Insulin onset, peak and duration of action

Insulin was first discovered in the early 1920's. Before then, diabetes could not be treated. Insulin was then taken from cow and pig pancreases, but nearly all are now treated with specially manufactured human insulin.

From the earliest days of treatment, insulin has been changed slightly to alter when it starts working, when it reaches a peak of action, and how long its effect will then last. These changes give more flexibility to how we treat diabetes.

The different types of insulin include the following:

- Regular human insulin: Identical to that made by the human pancreas, this is also known as *soluble* or *normal* human insulin. Regular human insulin is fast-acting, but from the time of its injection it still takes at least 30 minutes to start working. It is usually given 30 minutes before eating to allow it to have its effect, and usually lasts from 4 to 6 hours. Examples include Humulin S and Actrapid.
- Isophane insulin: This is regular insulin combined with "protamine", a substance which delays absorption from the injection site. Onset, peak and duration of action are all slowed. Protamine makes isophane insulin cloudy, in contrast to more recent long-acting insulins, which are clear. Examples of isophane insulins, (also known as *NPH* or *protamine* insulins) include Insulatard and Humulin I.
- Rapid-acting insulin analogues: These clear insulins are adapted so they are very rapidly absorbed. They start working almost immediately, and are ideal just before eating. In fact, they peak so rapidly that in some situations they may be better given *after* meals. Rapid-acting analogues do not last as long as regular human insulin, so they usually given with a long-acting insulin. Examples include Humalog (insulin lispro), Novorapid (insulin aspart) and Apidra (insulin glulisine).
- Slow-acting insulin analogues: These insulins are designed to last a long time. Also called *basal* insulins, they may be given once or twice daily to keep a steady amount of insulin acting between meals and overnight. Unlike isophane insulins, these longer-acting insulins have no steep rise and fall, or "peak", in their action. Lantus (insulin glargine) and Levemir (insulin detemir) are examples.
- Mixed insulin: Also known as *biphasic* insulin, mixed insulins combine the rapid onset and peak of action of fast-acting insulin (regular or analogue) with longer-lasting isophane insulin. Often taken in the morning by school children, they continue working throughout the day. The isophane insulin effect peaks around lunch-time, and so avoids the need for an injection then. Examples include Humulin M, combining isophane and regular insulin, and Novomix and Humalog Mix, combining isophane insulin with rapid-acting analogues.

Description	Action Type	Onset	Peak	Duration
Rapid-acting analogue	Ultra-short	5 - 10 mins	30 mins - 1 h	2 - 3 h
Regular	Fast / Short	30 mins	1 - 3 h	4 - 6 h
Isophane	Intermediate	1 - 3 h	4 - 6 h	8 - 12+ h
Slow-acting analogue	Slow / Long	3 - 4 h	-	18 - 24+ h
Mixed	Mixed	Depends on insulin types/amounts in mix		

Using blood glucose results to change insulin doses

Recording blood glucose results helps in managing diabetes. Writing down results may not seem very exciting, but looking at patterns of glucose results, and seeing how they respond to diet, exercise and insulin makes caring for diabetes much easier.

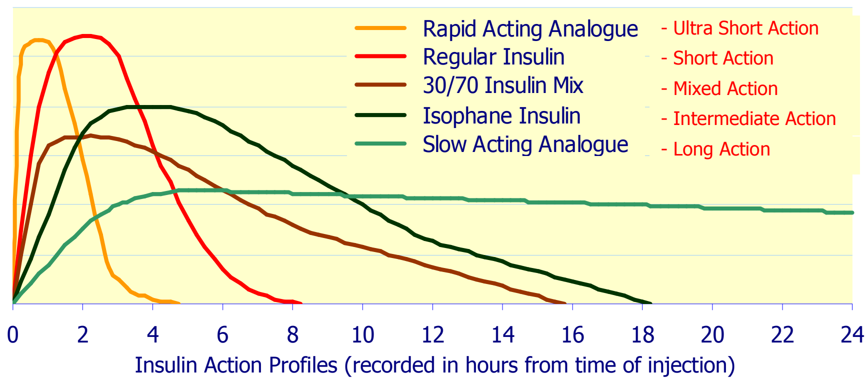
Blood glucose testing is vital because, along with knowledge of how and when injected insulin works, the doses of insulin needed to give good diabetes control may be worked out. As mentioned often in this guide, good diabetes control is needed to maintain good health, now and in the years to come.

good diabetes control is needed to maintain good health

For someone without diabetes, a "normal" blood glucose result when fasting is under 6 mmol/l. For children *with* diabetes, a target of less than 8 mmol/l (in four out of every five tests) helps maintain good diabetes control, while hopefully avoiding too many "hypos". Any results over 8 mmol/l are too high and, over a long period of time, may cause harm, particularly to small blood vessels throughout the body.

Too much insulin for the body's needs causes blood glucose concentrations to fall. Hypoglycaemia symptoms appear below 4 mmol/l (page G 08). Finding when "hypo" events occur most often allows planning of exercise, insulin timing, doses, and so on. If "low" or having symptoms of hypoglycaemia, extra carbohydrate will be necessary straight away, whatever action is taken to prevent this occurring in the future.

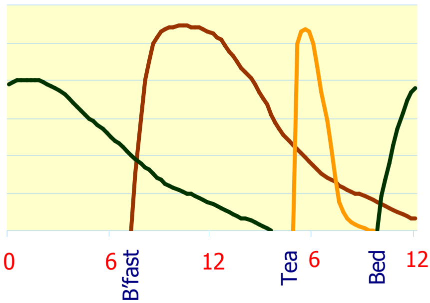
High and low blood glucose results have a significant impact on the life of someone with diabetes - both in the short-term and the long-term. Blood glucose results should be reviewed daily, and ideally should be between 4 and 8 mmol/l most of the time. If at a certain time of day, three results in a row are *not* in the 4 to 8 mmol/l range, action is needed to find out why, and then to make any necessary changes. Recording results without taking appropriate action makes future problems much more likely.



Above is a graph showing the different features of a variety of insulin types. Knowing how long a particular insulin takes to start working, when it is likely to reach its peak of action, and how long its action is likely to last, all help in planning the doses needed to keep blood glucose results in the target range. Looking after diabetes is very much easier when this information is known, understood and used every day.

! For more information on changing insulin doses, see "G 01 - 02" in the Guidelines section

Different patterns of insulin use

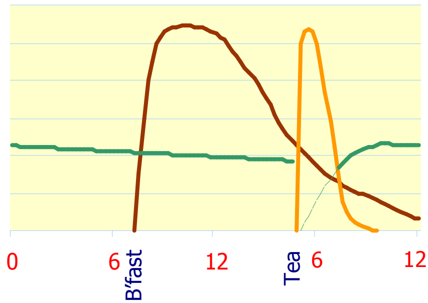


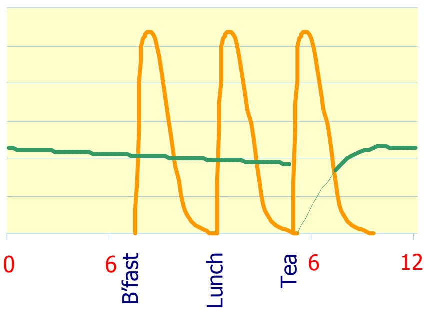
Three daily injections

- Mixed insulin before breakfast
- Rapid-acting analogue insulin before tea
- Intermediate isophane insulin before bed

Three daily injections

- Mixed insulin before breakfast
- Rapid-acting analogue insulin before tea
- Slow-acting analogue insulin before tea



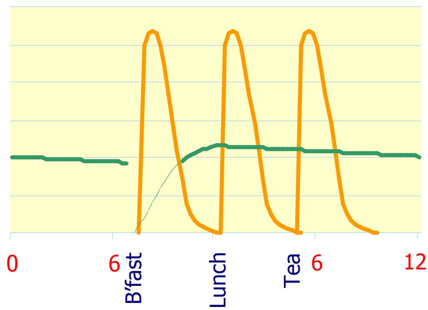


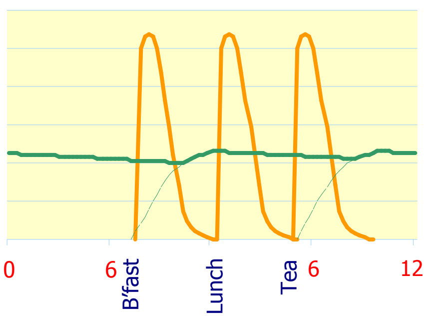
Four daily injections

- Rapid-acting analogue before breakfast
- Rapid-acting analogue insulin before lunch
- Rapid-acting analogue insulin before tea
- Slow-acting analogue insulin before tea

Four daily injections

- Slow-acting analogue before breakfast
- Rapid-acting analogue before breakfast
- Rapid-acting analogue before lunch
- Rapid-acting analogue before tea





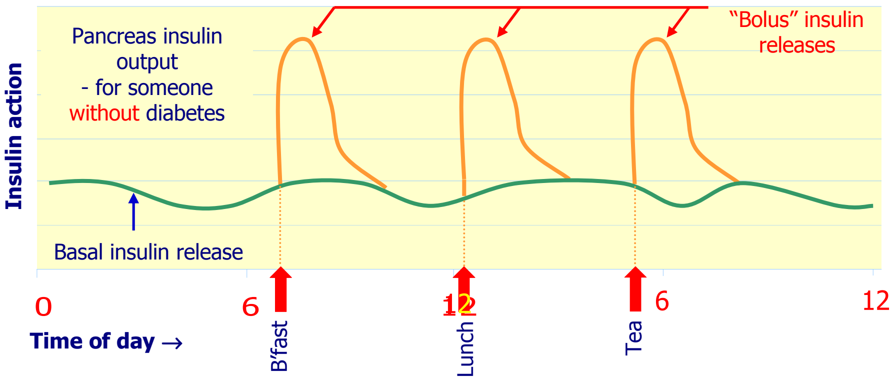
Five daily injections

- Slow-acting analogue before breakfast
- Rapid-acting analogue before breakfast
- Rapid-acting analogue before lunch
- Rapid-acting analogue before tea
- Slow-acting analogue before tea

Basal-Bolus insulin system

What is a "Basal-bolus" system?

For someone without diabetes, the pancreas releases insulin *between* meals at a steady pace. This is known as a "basal" rate. A meal of carbohydrate causes the pancreas to make a burst of insulin, called a "bolus". Diabetes treatment aims to match this "basal-bolus" release of insulin as closely as possible.



▲ Pancreas release of steady basal and mealtime bolus insulin without diabetes

Insulin may be altered so it is either absorbed slowly and steadily, or very rapidly. It then enters the blood stream and passes around the body, just as if released from the pancreas itself. More injections are usually needed in such a "basal-bolus" system, but despite this there are many advantages. Knowing how the insulins work, and how to adjust them, will give the best chance of excellent results.

Some advantages of a basal-bolus insulin system…

- More like the body's own pattern of insulin release.
- More lifestyle flexibility, with frequent change of insulin dose depending on:
  - carbohydrate eaten.
  - activity levels.
  - illness.
- More flexible timing of meals and snacks.
- Less carbohydrate needed for between-meal and before-bed snacks.
- Insulin may be given *after* meals (useful if unsure how well a child will eat).
- Reduced risk of hypoglycaemia (especially overnight).
- "Correction" doses given more easily if blood glucose results high.
- Flexible timing when travelling (very useful when crossing time zones).
- Basal insulins more consistent as more steadily absorbed than isophane insulins.

Description	Action Type	Onset	Peak	Duration
Rapid-acting analogue	Ultra-short	5 - 10 mins	30 mins - 1 h	2 - 3 h
Isophane	Intermediate	1 - 3 h	4 - 6 h	8 - 12+ h
Slow-acting analogue	Slow / Long	3 - 4 h	-	18 - 24+ h

Basal-Bolus insulin system - Basal insulins

Basal insulins in the background - Lantus and Levemir

Basal insulin analogues include "Lantus" (insulin glargine) and "Levemir" (insulin detemir). Both are clear, and last up to 24 hours after injection. Also known as slow- or long-acting analogue insulins, Lantus and Levemir allow glucose to pass into cells for use and storage in the same way as the body's own insulin. However, the structure is different to human insulin, and their affect lasts for many hours. They take several hours to begin working, and are given just once or twice daily.

Basal insulins may be given once or twice a day ... and have little or no peak of action

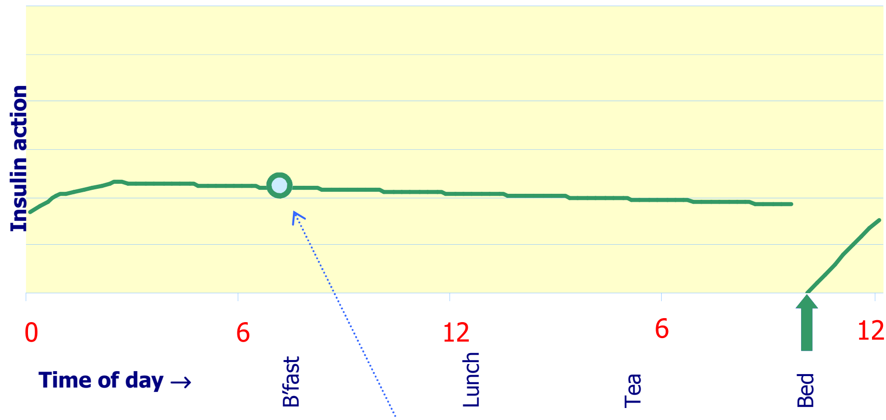
Basal analogue insulins also have little or no "peak" of action - they produce a fairly steady effect on blood glucose, right until their effect wears off. They are therefore less likely to cause overnight hypoglycaemia. Smaller bed-time snacks may be taken than when using isophane insulins, while still avoiding overnight hypoglycaemia.

Lantus and Levemir are usually given once a day to start. As their action fades 18-24 hours after injection, the actual time they are given is important - a blood glucose rise may occur as their effect wears off. This can be useful, such as in young children, who may need only small amounts of insulin. However, for others two basal insulin doses may be required each 24-hour period.

Apart from their speed of action, it is important to remember that basal insulin analogues are entirely clear. In contrast, older isophane insulins are cloudy. It is very important not to confuse rapid-acting and basal insulin analogues, as they appear identical, but have very different actions. Do not worry if you confuse them, but turn to Page G 03 for advice. Always call for advice if you are worried.

Basal insulin - once a day to start ...

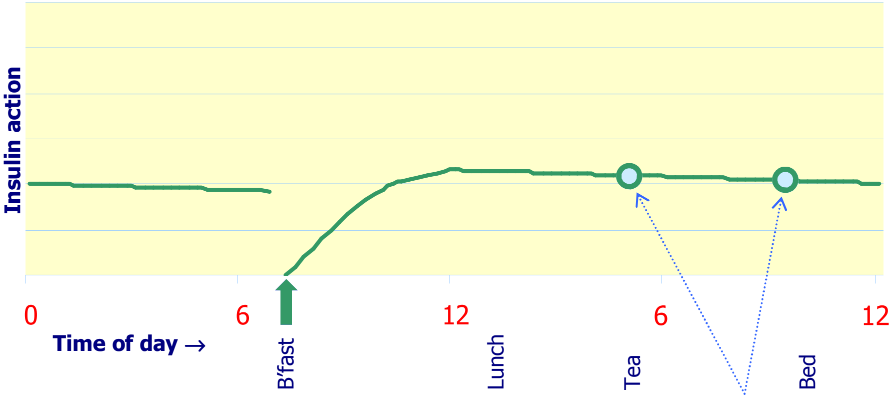
Lantus and Levemir are usually given just before bed, or perhaps before the evening meal. This steadily releases insulin overnight and into the following day until the next dose of basal insulin is given. Therefore, a before breakfast blood glucose test is a good guide to the correct dose of a bedtime basal insulin.



▲ Basal insulin once daily at bed - adjust using morning blood glucose results.

Basal-Bolus insulin system - Basal insulins (cont)

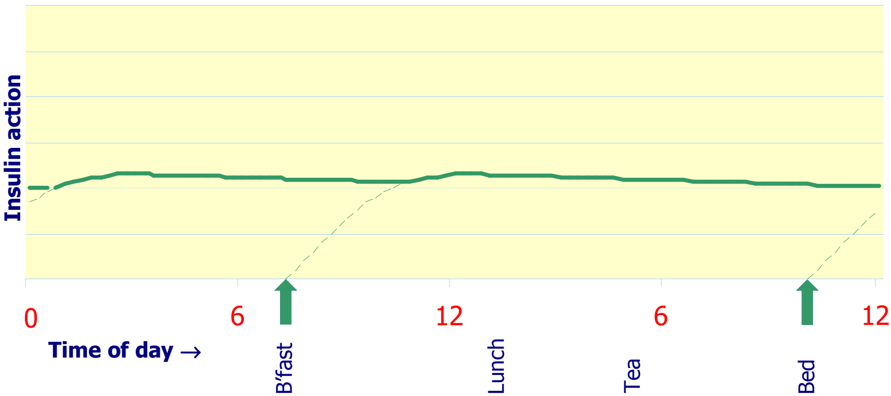
Although said to be effective for up to 24 hours, basal insulins may not actually last this long. Blood glucose will rise as their action fades, and this may be helpful in some cases. For example, young children often have lower blood glucose results on waking. By giving basal insulin at breakfast, the effect should fade overnight, and an increase in blood glucose should occur on waking. This allows more basal insulin to be given, while reducing the risk of overnight hypoglycaemia. Evening before-meal blood glucose results show the effect of a morning's basal insulin dose.



▲ **Basal insulin once daily at breakfast - adjust using evening glucose results.**

Basal insulin - twice a day might be needed ...

A single basal insulin dose may be unable to avoid *high* results in a 24 hour period. As an insulin's effect wears off, blood glucose concentration may rise. Taking a higher basal insulin dose may simply cause hypoglycaemia at other times. A second dose of basal insulin may help, allowing the effect of one injection to run into the next. The basal insulin effect is extended, rather than simply increased. Using two separate basal doses each day may have other advantages. For example, teenagers often need more insulin overnight due to hormonal activity. More basal insulin can be given at bedtime dose, making more insulin available during the night (see Page G 22).



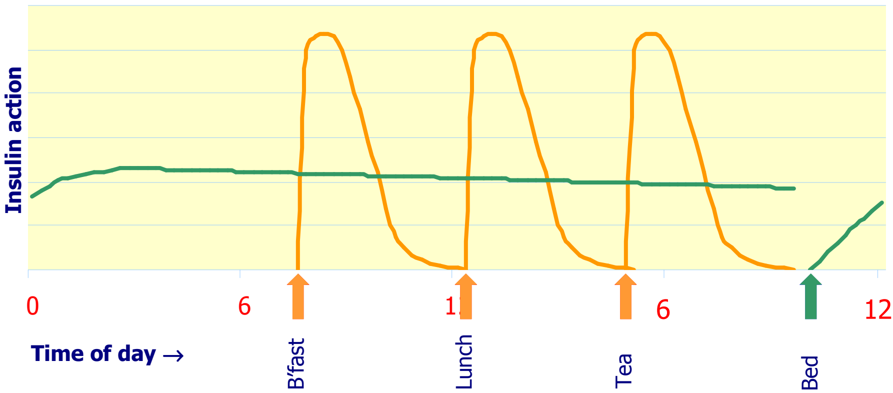
▲ **Basal insulin twice daily at breakfast and bed - extending basal insulin action.**

Information

Basal-Bolus insulin system - Bolus insulins

Bolus insulins at meal times - Humalog and Novorapid

Eating carbohydrate causes blood glucose to rise. In response, beta cells usually make insulin, returning blood glucose to the usual range. As Lantus and Levemir have no peak of action, they cannot quickly reduce blood glucose after meals. Rapid-acting "Bolus" insulin analogues (Humalog, Novorapid, and Apidra), however, act so rapidly they can closely match the glucose-lowering effect of the body's insulin.



▲ Basal insulin once daily at bedtime. Bolus insulin with meals.

Humalog (insulin lispro), Novorapid (insulin aspart), and Apidra (insulin glulisine) are examples of rapid-acting insulin analogues. Unlike injected "regular" or "soluble" human insulin (Actrapid and Humulin S), which should be given 30-40 minutes before eating, rapid-acting insulin analogues are absorbed almost immediately. Usually given directly before food, in some special situations they may be given *after* food.

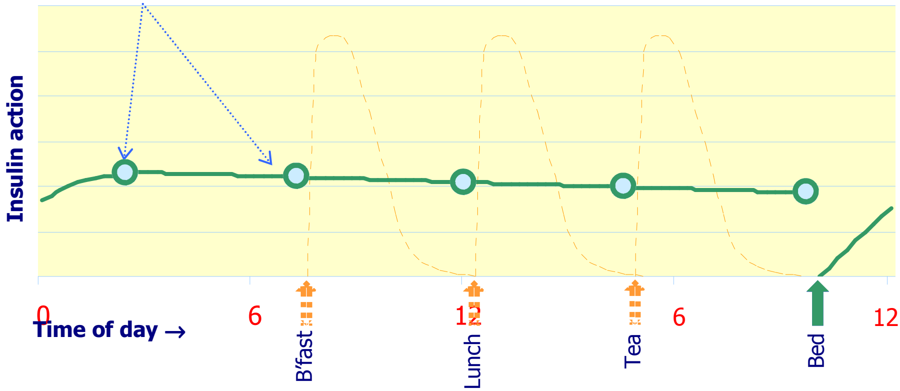
Rapid-acting insulins have an earlier peak of action (30 minutes from injection) and are shorter lasting (2 to 3 hours) than regular insulin. The blood glucose rise after a meal should therefore be lower, and the risk of becoming hypoglycaemic is also lower.

Slow-acting and rapid-acting insulin analogues cannot be mixed, and so two separate injections are needed even if taken at the same time. Each injection should probably also be given in a separate site, such as using one leg for basal insulin and the other for boluses. The table below is a summary of basal and bolus insulins.

Feature	Basal insulin	Bolus insulin
Action	• "baseline" steadily-acting insulin	• "bursts" of rapid-acting insulin
Duration	• 18-24 hours	• 2-3 hours
Frequency	• once or twice daily	• 3-4 times daily (with meals)
Glucose effect	• on Before-meal glucose results	• on After-meal glucose results
Overall impact	• "trends" over a period of time	• immediate changes or "events"
Examples	• Lantus, Levemir	• Apidra, Humalog, Novorapid

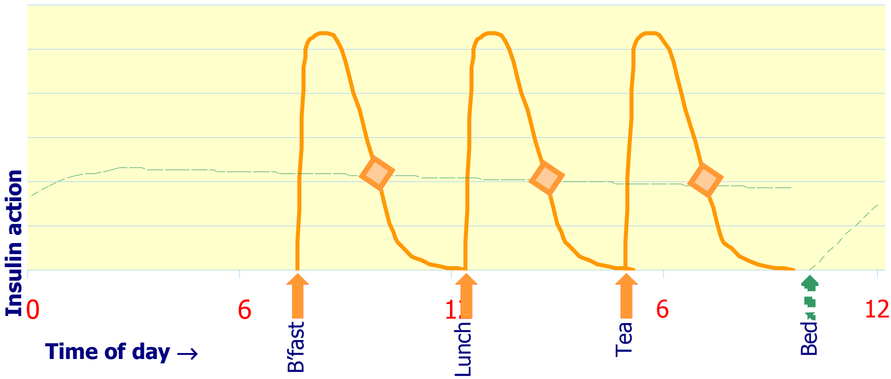
Using blood glucose results to adjust basal-bolus insulin doses

Frequent blood glucose testing allows better planning of insulin doses. Basal insulin has the greatest effect on before-meal, before-bed and overnight blood glucose results, and tests at these times guide us to the correct dose for Lantus or Levemir.



▲ Before-meal blood glucose tests guide the basal insulin dose.
Before-meal blood glucose testing mainly records the effect of basal insulin.

In contrast, rapid-acting bolus insulins (Apidra, Humalog and Novorapid) have most impact in the first couple of hours after injection. Testing the blood glucose *90 minutes after* bolus insulin injection shows whether the current dose should change. If correct, then blood glucose results should fall to within 2 mmols of the *pre-meal* amount. If the *after-meal* result is high, the dose of bolus insulin must increase, and if low, be reduced.

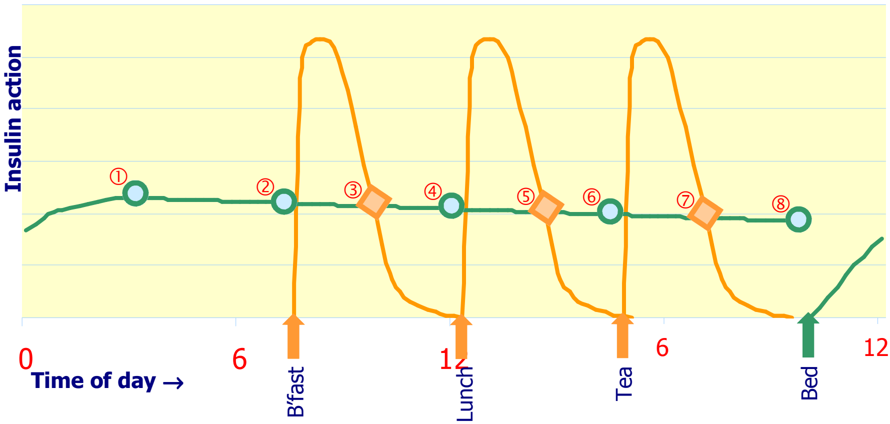


▲ After-meal blood glucose tests guide the bolus insulin dose. To check effect of meal-time bolus insulins on blood glucose, test 90 minutes *after* these injections. This shows how fast blood glucose falls to pre-meal values, allowing accurate bolus insulin adjustment.

If blood glucose tests are carried out before and after every main meal, before bed, and overnight as well, making adjustments to both basal *and* bolus insulin doses would require testing 8 or 9 times a day. When starting a basal-bolus insulin system, this so-called "8-point blood glucose profile" is useful in adjusting insulin doses.

Basal-Bolus insulin and the "8-point profile"

The graph below shows the 8 tests recommended to work out both basal and bolus insulin doses. Fortunately, these are not needed every day, and once rapid-acting bolus doses are established you should only need to check overnight and after-meal tests once or twice a month. Before-meal testing is still important, and if necessary results can be adjusted with "correction" doses of bolus insulin (see Page I 20).



▲ Before *and* after meal blood glucose tests - the "8-point profile"!
To check the effect meal-time bolus insulins have on blood glucose, test 90 minutes *after* these are injected. A blood glucose result taken then shows how quickly blood glucose falls again to pre-meal values. This is then used to adjust bolus insulin doses.

Adjusting bolus insulin depending on what is eaten

One advantage of a basal-bolus system is the ability to eat different carbohydrate amounts with each meal. Bolus insulin doses are adjusted to match the carbohydrate eaten by counting the carbohydrate eaten. Insulin boluses may be changed *each meal* depending on how much carbohydrate is taken - just as the pancreas would do.

If you can remember how and when the pancreas makes insulin, you are well on the way to understanding how to use the "basal-bolus" system. Many find it the easiest way to look after their diabetes because it simply makes good sense. It may require more injections, but for most the positives far outweigh the negatives.

Basal insulin affects blood glucose trends, while bolus insulin affects individual events

Long-acting basal insulin affects blood glucose patterns from week to week, over the long-term. In contrast, short-acting bolus insulin affects blood glucose results from meal to meal, in the short-term. Basal insulin affects blood glucose trends over time, while bolus insulin affects individual events, such as meals and exercise.

It is important to understand these differences between "basal" and "bolus" insulins. You should then be able to look after diabetes in most situations. Just three steps are needed to work out the correct doses of insulin:

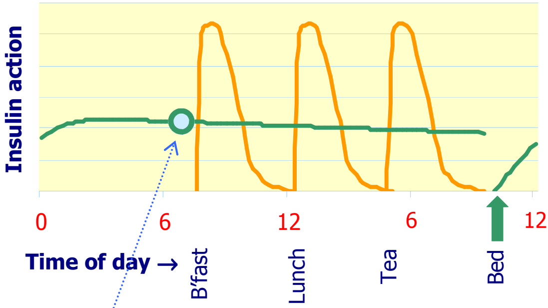
1. Adjust "trends" with basal insulin first.
2. Adjust "events" with bolus insulin next.
3. Make "corrections" with bolus insulin last.

Adjust basal insulin doses first, bolus insulin doses second, & add correction doses last.

Step 1 – work out Basal insulin dose first by looking at "trends"

Look at basal insulin doses first. Lantus and Levemir have most impact on daily blood glucose results. While Humalog and Novorapid boluses act on after-meal rises in blood glucose, basal insulins deal the rest of the day. Usually, about half of the day's insulin is given as basal insulin.

Several days of before-meal, before-bed, and overnight blood glucose results show the long-term effect of basal insulin. Trends in these results show the most suitable *basal* insulin dose - a before-meal blood glucose result about 8-12 hours after injection of basal insulin should be in the target range of 4-8 mmol/l.

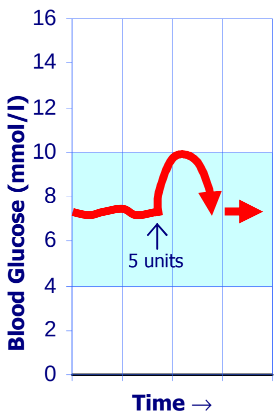


As discussed earlier, the before-breakfast blood glucose result is an excellent guide to the correct bed-time basal insulin dose. In the same way, basal insulin given at breakfast will have most impact on before-tea and before-bed results.

When blood glucose results 12 hours after basal insulin are between 4 and 8 mmol/l, it is always important to check what the blood glucose has been just before these injections. If usually high, the basal insulin may not be lasting a full 24 hours. Simply increasing the basal insulin dose will probably cause hypoglycaemia 12 hours after injection, and the only option then is to add a *second* basal insulin dose - 12 hours or so after the first basal insulin injection was given.

Step 2 – work out Bolus insulin doses by looking at "events"

When someone *without* diabetes eats carbohydrate, the pancreas releases just enough insulin to match the rise in blood glucose. When someone *has* diabetes, and the pancreas cannot make enough insulin, there are two choices:



1. Eat a fixed amount of carbohydrate, and match this with a fixed dose of insulin.
2. Eat a variable amount of carbohydrate, and match this with a variable dose of insulin.

The second option is more flexible, and using a "basal-bolus" system makes variable dosing much easier.

Bolus insulin injections mimic rapid insulin release from the pancreas. The "correct" bolus dose returns blood glucose to an acceptable range *after* eating carbohydrate. It will *also* includes any "correction" dose needed for a high before-meal blood glucose result, but this will be discussed in Step 3.

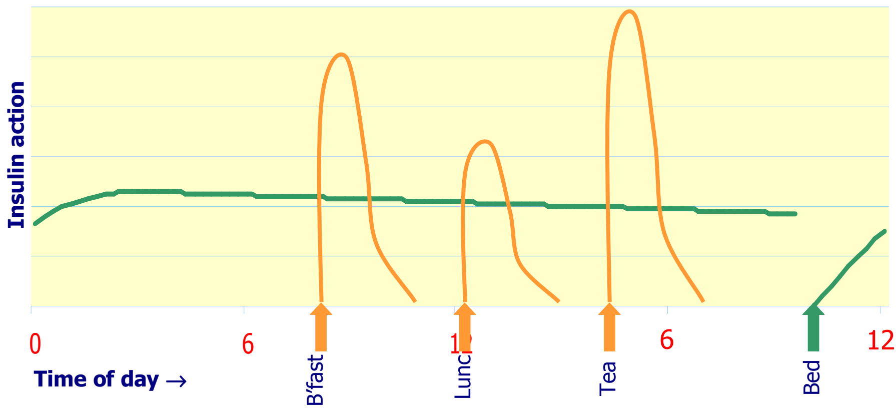
◀ **After-meal blood glucose result return to 7 mmol/l**

Step 2: Adjust Bolus insulin by observing "events"

Each carbohydrate meal can be thought of as a single "event". Exercise is another "event" to think about carefully. While basal insulin affects "trends" over days and weeks, bolus insulin acts rapidly on "events", making changes in minutes and hours.

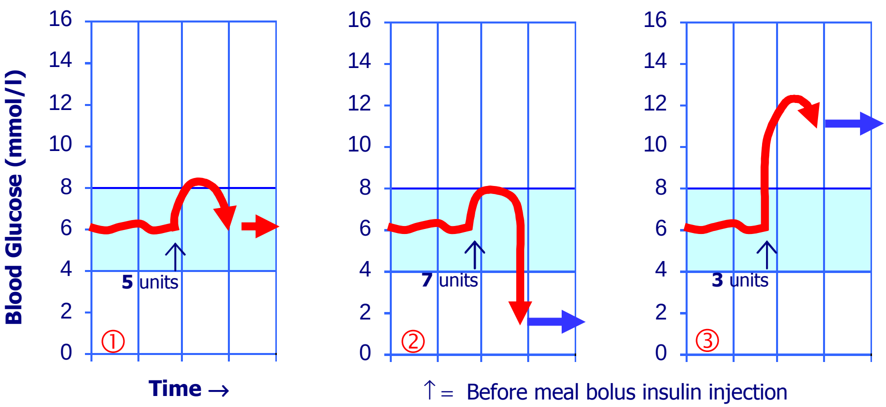
The Insulin:Carbohydrate Ratio, or "ICR"

More insulin is needed when more carbohydrate is eaten. An "insulin:carbohydrate ratio", or "ICR", can be used to work out how much insulin should be taken for each gram of carbohydrate eaten. To start with, an estimate will be made by the diabetes team, but as experience is gained, the ICR can be adjusted at home. An ICR usually varies from 0.5 units of insulin per 10 grams carbohydrate up to 2 units of insulin per 10 grams carbohydrate. It may also change for each meal.



▲ **Bolus insulin doses adjusted depending on amount of carbohydrate eaten.**

ICR adjustments are made by comparing after-"event" blood glucose results with before-"event" results. If the after-meal result is similar to the before-meal result (see ① below, and Page I 15), this suggests the ICR is correct - enough insulin has been given to allow the blood glucose to fall to the before-meal result. If too much insulin is given the after-meal blood glucose result will be lower than the before-meal result ②, but too little insulin will cause it to climb higher ③.



↑ = Before meal bolus insulin injection

Different meals may need different ICR's. While breakfast might need 1.5 units per 10 grams carbohydrate, lunch and tea may only need 1 unit per 10 grams. (See the example below). It also shows that less carbohydrate was eaten at lunch than at tea. Using the ICR, the insulin doses were changed so a smaller dose of insulin was given at lunch, and a larger dose given at tea - just as the pancreas would have done.

Insulin:Carbohydrate Ratios - an example

Meal	Carbohydrate	ICR		Insulin bolus	
• Breakfast	40 grams	1.5	unit/10g	**6** units/40 g	
• Lunch	50 grams	1	unit/10g	**5** units/50 g	of Humalog or Novorapid
• Tea	70 grams	1	unit/10g	**7** units/70 g	

If eating 20 grams or less, such as for a between-meal snack, an earlier dose of *basal* slow-acting insulin can usually deal with any blood glucose rise. However, if eating more than 20 grams, *bolus* rapid-acting insulin is needed. Main meals usually require a bolus of Humalog or Novorapid, and so will a large bed-time snack!

Rapid-acting insulin should be given when **more than 20 grams** of carbohydrate are eaten

Other factors affect how much bolus insulin is needed, and these include:

1. Fatty meals Fat slows carbohydrate absorption, so a fatty meal (such as fish and chips or pizza) will slow the rise in blood glucose following a meal. Taking a meal-time insulin bolus *after* a fatty meal might better match the delayed increase in blood glucose.
2. Larger meals ICR's may need to be reduced for particularly large amounts of carbohydrate. An ICR of 1 unit/10 grams may be needed for a 50 gram carbohydrate meal, but if 80 grams were eaten, just 0.5 units/10g might be better for the extra 30 grams. This gives a total bolus dose of 6.5 units, instead of 8 units otherwise calculated.

ICR's and bolus insulin doses for meals with large amounts of carbohydrate

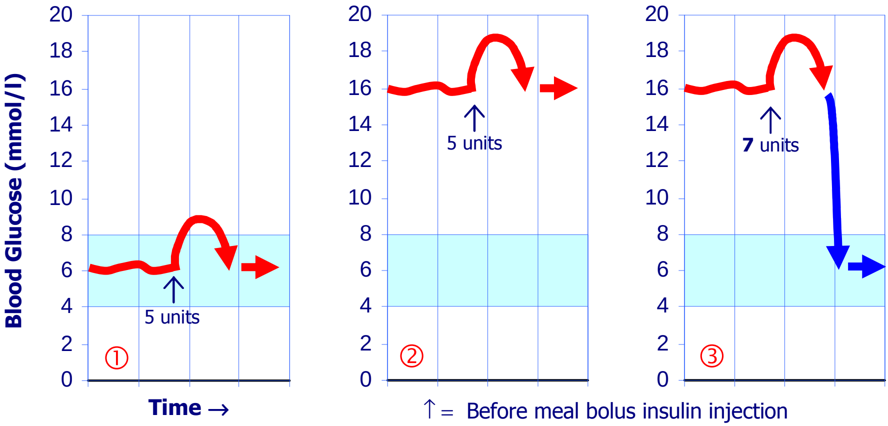
Carbohydrate	ICR			Calculation			Insulin bolus	
80 grams	1	unit/10g	for first 50 g	1	x	5	**5**	units/first 50 g
	0.5	unit/10g	for next 30 g	0.5	x	3	**1.5**	units/next 30g
				Total Bolus Dose:			**6.5**	units/80g total

3. Exercise Exercise before or after meals may affect later blood glucose results. Exercise is an "event" affecting blood glucose, and insulin dose should be altered. Remember that following sustained exercise, even if of low intensity (such as playing golf), basal insulin doses may also need to be cut, particularly any before tea or before bed doses. Contact the diabetes team for more details.
4. Illness If vomiting, basal insulin may prevent ketone production. Bolus insulin may not be needed if no meals more than 20 grams carbohydrate are eaten. Instead, spread carbohydrate content evenly through the day (eg Lucozade) and enough sugar-free fluid to stay hydrated. Refer to the sick-day guidelines on Page G07, and the "Food for Life" book.

Step 3 – making correction doses for high results: the "100 Rule"

When using an Insulin:Carbohydrate Ratio, the ideal insulin dose should return the blood glucose result *after*-a meal to the point it was just *before* the meal. If the blood glucose was 6 mmol/l before lunch, an suitable dose should return the blood glucose 90 minutes later to 6 mmol/l. If the result is 16 mmol/l, the correct dose using the ICR should reduce blood glucose to about 16 mmol/l, and so on.

A blood glucose of 16 mmol/l is clearly too high. An insulin dose based on an ICR *only* deals with a rise in blood glucose after a meal. It does *not* take into account whether the before-meal blood glucose concentration is *already* high. A "correction dose" is then needed, and understanding the difference between the two types of bolus insulin is important. Of course, if blood glucose results are *always* in the target range of 4-8 mol/l, then correction doses are not necessary. Most people, though, usually find they have to use a correction dose at some time.



Shown above are some blood glucose results for a person with diabetes. taking meal-time bolus insulin. The ICR is 1 unit per 10 grams carbohydrate, and a 50 gram meal has been eaten. This person takes 30 units of insulin every day (both bolus *and* basal insulin), and so this is the "Total Daily Dose".

In example ①, the before-meal blood glucose result of 6 mmol/l is in the "target range" of 4-8 mmol/l. The insulin dose calculated with the ICR is 5 units, and this returns the blood glucose to the before meal result of 6 mmol/l.

In example ② the same insulin dose of 5 units has been used, and again it returns the blood glucose to the before-meal result. However, this time the before-meal result is 16 mmol/l, and well above the "target range". This means the blood glucose result remains high, possibly until the next meal and beyond.

Finally, in example ③, the same 5 units of insulin for the 50 gram carbohydrate meal is taken, but a further 2 units has been added, making a total dose of 7 units. Along with the ICR-calculated dose, this "correction dose" of 2 units returns the blood glucose to the target range of 4-8 mmol/l.

[1]The "100 Rule" is based on work by Dr. Paul Davidson, Director, Diabetes Treatment Center, Atlanta, Ga, USA.

Step 3: Correction doses using "Insulin Sensitivity"

The "100 Rule"[1] helps work out a "correction dose"; the amount of insulin needed to lower a high blood glucose result towards the target range of 4-8 mmol/l. How responsive someone's blood glucose is to insulin is known as "Insulin Sensitivity".

Insulin Sensitivity suggests how well the body responds to insulin. It is found by dividing 100 by *all* the insulin taken on a typical day (the "Total Daily Dose", or "TDD"). It gives the expected fall in blood glucose for each unit of insulin taken, and can then be used to work out the dose of insulin dose needed to return a high blood glucose to the target range. The upper limit of the target range* is 8 mmol/l.

Insulin Sensitivity and Basal Bolus Correction Doses

This example shows how to calculate the Correction Dose needed by someone with diabetes who has a blood glucose of 18 mmol/l, and takes the following doses of insulin doses each day:

• Novorapid		8 units	before breakfast
• Novorapid		8 units	before lunch
• Novorapid		8 units	before tea
• Levemir		16 units	before tea
Total Daily Dose:		50 units	
Insulin Sensitivity	=	100 ÷ Total Daily Dose	
	=	100 ÷ 50	
	=	2 mmol/l of Glucose per unit of Insulin	
Blood Glucose fall required	=	18 mmol/l - 8 mmol/l (Target)	
	=	10 mmol/l fall	
Insulin Correction Dose	=	10 mmol/l ÷ 2 mmol/l per unit of insulin	
	=	5 units	

5 units is the suggested insulin dose of Humalog or Novorapid needed to lower blood glucose from 18 mmol/l to the target of 8 mmol/l.

An Insulin Sensitivity of 2, as shown here, means that 1 unit of insulin should cause blood glucose to fall 2 mmol/l. Therefore, a fall of 4 mmol/l will need 2 units, and of 8 mmol/l will need 4 units, and so on. The correction dose is calculated by dividing the desired fall in blood glucose by the Insulin Sensitivity (10 ÷ 2).

Divide required fall in blood glucose by Insulin Sensitivity to give Correction Dose

A correction dose should be given as well as any other dose of rapid-acting analogue due at the same time. For example, if the blood test above was taken before tea, then the Correction Dose should be added to the usual meal-time dose of 8 units of Novorapid. A total dose of 13 units would be needed.

If using a basal-bolus system, no extra injections are needed if correction doses are given at meal times - the correction dose is simply added to the bolus given for the carbohydrate eaten. Correction doses may be given at other times as well, but this of course requires a separate injection.

It is important to always first discuss using correction doses with your diabetes team.

If moderate or large ketones are present use Sick Day Rules (Page G 07) instead.

Step 3: Correction doses using "Insulin Sensitivity"

Correction doses can also be given when no other insulin is required, such as at lunch for someone on two or three insulin injections daily, or even overnight. Usually, though, they should never be given within 4 hours of the last dose of Humalog or Novorapid, to reduce the risk of hypoglycaemia.

Correction doses should not be given within 4 hours of the last bolus insulin dose

Insulin Sensitivity and Mixed Insulin Correction Doses

This example shows how to calculate a Correction Dose needed when using a mixed insulin before breakfast, such as Humulin M3, Humalog Mix 25, or Novomix 30, if they had a blood glucose of 18 mmol/l, and took the following doses of insulin doses each day:

• Humalog Mix 25		24 units	before breakfast
• Novorapid		8 units	before tea
• Levemir		16 units	before tea
Total Daily Dose:		50 units	
Insulin Sensitivity	=	100 ÷ Total Daily Dose	
	=	100 ÷ 50	
	=	2 mmol/l of Glucose per unit of Insulin	
Blood Glucose fall required	=	18 mmol/l - 8 mmol/l (Target)	
	=	10 mmol/l fall	
Insulin Correction Dose	=	10 mmol/l ÷ 2 mmol/l per unit of insulin	
	=	5 units	

Once again, dividing the required fall in blood glucose (10 mmol/l) by the Insulin Sensitivity (2 mmol/l per unit of insulin) gives a correction dose of 5 units. This is the suggested dose of Novorapid or Humalog (*not* Humalog Mix 25) needed to lower blood glucose from 18 mmol/l to the target of 8 mmol/l.

If the blood glucose is high at breakfast a *separate* dose of bolus insulin should be given *as well as* the usual dose of Humalog Mix 25. Simply increasing the dose of Humalog Mix 25 also increases the amount of cloudy, longer-acting isophane insulin given, and this may cause hypoglycaemia later in the day. If the high result occurs at lunch, a separate correction dose will also be needed. However, if the high blood glucose occurs at tea time, then the usual Novorapid dose may be simply increased, and no separate injection will be necessary.

Some things to remember about Correction doses:

1. Always discuss when and how to use correction doses with your diabetes team - the "100 Rule" is only a guide, and *must* be adjusted to the individual before use.
2. Care should always be used when using large correction doses, as factors other than insulin may be involved - consider trying smaller correction doses at first.
3. Do not use the "100 Rule" if you have frequent or severe hypos.
4. Exercise taken or about to take place lowers blood glucose, *without* extra insulin.
5. If correction doses are needed often, regular basal and bolus insulin doses are clearly not "correct", and must be adjusted using the guidelines (Pages G 02-04).
6. Always test for ketones if blood glucose over 14 mmol/l, and if moderate or large ketones found use Sick Day Rules (Page G 07) instead of using a correction dose.

Step 3: Correction doses using "Insulin Sensitivity"

Correction Dose Calculation Table

It is usually not too difficult to work out a correction dose - just divide the fall in blood glucose needed by the Insulin Sensitivity. However, to make it easier to find a correction dose, or simply to use as a "double check" of your own calculation, the following table gives suggested correction doses for a range of Total Daily Doses and current blood glucose results. Just use the following instructions:

1. Measure blood glucose and use Sick Day Rules (Page G 07) if over 14 mmol/l.
2. If no, trace or small ketones only present, find blood glucose result in "Current Blood Glucose" columns.
3. Work out insulin "Total Daily Dose" (TDD) by adding all insulin taken in one day (including rapid-acting, slow-acting and mixed insulins), and find TDD listed in the column on the far-left of the table.
4. The point where the "Current Blood Glucose" column meets the "Total Daily Dose" row gives the Correction Dose, usually taken as rapid-acting insulin analogue (Humalog or Novorapid).
5. Add Correction Dose to any regular dose of rapid-acting insulin analogue due to be given (such as at meal-time), or simply give as a separate dose at other times.
6. Do not use a correction dose within 4 hours of another dose of rapid-acting analogue insulin. Correction doses may be given overnight if necessary.
7. Always discuss Correction Doses with the Diabetes Team before first using them.

TDD	**IS**	**Current Blood Glucose**											
		10-11	12-13	14-15	16-17	18-19	20-21	22-23	24-25	26-27	28-29	30-31	32+
10-11	10	-	-	-	-	1	1	1	1.5	1.5	2	2	2
12-13	8	-	-	-	-	1	1	1.5	1.5	2	2	2	2.5
14-15	7	-	-	-	-	1	1	1.5	1.5	2	2	2.5	2.5
16-19	6	-	-	-	1	1.5	1.5	2	2.5	2.5	3	3.5	3.5
20-24	5	-	-	1	1.5	2	2	2.5	3	3.5	4	4	4.5
25-29	4	-	1	1.5	2	2.5	3	3.5	4	4.5	5	5	6
30-39	3	-	1	1.5	2	3	3.5	4	4.5	5	6	6	7
40-49	2.5	-	1.5	2	3	4	4	5	6	7	8	8	9
50-59	2	1	2	3	4	5	6	7	8	9	10	11	12
60-69	1.7	1	2	4	5	6	7	8	9	10	12	13	14
70-79	1.4	1	3	4	5	7	8	9	11	12	14	15	16
80-89	1.3	2	3	5	6	8	9	11	12	14	16	17	19
90-99	1.1	2	4	5	7	9	10	12	14	16	18	19	21
100+	1	2	4	6	8	10	12	14	16	18	20	22	24

e.g. If blood glucose currently 18 mmol/l and Total Daily Dose 50 units, the Correction Dose would be 5 units of insulin. This dose of Humalog or Novorapid would either be taken separately or added to any meal-time dose of rapid-acting insulin due to be taken.

Remember that the 100 Rule is a guide only, and caution should be used when a large correction dose is suggested. A smaller dose at first might be better. Giving three or more correction doses at the same time (such as before breakfast) in a single week suggests an increase in regular doses is needed (e.g. more evening Levemir).

If moderate or large ketones are present use Sick Day Rules (Page G 07) instead.