sensor glucose will be the same.
- **If your BG changes suddenly,** it will take **10-15 minutes or longer** for the tissue glucose to change. This delay is called the tissue glucose lag time.



It is for this reason that we do not recommend using a sensor to check for recovery from hypoglycaemia after treatment.

The sensor will continue to show low glucose levels even when your BG has risen with treatment. Not understanding this might result in overtreatment of hypoglycaemia resulting in subsequent high BG levels.

CAN I STOP DOING FINGER PRICK GLUCOSE MEASUREMENTS IF I USE A GLUCOSE SENSOR?

NO. Although the use of a glucose sensor markedly reduces the number of BG measurements, there are two reasons why you will still need to do some finger prick measurements.

1. Calibration

Some glucose sensors (e.g., Medtronic Guardian 3) require the user to enter capillary finger prick BG readings at least twice a day to ensure accuracy of the sensor glucose readings.

However, newer sensors that are being produced increasingly do not require calibration. Check with your healthcare team for more information.

2. Safety

Although the accuracy of glucose sensors is improving and they have been approved as replacements for finger prick glucose measurements, there are situations when a cross-check with a finger prick BG is required:

- When starting a new sensor to check accuracy
- Whenever symptoms do not match the glucose sensor reading
- During recovery from hypoglycaemia as the sensor readings lag behind your true glucose readings

WHAT IS CALIBRATION?

During calibration, the system is matching your sensor glucose level to your BGL provided. If done correctly, this improves the accuracy of the sensor glucose readings. However, if done incorrectly, this worsens the accuracy of your glucose sensor.

HOW DO I DO A PROPER CALIBRATION?

The aim of calibration is to provide the system with an accurate capillary BGL.

Follow the tips below to do a good calibration

Obtain an accurate capillary BG reading

- Clean and dry your finger to avoid any sugar contamination from food

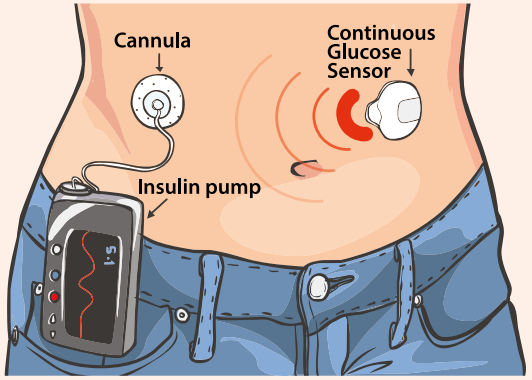
Enter the capillary BG reading for calibration immediately

- Use only fingertips to obtain blood samples for calibration
- Check that your BG strips are not expired
- If your BG readings are significantly different from the sensor readings, wash your hands and calibrate again

Artificial Pancreas Systems

WHAT IS AN ARTIFICIAL PANCREAS SYSTEM?

Artificial pancreas systems (APS) or hybrid closed-loop (HCL) systems combine an insulin pump with an implantable glucose sensor. Such systems can automatically make adjustments to the insulin delivered based on changes in the sensor glucose.



This figure shows an APS comprising an insulin pump and a continuous glucose monitoring (CGM) device.

The CGM device and insulin pump communicate and the insulin pump is able to make adjustments to insulin dosing based on real-time changes to sensor glucose.

Diabetes technology is evolving at a rapid pace. The information provided in this booklet is accurate at the time of publication. You should discuss with your healthcare provider about your region-specific availability, regulatory approvals and indications of use for diabetes technology which may change from time to time.

HOW IS AN APS DIFFERENT FROM OTHER INSULIN PUMPS?

Basic insulin pumps

Basic insulin pumps deliver basal insulin at **fixed preset rates**. The pump does not change the preset rates, although the user can manually change the basal rate and set temporary basal rates as percentages of the preset rates.

Sensor-augmented insulin pumps

Sensor-augmented insulin pumps (insulin pumps that communicate with an implantable glucose sensor) with predictive low glucose suspend can **automatically (without any user interaction) suspend the basal insulin delivery when hypoglycaemia is predicted.**

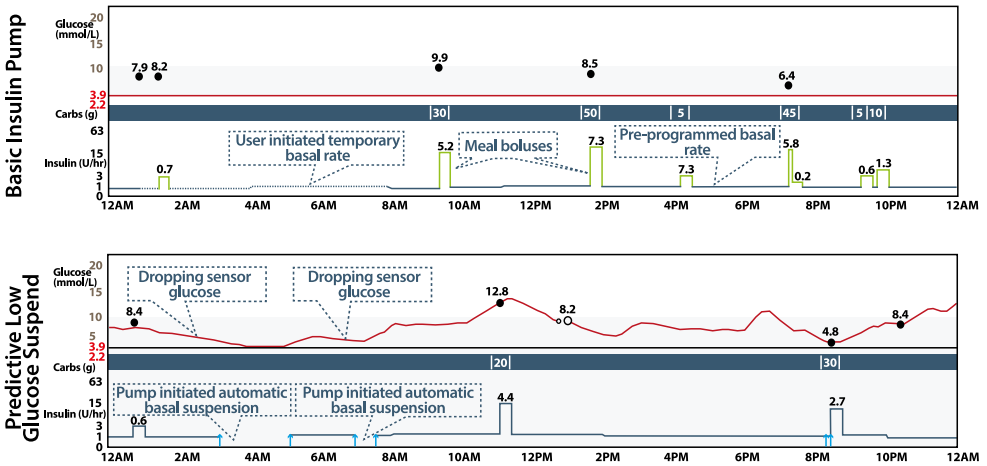
These pumps can also automatically resume the basal insulin delivery once the glucose levels rise.

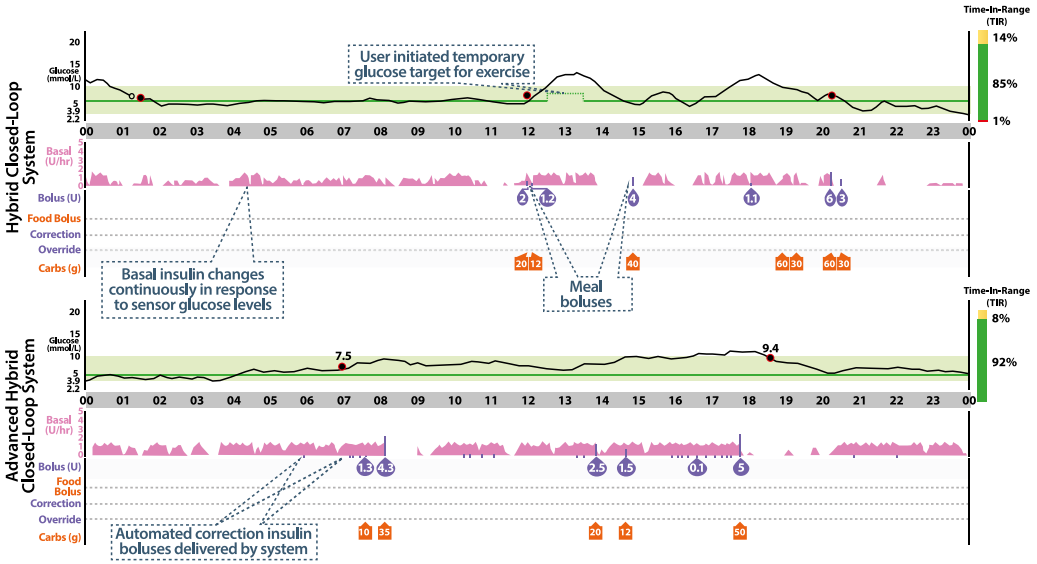
APS or HCL systems

APS or HCL systems **continuously adjust the basal rates** in response to the changes in sensor glucose. These systems do not have any fixed basal rates, and the basal insulin delivery continuously changes in response to the sensor glucose.

Advanced HCL systems are also able to automatically give correction insulin boluses when the sensor glucose is high. However, these systems cannot handle large fluctuations in glucose.

For safety in such situations, the system will revert to an open loop and use the pre-programmed basal rates. It will alert the user to deal with the high blood glucose (BG) and will automatically resume the closed loop once the BG has improved.





CAN I STOP MEASURING BG WHEN USING AN APS?

NO. Some glucose sensors still require finger prick BG measurements for calibration and safety (see page 62). In the future, newer sensors may not require calibrations. Check with your healthcare team for more information. Importantly, do check your BG level with a finger prick test if you feel your sensor is not giving you an accurate reading.

In addition, the APS will occasionally ask for a confirmatory BG reading as the system adapts to your insulin requirements. These requests may be more frequent in the beginning.

IS CARBOHYDRATE COUNTING NECESSARY WHEN USING AN APS?

The currently available APS cannot deal with large fluctuations in BG which may occur with large errors in carbohydrate counting, missing a meal bolus or delayed mealtime boluses.

If there are large fluctuations in BG that the system cannot handle, it exits to an open loop and prompts the user to take bolus insulin to correct the high glucose level.

When using an APS, it is ideal to maximise the time spent in closed loop since this will lead to higher time-in-range.

Accordingly, accurate carbohydrate counting and bolusing before consuming meals (meal announcements) remain essential to keep the system in a closed loop and help achieve optimal glucose outcomes.

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