Insulin pumps

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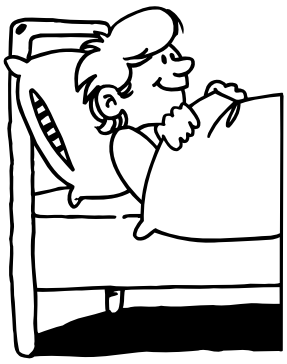
An insulin pump delivers insulin to your body in a way that much more closely mimics that of a normal pancreas. If treatment by injections does not give acceptable glucose control, many children and teenagers will feel much better after changing to pump therapy. More than 40% of those in the intensive treatment group in the DCCT study (see page 321) chose an insulin pump. In 2004 there were approximately 250,000 people with diabetes on insulin pumps in the US.

Insulin pump therapy (also called CSII, continuous subcutaneous insulin infusion) is more expensive than conventional syringe or pen therapy. In countries where insulin pumps are not subsidized, they may be difficult to afford. If this applies to you, ask your diabetes team whether you might be eligible for any grants or other financial help from local organisations or national charities.

Only rapid-acting or short-acting insulin is used in the insulin pump. Today most pumps are started using rapid-acting insulin (Novo-Rapid,[96] Humalog [899]and Apidra,[354] see page 188). A so called meta-analysis found a 0.26% lower HbA_{1c} among people using rapid-acting insulin compared to regular short-acting insulin.[161] A study comparing NovoRapid and Humalog found no difference between the two insulins in the effect on blood glucose levels and HbA_{1c} when used in pumps.[100] There was also no difference in the rate of hypoglycaemia or the number of blockages in pumps and infusion sets. Rapid-acting insulin can be diluted to U50 or U10 with sterile NPH diluent and stored for 1 month for use in pumps for infants or very young children.[456,785] In the past, short-acting insulin with a special solvent was used to prevent the catheter becoming blocked (Velosulin BR Human, Insuman Infusat). The action time and effect of this insulin is similar to ordinary short-acting insulin (Actrapid, Humulin S, Insuman Rapid).



"How do I wear the pump at night?" is usually one of the first questions asked by someone interested in trying a pump. You will be surprised by how quickly you get used to this, and find a solution that fits in with your sleeping habits.

The insulin pump will deliver a basal rate of insulin for 24 hours every day. Most modern

Disadvantages of using an insulin pump

- A small store of insulin in your body means you will be sensitive to any interruption in insulin supply, which puts you at risk of rapidly developing ketoacidosis.
- You need to do more regular monitoring tests if you are using an insulin pump.
- The pump will be attached to you 24 hours a day (except when you disconnect it). Some people feel this makes them more tied to their diabetes.
- The pump will be very obvious, for example if you go swimming in a public pool. So you will not be able to keep your diabetes secret. Other people may be curious about the pump, something people who are not yet entirely comfortable with their diabetes might find difficult to deal with.
- The pump's alarm is likely to go off every now and then, and you might need to stop your activities to change the infusion set at an inconvenient time.

Advantages of using an insulin pump

- The basal rate will give you sufficient amounts of insulin in the early morning to avoid a high blood glucose level when you wake up (dawn phenomenon).
- Some people need more insulin than others between meals. An insulin pump can provide this.
- The continuous supply of basal insulin makes it less essential to eat at regular intervals.
- You will always have your insulin with you.
- It is easier to take a bolus dose with the pump than to take an injection with a pen or syringe, especially if you don't feel like injecting when you are out.
- Your premeal doses can be adjusted in 0.1 unit increments or even 0.05 units on some pumps.
- You will be able to adjust the pump to take account of your differing needs for basal insulin during the day and night.
- The pump uses only rapid or short-acting insulin. These are likely to be more predictable in their effect than intermediate or long-acting insulins.
- The risk of severe hypoglycaemia is usually lessened by using an insulin pump.
- The fact that the body's insulin store is small will mean that additional insulin is less likely to be released in an unpredictable fashion during physical exercise.
- During and after exercise, a temporary basal rate can be used.
- Pumps are easy to adjust if you are travelling across time zones.

pumps can be adjusted for different basal insulin rates during the day and night. Extra insulin is given with meals (a "bolus dose") by pushing a button on the pump. The insulin is pumped through a thin tubing (catheter) that is connected to a metal needle or indwelling cannula placed under the skin (subcutaneously).

A common problem with pen injectors and syringes is that the insulin will not always give quite the same effect even if the dose is exactly the same. With an insulin pump, the insulin will be deposited in the same site for several days and the absorption will be more even.[518] In a research study, insulin absorption after a premeal dose was constant for four days when the cannula was inserted in an area free of lipohypertrophy (fatty lumps).[632]

The total insulin requirement per 24 hours usually decreases by around 15-20% after starting with insulin pump treatment.[95,180,781] A US study of adults found an average decrease of 26%, with greater percentage reductions for patients on Humalog, and for those with higher daily dosages.[98] In a study of children with diabetes, those who had not reached puberty showed little change in insulin requirements, while those

Reasons for starting with an insulin pump

- High HbA_{1c}.
- Complications of diabetes.
- High blood glucose levels during the night or morning (dawn phenomenon).
- Wide fluctuations in blood glucose.
- HbA_{1c} is OK with multiple injections but it takes too much work.
- Missed injections.
- Pain from insulin or injection needle.
- Recurrent severe hypoglycaemia.
- Hypoglycaemia unawareness.
- Possibility of having a lie in.
- Need for flexible meal sizes and schedules.
- Need to manage diabetes while exercising.
- Shift work / variable working patterns.
- Quality of life issues.
- Use of a pump from the time diabetes is diagnosed in pre-school children?

At one time, we would only give people insulin pumps if there were definite medical reasons, but now more attention is being paid to quality of life issues and the use of pumps is becoming more widespread. We have recently started several pre-school children on pumps from the onset of diabetes with very good results. Pre-school children often have an irregular lifestyle and the use of pumps for this age group can be very positive.[537,829]

of the adolescents decreased by an average of 18%.[164] The amount of basal insulin given by the pump was reduced by around 40% compared to the basal dose (intermediate or long-acting insulin) needed by young people on multiple injections. One study showed that the dose of basal insulin decreased by an average of 20% in children and adolescents after they started using an insulin pump.[365] The bolus doses decreased by approximately 25% in those who had a high HbA_{1c} before starting with the pump and by approximately 15% in those that had other reasons for using a pump.

The glucose control often improves, resulting in a lower HbA_{1c},[95,180,367] also in young children.[537,873] Some patients (especially teenage girls) will gain weight when they start using an insulin pump if they don't decrease their food intake as their glucose control improves. The extra glucose that, beforehand, was lost in the urine now remains in the body and is transformed into fat instead.

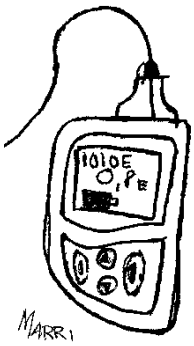
The risk of severe hypoglycaemia usually decreases with pump treatment,[95,180] even when used in children under the age of 6-7 years.[537,829,873] The risk of ketoacidosis may increase according to some studies [180] but appears to decrease in others.[95,829] The risk of ketoacidosis for young people using an insulin pump is approximately double that for people taking multiple daily injections.[366] Ketoacidotic episodes may occur soon after starting with a pump, before the person has got used to the new form of treatment.[367,585] Those teenagers who are prone to frequent episodes of ketoacidosis caused by interrupted insulin supply, may find the frequency and severity of these to be drastically reduced by using an insulin pump that makes a continuous insulin supply possible.[85,781]

Starting the pump

We start new pumps on an outpatient basis, except for the very youngest children (under 3 or 4 years old) who are admitted to hospital for a night or two. Patients attend a three-day pump school at the day care ward together with their parents (even older teenagers need to bring their parents to the sessions). No intermediate-acting insulin (Insulatard, Humulin I, Insuman Basal) is taken in the morning they start using the pump, and only half the dose the evening before for those using long-acting insulin (Lantus, Ultratard, Humulin Zn). Only the premeal

Insulin pump treatment will be easier if you: (adapted from [806])

- Are comfortable with the pump cannula being constantly attached to your body and understand how it works.
- Check your blood glucose regularly, at least 4 times a day (including morning and evening) and preferably before each meal.
- Regularly monitor ketones when you are ill or feeling sick, or when your blood glucose is repeatedly above 14 mmol/l (250 mg/dl) (preferably blood ketones).
- Recognize symptoms of low blood glucose. Always carry glucose tablets.
- Recognize early symptoms of ketoacidosis. Always carry extra insulin and a pen or syringe to be able to treat this condition.
- Make sure you keep in regular contact with your diabetes clinic.
- If you live alone, you should make sure you can always contact a close friend or relative.



Daytime basal rate

These guidelines apply to pumps with programmable basal rates. When new to the pump, it is advisable to make changes in basal rates in collaboration with your doctor and diabetes nurse.

A good idea is to divide the hours of the day into different basal rate profiles where each contains a main meal. Measure the blood glucose level before the meal a couple of days in a row to evaluate the basal rate.[473] Change the basal rate profile *before* the meal:

Blood test before meal	Measure
< 5 mmol/l < 90 mg/dl	Decrease the basal rate by 0.05U/h if the rate is <0.3U/h, 0.1 U/h if the rate is < 1U/h, 0.2 U/h if the rate is >1U/h.
>8-10 mmol/l >145-180 mg/dl	Increase the basal rate by 0.05U/h if the rate is <0.3U/h, 0.1 U/h if the rate is < 1U/h, 0.2 U/h if the rate is >1U/h.

Another way of adjusting your daytime basal rate is to skip breakfast (and the pre-breakfast bolus) and adjust the basal rate to keep the blood glucose level constant until lunchtime.[94] Repeat the procedure with the other meals during the day. In children, this may be difficult to accomplish but parents can try serving food that contains only protein and fat (i.e. no carbohydrates).

One good opportunity for finding out the basal rate can be when you are having a lie in. If your parent or friend takes an early blood glucose followed by a few more tests until you wake up, you will get a good understanding of your basal rate. Many pumps have the ability to use different basal rate profiles, for example during weekdays and weekends, or during periods of intense physical activity.

bolus of short-acting or rapid-acting insulin is taken in the morning. The pump cannula is inserted after anaesthetizing the skin (with EMLA®, Ametop® or similar) and using a skin disinfectant. The first pump bolus is given at lunchtime. Today, we start almost all new pumps on rapid-acting insulin. For a few patients, the slightly larger insulin depot when using short-acting insulin (Velosulin BR Human, Insuman Infusat) can help to avoid recurrent episodes of ketones/ketoacidosis.

Even though the amount of insulin you are receiving goes down when you start using a pump, you will probably find your blood glu-

cose levels will be in the lower range at first. If so, it is very important to lower your pump doses even further to avoid problems with hypoglycaemia. The reason you will need even lower doses is that when your blood glucose readings decrease, your insulin resistance will decrease as well (increased insulin sensitivity, see page 198). This implies that a certain insulin dose will be more effective at lowering your blood glucose level than the same dose was just a few days before.

The basal rate

The small amounts of insulin that the pump automatically delivers every hour is called the basal rate. An appropriate basal rate lets you keep your blood glucose levels stable when you are not eating, for example during the night or between meals. When starting a pump we usually set five basal rates: after midnight (12-3AM), early morning (3-7AM), morning (7AM-12noon), afternoon (12-6PM) and evening (6-12PM). The charts on page 169 give more details. It is important to emphasize that starting doses are only estimates, also that it is essential to monitor your blood glucose very frequently (including at night) during the first few weeks in order to establish correct basal rates and bolus doses. If the basal rates are set correctly, the pump user will usually be able to delay or skip meals, and sleep longer in the morning when they want to.

Approximately 40-50% of the daily insulin requirement is given as the basal rate (often close to 1 U/hour for an adult person).[402] The remainder is given as premeal bolus injections. For older children and teenagers, a starting dose of up to 60% as basal rate has been recommended with rapid-acting insulin (50% if using short-acting insulin in the pump).[473] Younger children often need a lower percentage of their daily dose as basal insulin. In a US study, children before puberty had 41% of their daily dose as basal insulin and the pubertal group had 46%.[164]

Night time basal rate

Check your blood glucose levels during a night after an ordinary day when you have been feeling well and have not had extra exercise. Adjust the premeal bolus dose before the evening snack to reach a blood glucose level of about 7-8 mmol/l (125-145 mg/dl) at 10-11 PM.[113]

Blood test at 3 AM and in the morning	Measure
< 6 mmol/l < 110 mg/dl	Decrease the basal rate after midnight and/or early in the morning by 0.05U/h if the rate is <0.3U/h, 0.1 U/h if the rate is < 1U/h, 0.2 U/h if the rate is >1U/h.
>9-10 mmol/l >160-180 mg/dl	Increase the basal rate after midnight and/or early in the morning by 0.05U/h if the rate is <0.3U/h, 0.1 U/h if the rate is < 1U/h, 0.2 U/h if the rate is >1U/h.

If your pump cannot be adjusted for different basal rate profiles, you should adjust it to fit the night time need of basal insulin to reach a blood glucose level of 6-7 mmol/l (110-125 mg/dl) at 3 AM.[113]

Make the changes in basal rates in collaboration with your doctor and diabetes nurse.

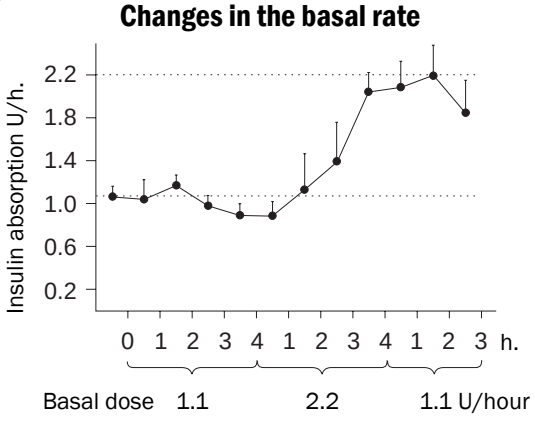
After a change in the basal rate, it will take 2-3 hours before the blood glucose level is affected when using short-acting insulin,[395] and approximately 1-2 hours with rapid-acting insulin. The basal insulin may be absorbed twice as rapidly if the person has a thin layer of subcutaneous fat (less than 10 mm in a lifted skin fold) compared to a thicker subcutaneous fat layer (more than 20 mm).[397]

The body's insulin requirement in adults is often about 20% lower between 1-3 AM compared

to 5-7 AM.[113] If you are using a pump with the possibility of different basal rates, you can administer a lower basal rate from 11-12 PM to 3 AM to avoid night time hypoglycaemia.[113] If you have problems with high glucose readings in the morning, you can try a slight increase in the basal rate (0.1-0.2 U/hour) between 3 and 7 AM. Many children below the age of puberty need a higher basal rate late in the evening (9 PM to 12 AM) [109,164] and it is not uncommon for the basal rate to need to be higher in the middle of the night (midnight-3 AM) than later in the morning (3-7AM).[831] This may be caused by an early rise in the level of growth hormone shortly after the child falls asleep.[164]

Do not make too great a change in the basal rate at any one time. It is usually sufficient to change by 0.1 U/hour if the basal rate is < 1 U/hour and by 0.2 U/hour if the basal rate is > 1 U/hour. You should not change the basal rate more than twice in any week as, otherwise, it may be difficult to see which change leads to what. To avoid hypoglycaemia you should be prepared to decrease the basal rate (especially at night) when blood tests start to show lower readings.

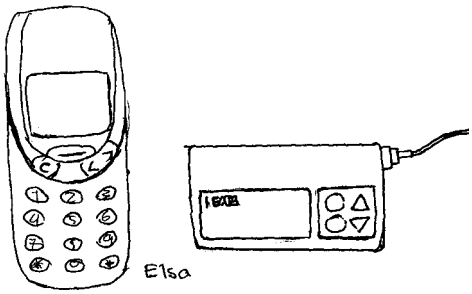
The advice on basal rates in this chapter are written for a pump that can be adjusted for different basal rate levels throughout the day and night. Some pumps can be adjusted for different basal rates every hour, and others can be set for different profiles for a longer or shorter period of time. However, if you have a pump that can be programmed for only one basal rate, you should adjust it according to your night time blood glucose values. You will then have to adjust the premeal bolus doses to fit the fixed basal rate.



When you change the basal rate using rapid-acting insulin analogues, it will take approximately 1-2 hours before the uptake of insulin into the bloodstream is increased. The reason for this is that when you increase the basal rate, part of the insulin will stay in the subcutaneous tissue as an insulin depot. When you decrease the basal rate, the insulin from the depot will continue to be released and absorbed into the bloodstream for another 1-2 hours until the depot has decreased in size. The graph is from a study where regular short-acting insulin was used, showing that the time before a change occurs is 2-3 hours with this type of insulin.[395]

Temporary change of the basal rate

Most pumps allow you to make temporary changes of the basal rate for one or several hours. This is practical if, for example, you have problems with low blood glucose and repeated hypoglycaemia for sustained periods despite extra food intake. It will usually help to decrease the basal rate or stop the pump com-



A modern insulin pump is small and easy to manage. You will soon master the different controls. Many teenagers with labile diabetes find life easier with an insulin pump. Even small children can benefit from using a pump. For example, one of our patients, a 3-year old boy, had better morning blood glucose levels in addition to less night time hypoglycaemia after starting with an insulin pump.

When should basal rates be changed?

(adapted from [94])

You should not change the profiles of the basal rate too often. When you are used to the pump it may be practical to change the basal rates once or twice in a month according to what your 24 hour blood glucose profiles show. Change the premeal bolus doses to adjust for temporary changes in diet or blood glucose readings or use the temporary basal rate. In the following situations it may be necessary to make changes to the basal rates:

- Illness with fever and increased need of insulin.
- Change in school or work activities with a new timetable or different physical activity.
- Change in body weight of 5-10% or more.
- Pregnancy.
- Women may have different insulin needs during different phases of the menstrual cycle (see page 284).
- Initiation of treatment with drugs that increase the need of insulin (such as cortisol or prednisolone).
- Prolonged physical exercise (such as a hiking or cycling trip lasting 12-24 hours or more).

Changing the basal rate

Since it takes 2-3 hours with regular insulin and 1-2 hours with NovoRapid or Humalog before a change in the basal rate will take effect (see chart on page 167), you must plan ahead.

① Change the dose 2 hours before you want it to take effect, e.g. increase from 3 AM if you want an increased insulin effect from 5 AM on.

② If you want a rapid increase in the effect of the basal rate (e.g. if you are ill with fever) you should administer an extra dose of insulin (corresponding to 2 hours of the basal rate) before increasing the basal rate. This will result in a rapid increase of the insulin depot resulting in a quicker absorption of insulin into the blood.

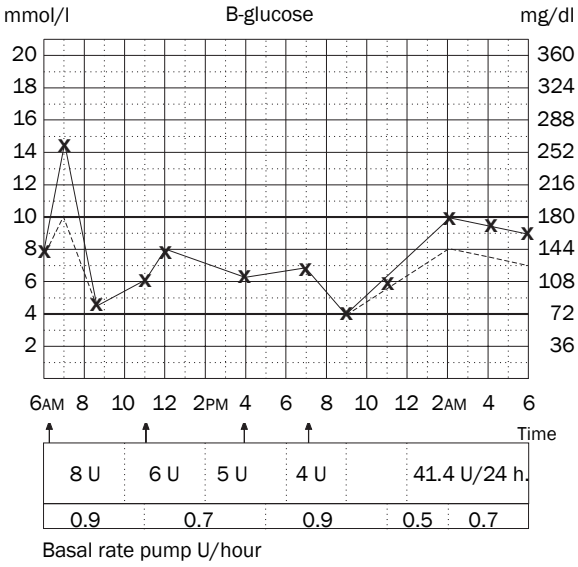
③ If you want to decrease the effect of the basal rate fast (e.g. if you are going to exercise) you should stop the basal rate for 2 hours and then start it again at a lower level. The insulin depot will then rapidly decrease in size and the change in basal rate will take effect sooner.

pletely for an hour or two. If your blood glucose is high at bedtime you can temporarily increase the basal rate by 10-20% (around 0.1-0.2 U/hour) for a couple of hours. If your blood glucose is low during the early part of the night, you can temporarily decrease the basal rate for a few hours by 10-20% (around 0.1-0.2 U/hour). The temporary basal rate is very useful for prolonged exercise. For example, during a 5 hour bike ride, try decreasing the basal rate by 50%. If you have exercised in the afternoon or evening, you should decrease the basal rate by 10-20% (around 0.1-0.2 U/hour) for the whole night.

If you work shifts, it may be a good idea to use the temporary basal rate during the nights you are working or use a separate profile programme if your pump has this feature. It is common to find you need to increase the basal dose during the latter part of the night to compensate for the stress effect of staying awake.

Premeal bolus doses

Take a bolus dose just before the meal if you are using rapid-acting insulin (NovoRapid, Humalog, Apidra), and 30 minutes before the meal when you are using regular insulin. However, the timing will also depend on what your actual blood glucose level is (see page 136 and 140). Adjust the bolus doses up or down in the same way as you would if you were on multiple injec-



Basal rate pump U/hour

Interpreting the 24 hour profile

(boy 40 kg, 88 lb)

It is best to take tests for a couple of days in a row to be sure that the results of any one day were not unusual. Start by looking at the evening snack since that affects the level your blood glucose will be on going to bed. The dotted line shows what the blood glucose values might have been with the suggested changes.

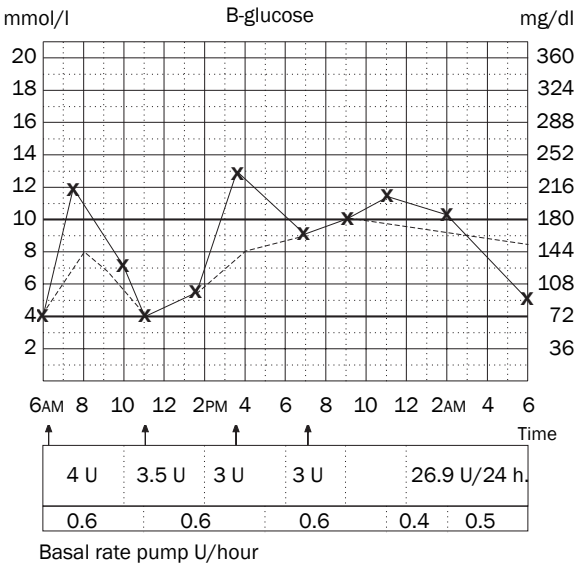
Evening snack: The blood glucose after the meal is a bit low. Decrease the dose by 1 unit. Adjust the dose so that you will have a blood glucose of about 6-8 mmol/l (110-145 mg/dl) when you go to bed.

Night: The basal rate needs to be increased slightly in the middle of the night to 0.6 U/hour as the blood glucose is rising until 3 AM. The blood glucose level from 3 AM to 7 AM is stable so this rate does not need to be changed.

Breakfast: The blood glucose rises very quickly after breakfast. If you use NovoRapid or Humalog you can try increasing the pre-breakfast dose to 9 U and lowering the basal rate to 0.8 U/hour. With short-acting insulin, the breakfast dose could have been given even earlier before breakfast to prevent the peak at 8 AM.

Lunch and dinner/tea: No changes.

Sit down when you have some time for yourself and consider all the doses for the next day. Don't change all doses at the same time as it can be difficult to see which change resulted in what. Let a few days go by between changes to make sure that the profiles look similar from day to day. Read the pump memory and write down in your logbook the total number of units your pump has delivered each day.



Basal rate pump U/hour

Interpreting the 24 hour profile

(girl 30 kg, 66 lb)

See the previous profile for general interpretation.

Evening snack: No changes in premeal bolus. Young children often need to have their highest basal rates before midnight. The rise in blood glucose before midnight indicates that an increase in basal rate of 0.1 U/hour from 9PM to midnight may be appropriate.

Night: The blood glucose does not change much between midnight and 3 AM. However, late at night it drops significantly, so reducing the basal rate from 3 AM to 0.4 U/hour is recommended. Young children often need less insulin during these hours and a further decrease to 0.3 U/hour may be appropriate.

Breakfast: The blood glucose rises quickly after breakfast and the dose should preferably be increased to 5 units. The basal rate is probably sufficient as the blood glucose is lowered at lunch again. However, when the breakfast bolus dose is increased to 5 units the basal rate might need to be decreased.

Lunch: The blood glucose two hours after the meal is only slightly increased indicating that the pre-meal bolus dose is correct. However, as the blood glucose rises prior to dinner/tea, the basal rate could be increased to 0.7 U/hour.

Dinner/tea: No changes.

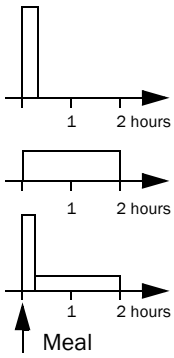
tions. See graph on page 144 for adjusting rapid-acting insulin. The breakfast dose is usually slightly larger than the other premeal bolus doses. Since the basal need of insulin between meals is now supplied via the pump, your premeal bolus doses will be lower than when on multiple injections. You will probably need to decrease the size of extra insulin doses as well if you eat something extra. On many pumps the type of bolus dose can be varied from rapid delivery (standard bolus), administered over a period of time (square or extended bolus), or a combination of both (dual or combination bolus). See the figure on page 170.

You can calculate the amount of insulin needed for a given amount of carbohydrates by dividing the total amount of carbohydrates eaten during the day by the amount of insulin taken as premeal bolus doses.[204] One unit will usually cover 10-15 grams of extra carbohydrate. If, for example, you eat ice cream containing 26 g of carbohydrate, 2 units of extra insulin will probably be enough. Modern "smart" pumps can calculate your bolus dose if you enter the amount of carbohydrate in a meal. See page 220 for advice on carbohydrate counting and insulin:carb ratio. They can also correct for high or low blood glucose levels with the help of your correction factor (see page 132).

With a pump you can adjust the premeal bolus to match the carbohydrate content of your meal. Breakfast usually contains a high proportion of carbohydrates.You may find that 1 unit of insulin can take care of a slightly lower amount of carbohydrates for breakfast compared to other meals. See page 220 for further advice on counting carbohydrates.

Square or dual bolus doses: when can they be useful?

- When you are eating pasta, as this gives a slower blood glucose rise;
- When you eat a meal rich in fat or protein that is digested more slowly, for example a pizza;
- When your meal is larger than usual;
- When you eat a meal that takes a longer time than usual, for example a three course dinner;
- When several small meals are eaten within a short period of time, for example at a birthday party;
- When you eat slowly, for example popcorn or crisps while watching a movie;
- If you have problems with delayed stomach emptying (see page 320).



Rapidly delivered bolus

Square or extended bolus = bolus over period of time

Dual or combination bolus = Initial bolus followed by bolus over longer period of time

The type of bolus dose can be varied on most pumps. A square or dual bolus may be preferred for a large meal that is rich in fat or proteins, a meal with low glycaemic index (see page 212), or when you will be eating over a longer period, at a party for example. These bolus doses may also work well if you have problems with delayed emptying of the stomach (gastroparesis, see page 320). In a study of a meal high in carbohydrates, calories and fat, the square (whole dose over 2 hours) and dual (70% as an immediate bolus and 30% over 2 hours) bolus provided the lowest glucose levels over a 4-hour period.[151]

With an insulin pump, you will not be bound to maintain a regular interval between meals (and insulin doses) as when you were on multiple injection treatment with short-acting insulin. The basal rate will probably make it possible to increase the time period between meals to 6-7 hours, which might be an advantage if you keep irregular hours.

You should, however, be aware of eating and taking premeal bolus doses with intervals of less than 2-3 hours as there will be a risk of overlapping insulin doses when using rapid-acting insulin in the pump. Try reducing the second premeal bolus by 1 or 2 units if the previous meal was only 2 hours earlier. Many modern pumps can subtract insulin "on board" before giving the second bolus dose to compensate for this effect.

When should you replace the accessories?

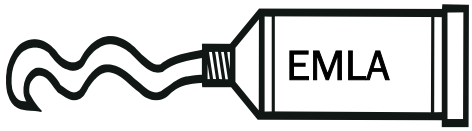
Teflon cannula	Start by replacing it 2-3 times a week. If there are no problems try using it 4-5 days before replacement. Some people, especially small children, may need to replace every second day.
Metal needle	Replace every second day, more often if signs of irritation are noted.
Tubing	Replace the tubing at least every other time you replace the cannula/needle and when you replace the reservoir.
Insulin reservoir	Some pumps have prefilled reservoirs, others need to be filled. Do not reuse them as the silicon on the plunger wears off, resulting in an occlusion or blockage alarm.

Change of insertion site

The most common insertion site is the abdomen. Avoid your waistline, belt line and underwear line and a 2 inch (5 cm) circle around your belly button (see illustration on page 124). With small children, it is preferable to use the buttocks as well to be able to spread the infusion sites, thereby decreasing the risk of fatty lumps (lipohypertrophies, see page 192). You can also use the thigh or the upper arm but both sites can result in an increased absorption of insulin when exercising. There is also a greater risk of the cannula catching on the clothing and being pulled out.

Individual advice is needed on how often the cannula should be replaced. We usually start by recommending the use of a soft teflon catheter, but some people prefer a short steel needle. Start by replacing the catheter twice a week and then try to increase the number of days between replacements. You can usually let the catheter remain in place for 3-4 days if your blood glucose readings do not become raised. Some people, especially young children, will need to replace it every 2 days. The longer the catheter remains in one site, the greater the risk of developing fatty lumps (lipohypertrophies) and infections. A steel needle usually needs to be replaced every second day.

Disinfect the insertion site with Hibiclens™, IV Prep™ or similar product. Skin-Prep™, Mastisol™ and Tincture of Benzoin™ leave a sticky film after drying to help the adhesive get a firm grip. Don't use products containing skin moisturizers, as these may cause the adhesive to loosen more easily. If you are allergic to the adhesive, it can cause redness or itching. Try



Always use a topical anaesthetic cream such as (EMLA®, Ametop®) before replacing the infusion set when beginning with pump treatment in children. Apply the cream 1½-2 hours ahead of time to get full effect. An alternative way of lessening the pain is to use an automatic inserter. Applying an ice cube is a quick way of decreasing the pain of insertion in less difficult cases.

Replacement of infusion set

- If you replace the infusion set before taking a premeal bolus it will be flushed by the larger volume of fluid.
- Avoid replacing your infusion set before bedtime as you will need to be awake for a couple of hours to see that it functions properly.
- Start by washing your hands with soap and water.
- Choose an insertion site well away from your beltline.
- Disinfect a skin area that is a little larger than the adhesive you are going to apply. Use Hibiclens™, IV Prep™ or a similar product. Applying Skin-Prep™, Mastisol™ or Tincture of Benzoin™ will make the adhesive stick better. Use a disinfectant for hand-washing as well if you have problems with skin infections.
- Be careful not to touch the sterile needle. Do not breathe or blow directly onto the needle, as this may contaminate it.
- Pinch a two-finger skin fold and insert the needle at a 45° angle (see illustration on page 124) or according to the instructions for other types of needles.
- Remove the protective tape and apply the adhesive carefully. If it sticks unevenly don't try to move it. There is a considerable risk of removing the catheter at the same time if you try to move the adhesive.
- Fill the cannula with insulin after removing the insertion needle. Depending on the length of the cannula, it needs to be filled with 0.3-1 unit of insulin to fill up the dead space.
- Withdraw the old catheter after the insertion of the new one. Pull the adhesive from the side where the tip of the infusion set is located and it will come off more easily.
- If you have problems removing sticky traces of adhesive, try a remover such as Detachol™ or Uni-Solve™.

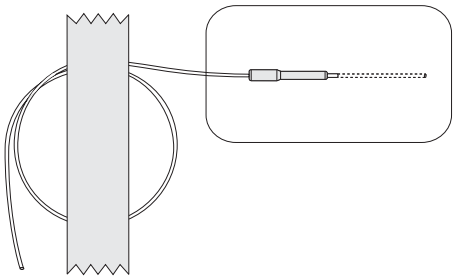
another type of adhesive or infusion set. Another solution is to apply a thin transparent adhesive (like Tegaderm™, IV 3000™ or Polyskin™) and then insert the cannula through it. In this way the cannula adhesive will not get into contact with the skin. A thicker stoma type adhesive (like Duoderm™ or Compeed™) will often help in especially difficult cases. A small hole needs to be cut for the catheter in these thicker types of adhesives.

Avoid inserting the cannula in skin folds, close to the tummy button or under the waistline. Straighten your back before you apply the adhesive to avoid tight skin. Always check your blood glucose level 2-3 hours after replacing the infusion set to make sure that it works properly.

Insert the new metal infusion set before you remove the old one. If you do it the other way around, you will be at greater risk of contaminating your hands on the old site and therefore of transferring bacteria to the new site. Insert the new infusion set at least 4-6 centimetres (2 inches) away from the old one to avoid developing fatty lumps. The adhesive should not cover a previous infusion site until it has healed completely. It is best to change sides on the abdomen (left/right) with each replacement.

Some sets of tubing and cannulas need to be filled with insulin before the needle is inserted. With others you need to give a small amount of extra insulin (around half to a full unit) after insertion to fill up the air inside it (called dead space). Even if you have filled the tubing by pressing the reservoir plunger you need to build up the pressure in the tubing by giving a priming dose with the pump to make sure insulin appears at the tip of the tubing.

The blood glucose level should always be checked 3 hours after changing the infusion set to ensure proper insulin delivery. It is not a good idea to change infusion sites just before going to bed. Since the basal rate runs very slowly during the night, it may take longer for the alarm to be triggered if something is wrong



For young children it may be a good idea to put the tubing in a sling and fix it with some adhesive to minimize the risk of pulling the cannula loose if the tubing is pulled or jerked, for example if you drop the pump.

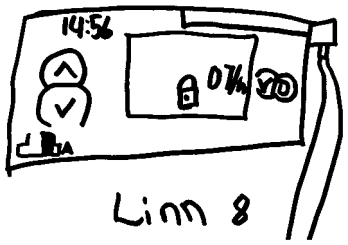
with the new insertion site. Many pump users find it more convenient to replace the infusion site straight after coming home from school or work. This leaves plenty of time to find out if something is wrong with the new infusion site. If you replace the cannula and tubing before taking a meal bolus dose, this will clear away any tissue from the cannula or needle.

Problems with irritation or infection at the insertion site can be prevented by careful hand washing, disinfection and infusion set replacement every second or third day. Use chlorhexidine in alcohol (Hibiscrub™) or a similar agent for hand-washing. If you have recurring problems with infected sites in spite of good hygiene routines, it might mean that the bacteria originate from your armpits or nostrils. If tests show you have bacteria (staphylococci) in your nasal cavity, you may need antibiotic treatment. Another approach is the application of local antibiotics to each nostril nightly, and chlorhexidine body washes on a daily basis.

If you have problems with fatty lumps or redness of the skin you should replace the infusion set more frequently. If the redness doesn't disappear soon after you have replaced the cannula, you can speed up the healing process by applying a dressing soaked in warm soapy water for 20 minutes four times daily. You can also try an antibiotic ointment or hydrogen peroxide cream. If the redness increases or starts hurting, you might need antibiotic treatment. Contact your diabetes healthcare team or doctor.

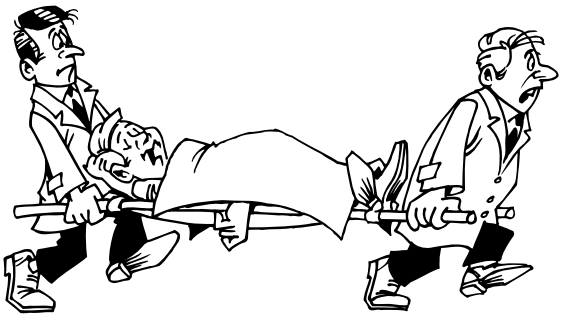
How many tests should you take when using an insulin pump?

- Blood glucose at least 4 times daily (including morning and before going to bed), preferably 4-5/day, especially if you are using Novo-Rapid or Humalog in the pump.
- One or two 24 hour profiles every or every other week with readings taken before and 1½-2 hours after each meal and at night.
- Before each meal if you are ill or feeling unwell for any reason at all.
- Check for ketones if you are nauseous, when you are ill, or when your blood glucose level is high (>14 mmol/l (250 mg/dl)).



More frequent home monitoring

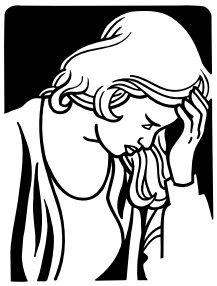
Since there is a greater risk of insulin deficiency with a pump, you must be willing to test your blood glucose level more often. At the very least, you will need to be doing 4 tests a day including morning and late evening. Preferably you should test before each meal. You must also be careful to check for ketones if your blood glucose is high, or if you are feeling unwell, as ketones are a sign of insulin deficiency. It is a good idea to keep reagent strips for blood ketone monitoring at home, so that you can monitor the effect of extra insulin doses given in this situation (see page 102). A 24 hour blood glucose profile with tests before and 1-1½



There is an increased risk of ketoacidosis in pump users if there is any interruption to insulin delivery as the insulin depot is so small. Ketoacidosis must be treated in the hospital with intravenous insulin and fluids. To avoid risking ketoacidosis, **always use a pen or syringe** when taking extra insulin if your blood glucose is high and you have ketones in your blood or urine.

hours after each meal is needed every week or every second week to allow you to adjust your doses correctly. You should also take night time tests when compiling a 24 hour profile (at 2-3 AM and if necessary at 5 AM as well).

Record your test results in a logbook where you can document clearly the pump's basal rate. We find it best to use a logbook where every entry is written on a blood glucose chart. Doing this will help you to see patterns in your blood glucose readings (see charts on page 169). Make it part of your routine to check the pump daily for the total number of units delivered every 24 hours and record this in your logbook.



If you are not feeling well, remember to test your blood or urine for ketones as a matter of course!

KETONE ALERT!

If you are using an insulin pump, you are at greater risk of ketoacidosis because you have a very small insulin depot.

ALWAYS check your blood glucose and ketones when you are not feeling well. Check for ketones in the following situations too:

- If you wake up with a blood glucose of more than 14 mmol/l (250 mg/dl).
- If your blood glucose has been higher than 14 mmol/l (250 mg/dl) for more than a couple of hours.
- If you are ill and running a temperature (for example with a cold or flu).
- If you have any symptoms of insulin deficiency (nausea, vomiting, abdominal pain, rapid breathing, or your breath smells "fruity" or of "pear drops"').

If your ketone levels increase, this means that you are becoming more and more insulin-deficient. You will need to contact your doctor to discuss what to do next!

Be aware that insulin deficiency leading to increased ketone production shows in the urine within a couple of hours. With a blood ketone test, you will detect ketones even earlier. If you take extra insulin, the production of ketones will stop and the level of blood ketones will decrease within an hour or two (you may notice an increase in the first hour after extra insulin is given but the level should then drop). The excretion of ketones in the urine will continue for many hours but you should notice the concentration stabilizing, then decreasing, as the hours pass.

If you are the least bit concerned, or cannot get hold of someone who is familiar with insulin pumps over the phone, you should take an injection of insulin by pen or syringe and then go to your nearest hospital casualty department.

Always bring extra insulin to give with a pen or syringe wherever you go, even if you expect to be away from home for only a couple of hours or so.

Causes of ketoacidosis

- Insulin delivery is interrupted, for example by a leak in the piece connecting the tubing to the reservoir or a cannula that has come out.
- Increased insulin requirements caused by illness (e.g. a cold with fever) without the insulin dose being increased.
- Inflammation or infection at the infusion site (indicated by redness or pus).
- Decreased insulin absorption, for example caused by inserting the infusion set into a fat pad (lipohypertrophy).
- Decreased insulin potency, for example after it has been frozen or exposed to heat or sunlight.

Insulin depot with a pump

The disadvantage of using an insulin pump is that the insulin depot will be very small, since only rapid or short-acting insulin is used. This will be important if the pump gets blocked, or if you intentionally turn it off when playing sport or swimming, for example. If the insulin supply is interrupted you will very soon develop symptoms of insulin deficiency such as high blood glucose, nausea and vomiting (see "Depot effect" on page 80).

Thicker layers of subcutaneous fat will result in a larger insulin depot of the basal dose. In one study a basal rate of 1 U/h of short-acting insulin was used. The insulin depot for those people with a subcutaneous fat layer of 40 mm (1½ inch) was close to 6 U while those with less than 10 mm (1/3 inch) subcutaneous fat had only 1 U in their depot.[397] This suggests that thin people will be more sensitive to an interrupted basal rate since their insulin depot is smaller.

High blood glucose and ketones?

If your blood glucose is higher than 14 mmol/l (250 mg/dl) and you have ketones in the blood (>0.5 mmol/l) or urine (moderate or large), this indicates a blocked insulin supply or increased need of insulin, for example, because of an infection.

① Take 0.1 U/kg (0.5 units/10 lb) body weight of preferably rapid-acting NovoRapid or Humalog (otherwise short-acting insulin) **with a pen or a syringe.** Don't use the pump as you cannot be sure whether or not it works properly.

② Measure blood glucose every hour. If it doesn't decrease, the insulin dose of 0.1 U/kg (0.5 units/10 lb) body weight can be repeated (every 1-2 hours with rapid-acting insulin, every 2-3 hours with regular short-acting insulin). Measure blood ketones if you have such strips available (see page 102). Often there will be an increase in the first hour after insulin is given but after that you should find the level decreases.

③ Check the pump by disconnecting the tubing from the cannula/needle. Activate a prime dose. Insulin should immediately appear from the tubing. If not, replace the tubing.

④ Replace the cannula/needle if the tubing works well. Check for signs of redness in the skin and of moisture close to the infusion site as this would indicate insulin leakage.

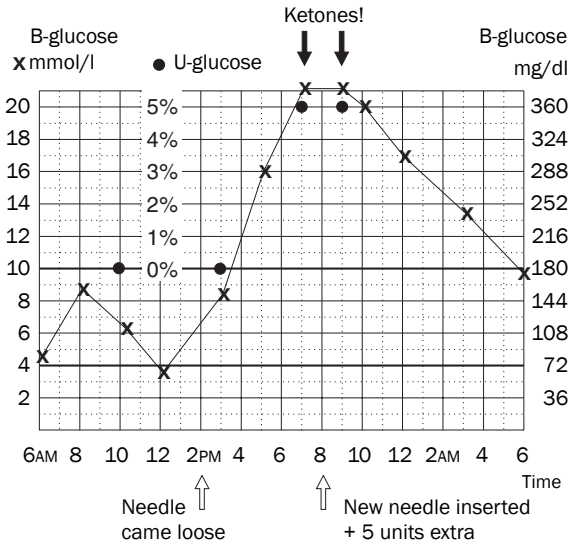
⑤ Be sure to drink large amounts of sugar-free fluids. If your blood glucose is approximately 10-11 mmol/l (180-200 mg/dl) or below and you still have high ketone levels in the blood, you will need to drink fluids containing sugar and repeat the extra dose of rapid-acting insulin.

Ketoacidosis

A small insulin depot will result in early insulin deficiency symptoms if something goes wrong with the pump or the tubing. Your blood glucose will be high within 2-4 hours of inter-

Causes of a lack in insulin delivery

- The connector between the tubing and the insulin reservoir can be cracked. Feel it with your fingers. It may smell of insulin even if you do not see a leak.
- Hole in the tubing. (A cat bite in the tubing resulted in leakage which led to ketoacidosis for a teenage girl.)
- Air in the tubing is not dangerous as such but will give you less insulin.
- If the tubing is squeezed or bent, e.g. by a belt or tight jeans, it will take several hours before the pump's blockage alarm is triggered.



A few hours of interrupted insulin supply is sufficient to make the blood glucose rise quickly. The blood glucose will rise even if you don't eat because the liver will produce glucose when there is a lack of insulin (see page 32). When the blood glucose level was raised in the evening, this teenager was feeling nauseous. He checked for ketones and discovered that something was wrong. When he examined the needle, he found that it had come out so the insulin could not get into his body. He gave himself 5 extra units (0.1 U/kg, 0.5 U/10 lb) with a pen injector, replaced the needle and started the pump. The blood glucose level returned to normal during the night.

If the blood glucose rises quickly you should remove the infusion set. Give a bolus dose and see if insulin comes out from the tip of the catheter. Bend the catheter and give another bolus dose. The pump should now give a blockage alarm. Check the tubing and connections for leaks. Replace the infusion set and check the blood glucose level frequently to make sure it goes down. Take an extra injection (with a pen or syringe) of 0.1 U/kg (0.5 units/10 lb) body weight if you have raised ketone levels, and check your blood glucose again after 1-2 hours. Repeat the dose if necessary.

rupted insulin delivery (see chart on page 178). One night's interrupted insulin supply is enough to cause incipient ketoacidosis in the morning with symptoms of insulin deficiency such as nausea and vomiting. Be extra careful to check both blood glucose and ketones whenever you are feeling at all unwell.

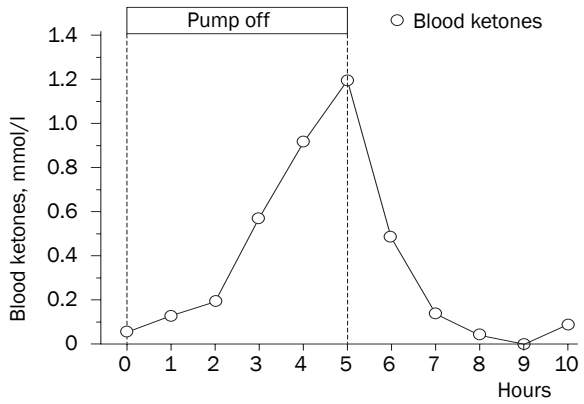
It is very important to be able to recognize symptoms of insulin deficiency early on (nausea, vomiting, abdominal pain, rapid breathing, fruity smell on the breath). To avoid episodes of ketoacidosis, we admit the person to the day care ward a few weeks after pump start and the pump is stopped for 6-8 hours (except in the younger children). See graph on page 178. Pump wearers (and family members) will learn to recognize the individual symptoms caused by lack of insulin, and can practise taking extra insulin with a pen or syringe under safe conditions. None of the patients who have undergone this form of test have had more than a mild degree of nausea with ketone levels of up to 2 mmol/l (with a normal pH). This reassures them that they can tolerate being without the pump for 6-8 hours ("a night's sleep") without risk of ketoacidosis. This procedure has also been recommended for adult pump users.[693]

If your blood glucose is above 15 mmol/l (270 mg/dl) and you have ketones in the urine or blood you should take an extra dose (0.1 U/kg or 0.5 U/10 lb. body weight) of insulin (preferably rapid-acting NovoRapid or Humalog if available). The dose can be repeated after 1-2

hours if necessary (2-3 hours with short-acting insulin). Contact the hospital if you vomit or feel sick and are unable to drink. If you often have episodes of raised ketones or ketoacidosis, it may be a good idea to replace part of the night time basal rate with an injection of long-acting insulin in the evening. This will make insulin deficiency less likely to occur. We have found using a low dose of Lantus (0.1 U/kg) to be particularly effective in this situation (you may need to lower the basal rate in the pump slightly).

Disconnecting the pump

Sometimes you will want to disconnect the pump for one reason or another, for example when playing sports, doing aerobics, or swimming. Most infusion sets allow you to disconnect the tubing by using a silicon membrane as a one way valve.



In this study of adults, the pump was stopped for 5 hours.[343] Blood ketone (beta-hydroxybutyric acid) levels increased rapidly to around 1.2 mmol/l. When the pump was started again, a bolus dose was given along with a meal and 1-4 U of extra insulin, resulting in a quick decline in ketone levels. Monitoring blood ketones is an effective method of monitoring the degree of insulin deficiency if you are having pump problems (see page 102). The ketone levels are comparable to those we have found in children and teenagers (see page 178).

Causes of high blood glucose

(adapted from [776])

① **The pump**
- Basal rate too low
- The pump has triggered an alarm and shut itself off
- Other problems with the pump

② **Insulin reservoir**
- Wrong position in the pump
- Empty reservoir or plunger is stuck
- Leakage in the connection with the tubing

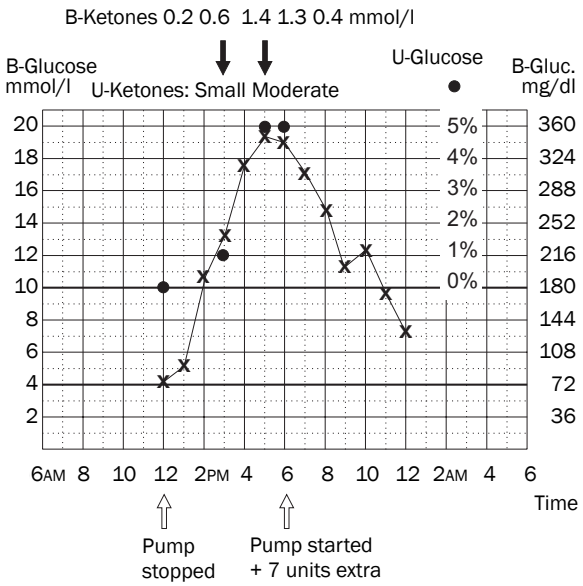
③ **Infusion set**
- Forgetting to fill the tubing when replacing
- Leakage in connections or hole in tubing (feel the tubing and smell your fingers)
- Adhesive and/or cannula has come loose
- Air in the tubing
- Blood in the tubing
- Infusion set has been in place for too long
- The tubing was replaced in the evening without checking blood glucose after 3 hours to ensure proper insulin delivery.
- Bent or squeezed tubing
- Blocked cannula/needle or tubing

④ **Infusion site**
- Redness, irritation / infection
- Fat pad at the infusion site
- Placement close to belt or waistband

⑤ **Insulin**
- Cloudy insulin
- Expiry date passed
- Exposed to heat / sunlight or extreme cold

Taking a bath or shower

Most pumps can tolerate some water but we recommend disconnecting them when taking a bath or shower. You should also disconnect the pump if you have a sauna since insulin can't take the heat. The heat in a sauna will also cause previously injected insulin to be absorbed much more quickly (see page 80).



It is important to familiarize yourself with the symptoms of insulin deficiency (nausea, vomiting, abdominal pain, rapid breathing, fruity smell on the breath) and we therefore plan a "pump-stop" some weeks after pump initiation. This graph was recorded at our day care ward when a planned pump stop was performed (see page 176). This 15-year old boy stopped his pump with Humalog at 5 AM. He was without insulin for 6 hours and felt slightly nauseous when his blood glucose increased and ketones were present. When he started the pump again at 1 PM he had his lunch and gave himself 7 units extra (0.1 units/kg) besides his normal premeal dose. Typically, blood ketones will rise to around 1.5 mmol/l when performing a pump stop like this. A few patients have been slightly nauseous, but the stop has not caused ketoacidosis in any of them (pH has not been affected).

If your blood glucose rises like this and you have raised ketone levels, you should take an extra dose of approximately 0.1 U/kg body weight (0.5 U/10 lb). **Always use a pen or syringe to be on the safe side!** Remove the cannula and take a bolus, watching whether insulin appears from the tip. Bend the cannula and take another bolus. The pump should now give an occlusion or blockage alarm. Check the tubing and connections for leakage (smell your fingers). Replace the cannula. Test your blood glucose again after 1-2 hours and repeat the bolus if necessary.

Pump alarm

Insulin pumps seldom malfunction. If yours does, the pump will stop and give an alarm. There is no risk that the pump will pulse or surge, giving you too much insulin. The pump alarm will go off when something is wrong, for example if the tubing is blocked, the insulin container empty or the batteries flat. However, the pump cannot detect if the insulin is leaking somewhere, for example if the cannula has come out, the connections have come loose or there is a hole in the tubing (pets can bite through it). Check the operating instructions to see what the different alarms stand for and how to respond to them.

Most pumps have an alarm that is triggered if you have not pushed any of the buttons after a certain number of hours. It may wake you up early in the morning if you didn't take your evening snack insulin or forgot to push one of the buttons before going to bed. We usually recommend this alarm be set for 14-16 hours.

Occlusion or blockage alarm

The pump alarm will be triggered if there is an increased resistance when pumping insulin. But it cannot tell whereabouts in the system the problem may be. It may be that the insulin reservoir is empty, the plunger may be sluggish, or the tubing or cannula blocked. The tubing can be bent or squeezed, for example by a belt buckle. If the occlusion or blockage alarm is triggered, start by checking the tubing for bends or pinches. Then give the remainder of the premeal bolus. If no alarm is triggered, all is well now and you have received the intended amount of insulin. If the alarm goes off again, the next step is to stretch out and try careful massaging of the infusion port and catheter under the skin (only for infusion sets that do not have perpendicular cannula). If the tubing hasn't been disconnected, there is no need to

Disconnecting the pump

Time that the pump has been disconnected	Measure
< ½-1 hour	No extra insulin needed.
1-2 hours	Take an extra dose when you connect the pump corresponding to the basal rate you have missed.
2-4 hours	Take an extra dose before you disconnect the pump corresponding to the basal rate that you should have had during the missing 1-2 hours. Check your blood glucose when you connect the pump and take an extra bolus dose corresponding to 1-2 hours' basal rate if needed.
> 4 hours	Dose as above before disconnecting. Using a pen injector or syringe, take extra insulin every 3-4 hours corresponding to the missed basal rate. Take the premeal bolus dose with a pen or syringe.

If you remove the pump to exercise, you will probably need to lower the doses more than suggested above. Test this to find out what is right for you. Always leave the pump in "run" mode when disconnecting for a shorter time, as this prevents you from forgetting to turn it on again when you reconnect it.

Make sure there is no air in the tubing when reconnecting it. Prime it with some insulin if necessary. Do not put the pump lower than the insertion site when reconnecting (for example on the floor when in the gym). If you do, there is a risk that gravity will pull some air into the tubing.

Problems with the pump?

Problem	Measure
Infection/irritation at the infusion site	Wash hands and skin with chlorhexidine in alcohol. Replace infusion set more frequently.
Blocked infusion set	It can be bent or blocked by coagulation or insulin crystals. Replace it.
Blocked tubing	Can be caused by precipitation of insulin. Disconnect the cannula from the tubing and give a prime dose. Replace if the alarm is triggered.
Blood in the tubing	Replace the infusion set.
Air in the tubing	No insulin delivered. See page 181.
White spots on the inner layer of the tubing	Most tubing is made from double plastic layers that can come apart, showing as white spots. This does not affect the function or the insulin.
Leakage of insulin at the insertion site	Has the needle/cannula come loose? Is there a bent cannula? Replace the infusion set.

take any more than the remaining premeal dose of insulin if the pump now works without an alarm (unless the blood glucose level is still raised).

If the cannula or tubing is blocked it may take several hours before the pressure has increased enough to trigger the alarm. During this time you will not have received any insulin. Find out how much is needed to trigger the alarm in your pump. It may also depend on what kind of tubing you have, and how long it is. Test it by pushing the steel needle into a rubber cork or pinch the end of the cannula. If you then give a bolus dose you will see how many units are pushed into the tubing before the alarm is triggered. For example, if your pump has given 4.3 units of the meal bolus dose when the alarm

Problems with the pump, cont.

Problem	Measure
Moisture under the adhesive	This indicates insulin leakage. Replace the infusion set.
Adhesive comes off	If EMLA®- cream has been used, wash it off carefully with water. Disinfect the skin with Skin-Prep® that leaves a sticky film when drying. Warm the adhesive with your hand after application. Apply extra tape if needed.
Itching, eczema from adhesive	Apply hydrocortisone cream. Use a stoma-type adhesive.
Sticky traces of adhesive	Wipe off with special remover or medical benzine.
Sore skin from plastic on set	Apply a piece of tape beneath the hard plastic.
Scars in the skin from old catheters	Often more visible with dark skin. Replace cannula/needle more frequently. Try using a metal needle.
Redness of the skin over the cannula tip	Can be caused by insulin allergy. See page 193
Nothing works	Try running the pump with both insulin and tubing removed.

goes off and 2.6 units are needed to build up pressure to trigger the alarm, you will have only received 4.3 less 2.6 units, or 1.7 units of the bolus dose.

For smaller children we often use insulin of 40 or 50 U/ml, for infants 10 U/ml. This means that fewer units are needed before the alarm goes off since the fluid volume is larger. If 2.5 units of 100 U/ml are needed to trigger the alarm, this will equal 1 unit of 40 U/ml.

Sometimes the pump will trigger the alarm for a block in the tubing even after you have replaced

The pump alarm will tell you if there is a blockage in the tubing or cannula/needle. The alarm is triggered by the increased pressure in the tubing. However, if the pressure goes down, for example because of a leaking connection, a cannula that has come out, or a hole in the tubing, the alarm will not go off. This type of delivery failure can only be detected by repeated monitoring of glucose and ketones. If you suspect a leak, feel along the tubing and smell your fingers; insulin has a very distinctive smell. **If the pump alarm goes off, and your blood glucose is high, you should first give yourself an extra injection with a pen or syringe and then check all possible reasons for the alarm.**

both the tubing and the cannula. If this happens, remove the insulin reservoir from the pump. Then start the pump again. If the alarm still goes off, the problem is an internal one, such as a motor problem. Don't reuse the pump reservoir. If doing so, the silicon on the plunger wears off, and this may result in a occlusion or blockage alarm.

Leakage of insulin

The pump can't trigger the alarm if there is an insulin leak. It will only trigger if the motor runs against an increased resistance. Insulin can be deposited outside the infusion site if the cannula has been retracted. Often this can only be detected when you take a bolus dose. When the basal dose is running, the amounts of insulin are so small that it can be difficult to pick up leaks.

The tubing connector on the pump end can crack, causing leakage, especially if you apply too much force when connecting it. Feel the connector with your fingers. If it is leaking, you

Occlusion or blockage alarm

① Check the tubing for bends and pinching. Try a careful massage of the infusion port and the catheter under the skin. If the alarm was triggered when taking a premeal bolus, take the remaining portion.

No alarm → OK, no problems
Alarm ↓

② Disconnect cannula/needle from tubing. Start a prime dose with the pump.

No alarm → Replace cannula/needle
Alarm ↓

③ Disconnect tubing from insulin reservoir. Start a prime dose with the pump.

No alarm → Replace tubing
Alarm ↓

④ Remove the insulin reservoir from the pump and start a prime dose.

No alarm → Replace reservoir
Alarm ↓

⑤ Something is wrong with the pump. Contact the pump dealer and deliver insulin with a pen or syringe.

When to call the hospital or your diabetes team

- The first time you become ill after you have started with the pump.
- If you have been feeling too sick to eat for more than 6-8 hours.
- If you have vomited more than once during a 4-6 hour period.
- If your blood glucose level has not come down, or the ketone level is still running high after the second extra dose of insulin.
- If your general well-being is deteriorating.
- If you are at all uncertain as to how to handle the situation.

can often detect the smell of insulin. Sometimes a cat or dog may be able to warn you that there is a leak as they often like the smell of insulin.

Air in the tubing

When you connect the tubing to the pump there is always a risk of air coming in, especially if you fill it with cold insulin. Air will come out of the solution when the temperature rises. Always make sure that the insulin is at room temperature before refilling the reservoir. Introducing air into the subcutaneous tissue is not dangerous in itself, but you will miss out on the corresponding amount of insulin. The alarm will not be triggered since the pump's micro-computer cannot tell the difference between air and insulin in the tubing.

If you see air in the tubing when you are about to take a premeal bolus dose you can compensate with a little extra insulin. Five to seven cm (2-3 inches) of air in the tubing usually corresponds to 1 unit of insulin. To find out the exact dimension of your pump tubing, give a bolus dose of 1 unit when you are priming the tubing. Make a mark on the tubing with a felt tip pen corresponding to the length that the insulin travels for that unit.

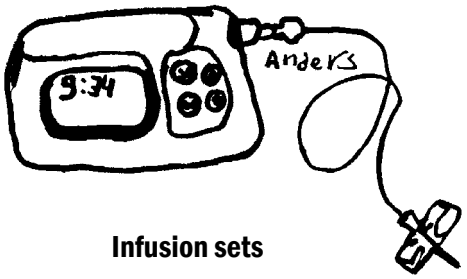
If the air in the tubing corresponds to more than ½-1 unit when the basal rate is running (e.g. between meals) it is best to disconnect the tubing from the cannula in the skin. Prime the tubing to purge the air and fill it with insulin once again.

Sick days and fever

When you are ill, especially if you are running a temperature, your body will increase its insulin requirements, often by 25% for each degree Celsius (every 2 degrees Farenheight) of fever (see page 264). It is advisable to begin by increasing the basal rate. Start by a 10-20%

Insulin pump and illness

- Continue with your ordinary meal bolus doses even if you eat less, increasing them by 1 Unit if necessary (2 Units if your dose to start with is 10 Units or more, ½U if dose is < 3 U). Begin by increasing the basal dose if you have a raised temperature.
- Increase the basal rate by 10-20% (0.1-0.2 U/hour, 0.2-0.4 U/h. if the basal rate is > 1U/h.) if your blood glucose continues to be high.
- Check your blood glucose every 2 to 4 hours. Check for ketones frequently. Keep good records in your logbook.
- Take extra insulin (1 U/10 kg or 0.5 U/10 lb body weight), preferably NovoRapid or Humalog, if your blood glucose is high and you have ketones. Give another 1 U/10 kg (0.5 U/10 lb) every second hour until the blood glucose is below 10 mmol/l (180 mg/dl) and the level of ketones is decreasing.
- Give all extra doses of insulin with a pen or syringe if your blood glucose has risen suddenly. This is in case the high blood glucose has been caused by a problem with the pump.
- Try to drink large amounts of fluids as this will increase the excretion of ketones and lessen the risk of dehydration. As long as there is glucose in your urine, you will lose extra fluid. Drink glucose-free fluids when your blood glucose is above 10-12 mmol/l (180-215 mg/dl) and change to something containing glucose when the blood glucose is below this level. If you feel nauseous, try to drink small amounts (a couple of sips) at a time.
- Try to drink something sweet if hypoglycaemia is a problem. You may need to lower the basal rate but never discontinue it completely.



Infusion sets

Brand	Length cm	inches
Classic	60, 80, 110	24, 31, 43
Cleo 90 ®(6, 9 mm)	55, 80, 110	23, 31, 43
Comfort ®	30, 60, 80, 110	12, 24, 32, 43
Inset (6, 9 mm)	60, 110	43, 23
Silhouette ®	60, 110	43, 23
Simple Choice Easy (12mm or 17 mm cannula length)	60, 110	43, 23
Sof-set ®	61, 107	24, 42
Sof-set ® Micro (6mm)	61, 107	24, 42
Tender	60, 80, 110	24, 31, 43
Quick-Set ®(6, 9 mm)	60, 110	43, 23
Ultraflex (8, 10 mm)	60, 80, 110	24, 31, 43
Steel needles:		
Rapid (6, 8, 10, 12 mm)	60, 80, 110	24, 31, 43
Polyfin ®	61, 107	24, 42

For most tubings, 5-7 cm (2-3 inches) contain approximately 1 unit of insulin. Test your tubing by putting a felt pen mark on its end, then deliver one unit at a time as a bolus dose.

The Silhouette, Sof-set and Quick-Set infusion sets can be used with an automatic inserter that lessens the pain.

increase when you notice that your blood glucose is rising. You will probably also need to increase the meal bolus doses in response to your blood glucose readings. It is important that you test your glucose level before each meal if you are ill, and preferably 1½ -2 hours after the meal as well. Usually, you will need to monitor your blood glucose levels during the night as well.

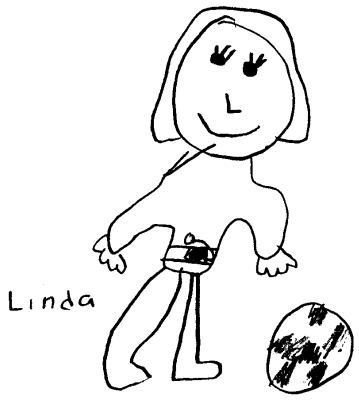
Pump removal doses

It is very important always to carry extra insulin wherever you go in case your pump fails to work properly. Check to see that the insulin has

not expired. You should have your pump removal doses written down and with you in case you need to use a pen or syringe as a temporary measure. The total number of units over 24 hours will probably need to be increased by 10-20% if you stop using the pump for a whole day or more.

Use the old doses

It is easiest to start with the same doses that you had when you used a pen injector or syringes, provided that you have written down the doses and not too much time has elapsed since then so that you still have more or less the same insulin requirements.



Many people with diabetes are successful in competitive sports. Others, like most children, just play for the fun of it. In either case, the pump helps keep the blood glucose at an appropriate level both during and after exercise.

Rapid-acting insulin (NovoRapid, Humalog or Apidra) in the pump

You can continue taking the same premeal bolus doses with a pen or syringe. Replace the basal dose with intermediate-acting insulin. Divide the total basal dose during the day, taking one third in the morning as NPH insulin, and two thirds at bedtime. You will probably need to increase the total NPH dose by 10-20% compared to the total pump basal over 24 hours.

Regular short-acting insulin in the pump

Look at the pump doses. The breakfast dose with a pen will be the sum of the pump pre-breakfast bolus dose and the number of basal units the pump would have delivered between breakfast and lunch. If you have a high basal rate (>1.5-2 U/hour), start by counting just 1-1.5 U/hour when calculating the dose when using a pen or syringe.

Calculating the bedtime dose

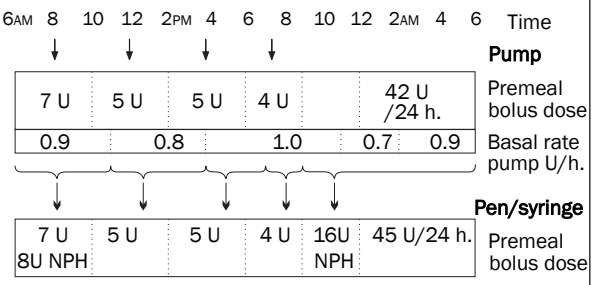
The bedtime dose of intermediate-acting insulin (Insulatard, Humulin I, Insuman Basal) is calculated by adding the basal rates between 10 PM and 8 AM (see example on page 184). You can also use short-acting insulin (*not* NovoRapid or Humalog) during the night, giving two doses, at 10 PM and 3 AM, corresponding to the sum of the basal rates during the night.

Long-acting basal insulin

Another alternative is to replace the basal dose in the pump with long-acting insulin (Lantus, Ultratard, Humulin Zn) and to use the same bolus doses (and type of insulin) before meals as when using the pump. However, it will take several days for the doses of long-acting basal insulin to have a stable effect, so this may be a better alternative only if you know that you will be without the pump for more than a day or two. Take the total basal dose during 24 hours, and take the same dose of Lantus as one dose at dinner/tea or the evening snack.[101] For Ultratard and Humulin Zn, add 10-20% and divide into two equal doses that you take with breakfast and dinner/tea around 5-6 PM. Take the same amount of bolus insulin as when on the pump.

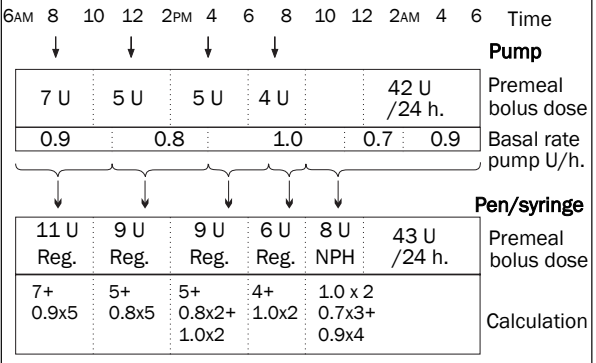
Pump removal doses

NovoRapid or Humalog in the pump:



Sometimes you must use an insulin pen or a syringe for a while, for example if something is wrong with the pump. Continue with the same doses of NovoRapid or Humalog before meals as when on the pump. Replace the basal dose with an intermediate-acting insulin (NPH) given twice daily. Take the basal rate in pump, add 20% (20 U+20% = 24U) and divide it into 2 doses of intermediate-acting insulin. Give 1/3 in the morning and 2/3 in the evening and adjust according to blood glucose monitoring. If you will be without the pump for more than one day, you may try substituting the basal rate with the same number of units, taken as Lantus once daily.[101]

Short-acting insulin in the pump:



NPH = Intermediate-acting bedtime insulin

With short-acting insulin, you can calculate which dose to use if you add the meal bolus dose in the pump with the basal rate. You will probably need to increase the night dose since the pump is more effective, giving more insulin late at night and early in the morning than you would get from the intermediate acting bedtime insulin. Check with your diabetes nurse if you are unsure what doses you used when you were on multiple injections.

Admission to hospital

If you are admitted to hospital in an acute situation, you may well find that none of the staff members on duty are familiar with your pump. So, if you have any problems using it, it would be best to begin injecting insulin with a pen or syringe until the daytime staff arrive. If you are being sick or have signs of ketoacidosis, the best treatment may be by intravenous insulin (see page 69).

Physical exercise

Try wearing the pump in a case on a strong elastic waistband during exercise. If you are involved in contact sports, you can disconnect the pump for 1-2 hours without taking any extra insulin. If you are exercising for longer than 2 hours, it will probably be better to keep the pump connected and temporarily decrease the basal rate. Try half the basal rate while exercising and for the following hour or two. You may need to lower the basal rate even more, but the only way to know for sure is to try it yourself. Another alternative is to connect the pump again for a short while when you are halfway through the exercise (for example at half-time in a game of sport), and take a small bolus dose. If you have problems with hypoglycaemia early in your exercise session, you will need to disconnect the pump at least 2 hours before the session starts. [305] Wearing the pump during 45 min. activity on an exercise bicycle increased the risk of late hypoglycaemia 2.5-12 hours after exercise.[9]

If you are using rapid-acting insulin, your blood glucose level may plummet if you exercise shortly after taking the premeal bolus dose (see graphs on page 255) without decreasing it. With short-acting insulin you can try taking half the meal bolus dose if you are exercising 2-3 hours after a meal, or even skipping it if the exercise is particularly strenuous. However, you will probably then need to keep the pump connected to get the basal rate during the entire period of exercise.[862]

An insulin pump needs to be looked after, and tubing and batteries need to be replaced. When the alarm goes off, you must know how to respond. You will be the "first line pump mechanic" and will probably find that you soon learn how to take care of the practical details.

In the winter when it's cold, you must keep the pump close to your body. The tubing is very thin and no part of it must be outside the clothing, or it will easily freeze. It may be a bit awkward taking the bolus dose but since the insulin can't be allowed to freeze, you must protect it from low temperatures.

Don't forget to refill your glucose stores after exercise (see page 250). After strenuous exercise (e.g. a ball game or skiing) you must decrease the basal rate by 10-20% (0.1-0.2 U/hour) or even more during the night to avoid hypoglycaemia. Try this out yourself and note the blood glucose test results in the logbook for future reference should you be faced with the same situation again.

When you go to a diabetes or sports camp you will be very active for several days in a row. Try lowering the basal rate 10-20% (0.1-0.2 U/hour) when you arrive at the camp, and then adjust it according to your blood glucose levels.

Using the pump at night only

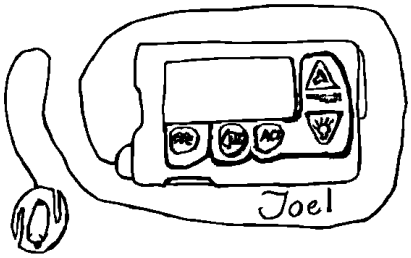
Some people feel that the pump has obvious advantages during the night but that multiple injections are better during the day. This may be the situation for a child who is not yet ready to manage the pump alone without adult supervision. Using a pump at night time may be a good alternative for children who are using intermediate- acting insulin (Insulatard, Humulin I, Insuman Basal) at bedtime and experience problems with night time hypoglycaemia or high blood glucose levels in the early morning.[474] It is perfectly acceptable to connect the pump in the evening, let it stay in place overnight, and disconnect it the next morning. During the day you can use a pen injector or syringe for premeal bolus doses. Talk to your diabetes doctor if this sounds like the right approach for you.

In a group of children aged 7-10 years, the pump was used for the dinner and evening snack bolus doses and for the basal rate during the night.[474] Intermediate-acting NPH was given in the morning and premeal boluses during the day were given as injections of rapid-acting insulin. The children's blood glucose readings were lower with the night time pump than when using bedtime NPH insulin. In one study of night time pumps in adults, the morning blood glucose levels were more even and the patients also experienced fewer episodes of hypoglycaemia in the daytime.[463]

Night time pump may be a good alternative if you are on a seaside holiday, doing swimming and surfing. Disconnect the pump in the morning and take your meal bolus doses with a pen or syringe, then connect the pump again when you come back to the hotel in the afternoon or evening. Since you will probably be exercising more than usual, you may not need to take any injection of basal insulin in the morning.

When should I disconnect the pump?

- In the bath tub
- In a public bath or swimming pool
- In a sauna or jacuzzi
- During an X-ray, Cat scan or MRI scan



Is the pump a nuisance?

You must keep your insulin pump next to you 24 hours a day. Many people ask us, "How do you sleep with it?" But they are then surprised by how quickly they get used to wearing the pump at night. Some people who lie quite still put the pump beside or under the pillow and wake up in the morning with it still there. Others, who are more restless, find it better to have the pump on a waistband, leg band, or in a pyjama pocket.

On rare occasions, some people have taken bolus doses while sleeping. It may well be that they have dreamt of eating and are so used to the pump that they have taken a bolus dose without waking up. If you have hypoglycaemia unexpectedly in the morning, it is a good idea to check the pump memory to find out if you have taken a dose in your sleep. If this is the case, you should wear the pump in a case at night to prevent you from pressing the buttons. in error. Another solution is to lock the pump at night, or to use a remote control for bolusing and place this far away from your bed at night.

An 18 year old girl said that the first question friends asked her was, "What do you do with the pump when having sex?" Fortunately, it is easy to disconnect the pump for a short while to stop it getting in the way. Making love also involves physical exercise, so be aware that you might need a little less insulin for a while. Just don't forget to reconnect the pump afterwards.

Does using a pump cause weight gain?

If you have an increased HbA_{1c}, there is a risk of gaining weight when your blood glucose improves since less glucose will be lost via the urine. If you have frequent hypoglycaemic episodes you will be likely to gain weight since you will find yourself needing frequent snacks. If you start treating yourself to sweets and crisps you are bound to put on weight. Talk to your dietitian about how to find a way around these problems. It might be easier to lose weight without an increase in HbA_{1c} if you have an insulin pump because you can then decrease both your food intake and meal bolus doses but be able to ensure you meet your basal insulin requirements.

Having a lie in

With an insulin pump it is easier to sleep longer in the morning as your basal need for insulin is covered automatically. To find a suitable basal rate, skip breakfast (don't take the breakfast bolus dose either) and test your blood glucose several times until lunch. If the level hasn't changed you know it will work well when you sleep in late. Before you know how your body reacts, it is a good idea to have a parent or relative help check your blood glucose at 7-8 AM and adjust the basal rate accordingly. If it is below 3.5-4.0 mmol/l (65-70 mg/dl) it may be easier for them to shut off the pump for a while than to wake you up in order to eat something.

Travel tips

Always take extra insulin and an insulin pen or syringes wherever you go. Don't forget to adjust the pump's clock if you travel across time zones. Change the clock to the new time when you arrive at your destination. Since you will be sitting still on the plane, it may be a good idea to increase the basal rate slightly on a long trip. Measure your blood glucose before each meal and make necessary adjustments to the bolus dose. You may need a certificate for customs declaring that you need to wear an insulin pump. The pump does not usually trigger the metal detector at airports. If you travel in a very hot climate, the insulin may lose its potency. You may need to change insulin cartridges every 1-2 days. If you fill your reservoirs yourself, do not fill with more insulin than you will use in this time. Keep your insulin supply in a refrigerator, if possible. See page 301 for further travel tips.

Toddlers using pumps

No child is too young to use a pump. They have been used successfully even in babies only a few weeks old. In a US study of toddlers aged 2-5 years, HbA_{1c} decreased from 9.5% to 7.9% and the number of instances of severe hypoglycaemia decreased from approximately one episode every 2 months to approximately one episode every 10 months.[537] For young children with basal rates < 0.3 U per hour U-40 or U-50 can be used, for babies often U-10. Small children may need a lower percentage of the total daily dose as the basal rate (down to 40%). Young children often need the highest basal rate in the late evening from 9PM-12AM.[109]

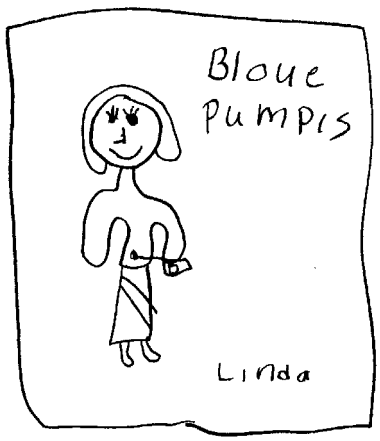
Using an insulin pump works well for all age groups; no child is too young to try one. Even babies only a few weeks old have used insulin pumps successfully. If your child has unpredictable eating habits, it is very practical to be able to give small bolus doses every time he or she eats something. The best insertion site for the infusion set in toddlers is the buttocks.

Especially picky and unpredictable eaters will benefit from repeated small bolus doses in accordance with their eating habits. Dual/combined or square/extended bolus can be very effective if there is any doubt about just how much a child will eat. The pump can be kept out of reach of the toddler by being worn in a harness between the shoulders. Children from the age of 4-5 years can often wear the pump in the same way as older children. In our experience, they very quickly learn not to interfere with the pump. If in doubt, use a pump on which the buttons can be locked.

The buttocks are often used for infusion sites for the very youngest, since the cannula then is out of sight. If the child wears nappies, position the insertion site so that it won't be soiled by the nappy contents.

Pregnancy

Using an insulin pump is an excellent way to obtain blood glucose values close to those of a person without diabetes.[457] With a close to normal blood glucose, the risk of complications during pregnancy decreases to the same levels as for women without diabetes (see page 280). In pregnancy, basal needs are usually only 40% of the total daily dose.[244] The insulin requirements will gradually increase during pregnancy, but will often plummet after delivery (see page 282). During the later part of pregnancy it might be difficult to have the pump cannula on the distended abdomen. Instead, it would be a



Many people come to look upon their pump as a reliable friend that they will use for many years. Little Linda has even given her pump a name "Bloue Pumpis".

good idea to use the buttocks, the upper part of the thighs or the upper arm.

There is an increased risk of ketoacidosis during pregnancy. You should check your blood glucose more often and also change tubing and cannulas more often (every day with metal needles and every other day with teflon catheters). Contact the hospital immediately if your blood glucose level is high and you have raised levels of ketones in your blood or urine. Adding a bedtime dose of intermediate-acting insulin (0.2 U/kg) to cover part of the normal basal dose delivered by the pump has decreased the risk of ketoacidosis considerably.[571]

Rapid-acting insulin in the pump

As rapid-acting insulin (NovoRapid and Humalog) acts more quickly and more closely mimics the insulin response in a person without diabetes, it is the logical choice for use in insulin pumps.

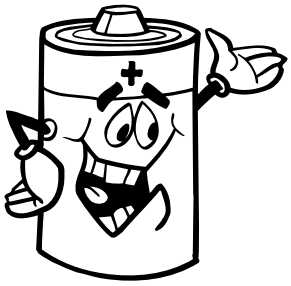
One problem when using insulin with an even shorter duration is that your body's insulin depot will go down considerably as well (see page 175). This implies that symptoms of insulin deficiency will arise fast if the pump fails. The production of ketones will start after approximately 4 hours when a pump with Humalog is stopped.[824] One can compare a pump-free period of about 4 hours with rapid-acting insulin to about 6 hours with regular short-acting insulin. However, this can vary considerably from one individual to another.

NovoRapid and Humalog are now both approved for pump use in most countries and their use is increasing fast. The experiences to date are positive. In our department, we start all new pumps with rapid-acting insulin. However, if you develop symptoms very quickly after an interruption of the insulin supply, you may be better off using regular short-acting insulin.

When switching from short-acting to rapid-acting insulin in the pump, you may need to lower the bolus doses slightly (by approximately 1-2 units) since the bolus doses of regular short-acting insulin supplied part of the basal insulin, overlapping with the next meal as well. To compensate for this you may need instead to increase the basal rate slightly, when you are using either NovoRapid [99] or Humalog.[159]

The onset of action with a premeal bolus dose of NovoRapid or Humalog may be too rapid in certain situations, such as eating a meal that is digested slowly because it is rich in fat and carbohydrates (e.g. pasta or pizza), or a long drawn-out dinner with many courses. You can then try taking the bolus dose after the meal. If you have a pump that can deliver the dose more slowly (square or extended bolus, see illustration on page 170) this is an ideal solution in these situations. You can use this type of bolus dose even if you have problems with gastroparesis (slower emptying of the stomach due to diabetic neuropathy, see page 318). See the chapters on insulin adjustments on page 141 and diet on page 209 for further advice on the use of NovoRapid and Humalog.

If you use regular short-acting insulin in the pump and want to sleep half an hour longer in



Remember to bring extra batteries and other accessories when you are away from home for more than a couple of hours. Also bring a pen or syringe and rapid-acting insulin so you can take extra insulin if your pump stops working properly.

the morning, you can take the pre-breakfast dose with rapid-acting insulin in a pen or syringe immediately before eating instead of 30 minutes earlier. NovoRapid or Humalog is also a good alternative if your blood glucose is high before you eat.

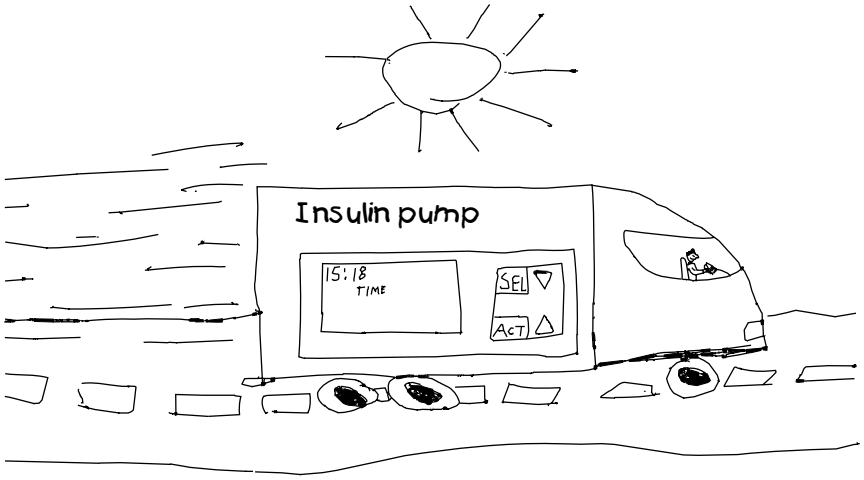
Which type of treatment do the health professionals prefer?

In an American study, professional members of AADE (American Academy of Diabetes Educators) and ADA (American Diabetes Association), mainly nurses, doctors and dietitians, were asked how they treated their own diabetes.[331] The results showed that as many as 60% of the AADE members with diabetes and 52% of the ADA members with diabetes used insulin pumps. Only 3-4% used 1-2 injections per day. The rest used multiple injections with 3-4 doses per day. The average HbA_{1c} for pump users was 6.7%, for multiple injections 7.2%. One interesting observation was that diabetes (type 1) was 13 times more common among the AADE and ADA members than in the general population. The explanation may be that since diabetes generally develops at a younger age (average age at onset in the US is 16 years), the disease may influence a person towards choosing a career involving diabetes care.

Research findings: Rapid-acting insulin and pumps

- Long-term studies show that individuals can achieve a 0.5% lower HbA_{1c} when using Humalog in the pump without increasing the risk of severe hypoglycaemia or ketoacidosis.[743,586]
- In a Canadian pump study, regular short-acting insulin and rapid-acting insulin were used in insulin pumps during a 3 month double-blind cross-over study.[899] All bolus doses were given immediately before the meals. HbA_{1c} was significantly lower (7.7% compared to 8.0%) when using rapid-acting insulin but there was no difference in the frequency of hypoglycaemia.
- In a French pump study, blood glucose levels were more stable and the number of readings below 2.0 mmol/l (36 mg/dl) decreased when using Humalog.[586]
- In a German study of adults, the pump was stopped from 10 PM in the evening until 7 AM in the morning. With Humalog, the changes in blood glucose and ketones developed 1.5-2 hours earlier than with regular short-acting insulin.[693] Blood glucose increased with about 11 mmol/l (200 mg/dl) in 6 hours using Humalog compared to about 6 mmol/l (110 mg/dl) with short-acting insulin. One patient stopped the test after 7 hours due to headache and nausea but no one developed ketoacidosis.
- In an Italian study of adults, the pump was stopped for 5 hours in the morning without eating breakfast. During these hours, glucose levels increased by 5.6 mmol/l (100 mg/dl) on average when using short-acting insulin (Velosulin) compared to 9.2 mmol/l (165 mg/dl) with Humalog.[343] Blood ketone levels rose to about 1.2 mmol/l when using Humalog compared to 0.9 mmol/l with Velosulin (see figure on page 177).
- In an American study, the differences between regular short-acting insulin and Humalog were not as pronounced when the pumps were stopped for 6 hours.[47]

For further reading on insulin pumps, try either of the following: *The Insulin Pump Therapy Book* by Linda Fredrickson (Ed.), Minimed Inc. 1995, Sylmar, CA, USA; *Pumping Insulin* by John Walsh and Ruth Roberts, Torrey Pines Press 2000, San Diego, US; *Think like a pancreas* by Gary Scheiner, Marlowe 2004, New York, USA and *Insulin Pump Therapy Demystified* by Gabrielle Kaplan-Mayer, Marlowe 2002, New York, USA.



An insulin pump will enable you to "fine tune" your insulin doses and will give you more "horsepower under the bonnet" for taking care of your diabetes. However, greater knowledge and attention will be needed if it is to work well, just like a stronger and faster car. Used correctly, an insulin pump is a very good tool that can give you wonderful support on your long diabetes journey.