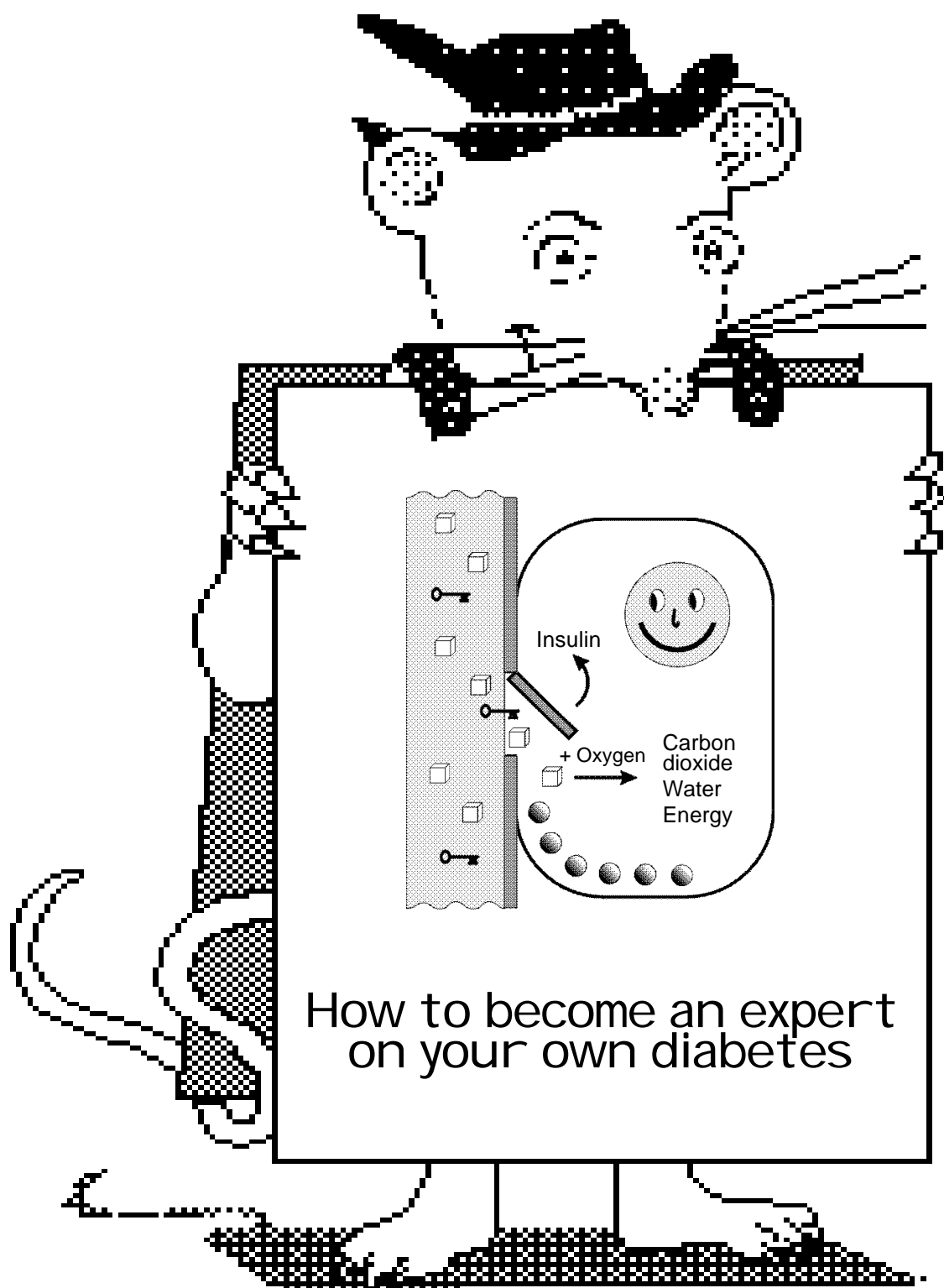


INSULIN-DEPENDENT DIABETES

in Children, Adolescents and Adults





This book shows in a practical way what you need to know to be able to take good care of your diabetes. Having diabetes means that you need to know more about the disease than the average doctor, to be able to understand and take care of your illness in an appropriate way. This is necessary both to enjoy your life today, and to avoid and postpone late complications of diabetes. Modern research shows unambiguously that a lower mean blood glucose will lessen the risk of late complications. By reading this book you will learn how this can be accomplished through an intensive diabetes management.

Sometimes in this book I speak directly to you, the person with diabetes, and sometimes I address your family or parents. At other times there is even information for third parties, like the diabetes team members. When you are reading this book, just imagine that we are all together, sitting around a table, discussing diabetes. Remember that you run your own life - don't let your diabetes take over! Instead you can learn how to handle your diabetes in the different situations that life has to offer.

This book is applicable to children, adolescents and adults having insulin-dependent diabetes. It is also meant for teaching persons involved in diabetes and diabetes care, such as nurses, doctors, dietitians, teachers, child care staff and others.

The author is consultant pediatrician at Uddevalla Hospital in Sweden, specializing in diabetes.

The book was awarded the price for best pedagogical book by the Swedish Society for Diabetology in 1998.

You will find more information about the book at <http://www.piara.com/eng> and http://www.childrenwithdiabetes.com/d_06_b00.htm#hanas

The cover illustration shows how glucose enters into the cell with the help of insulin.

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Insulin pump

Our aim is to be able to offer all diabetic individuals an insulin treatment that is right for them. When multiple injection treatment does not give acceptable glycemic control we usually suggest an insulin pump. Many of our teenagers with brittle diabetes feel much better after the transition to pump therapy. More than 40 % of those in the intensive treatment group in the DCCT-study chose an insulin pump. There are 32.000 patients on insulin pumps in North America (1997).

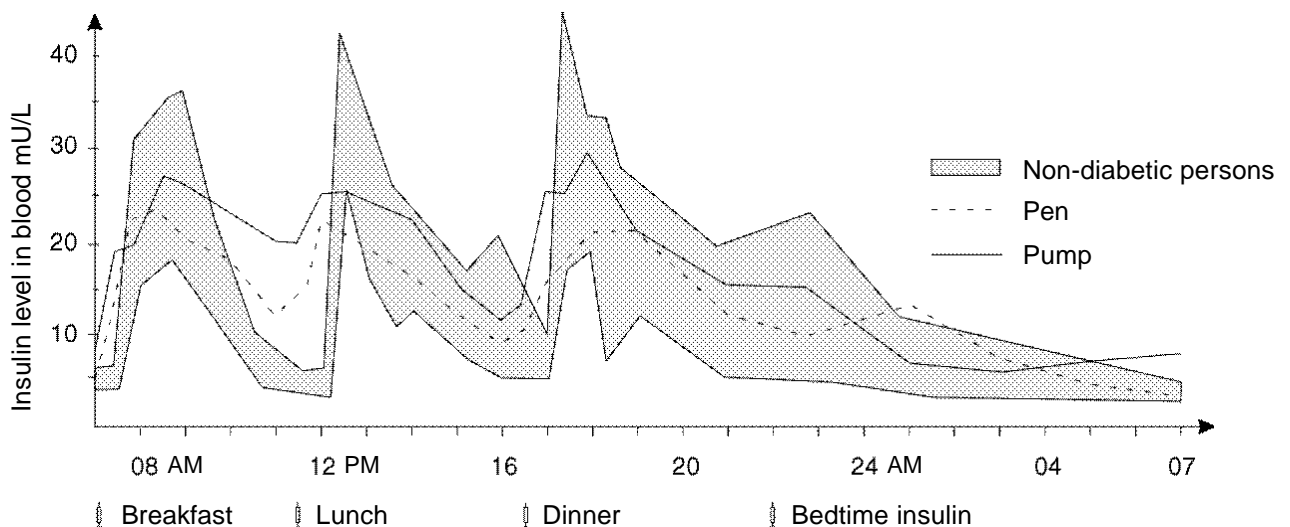
Insulin pump therapy is more expensive than conventional syringe or pen therapy. Since insulin pumps are not subsidized in most countries they may be a financial burden. Ask your diabetes team how this can be solved in your community.

Only short acting insulin is used in the insulin pump. Often short-acting insulin with special solvent is used to avoid blockage of the catheter (buffered insulin, Velosulin, Isuman Infusate). The action time and effect of this insulin is similar to ordinary short-acting insulin (e.g. Actrapid, Humulin Regular, Isuman Rapid). Today most catheters are made of a material with less risk of blockage, and ordinary short-acting insulin will usually suffice.³⁷⁵ Buffered U-40 insulin for smaller



children is not available. We have had no problems with catheter blockage using regular short-acting 40 U/ml insulin in insulin pumps. Direct-acting insulin (Humalog) has also been tried with success in insulin pumps⁴³⁸ (see page 119).

The insulin pump will deliver a steady basal rate of insulin 24 hours a day. Most modern pumps can be adjusted for different basal insulin rates during the day and night. Extra insulin is given with meals by pushing a button on the pump (bolus dose). The insulin is pumped through a thin tubing (catheter) that is connected to a metal needle or indwelling catheter placed subcutaneously.



This figure is from a study where insulin levels in the blood were compared when using different types of insulin treatment.³⁰⁹ The patients in this study used insulin pens with 3 premeal doses of short-acting insulin and one dose of bedtime insulin. The graph shows that pump therapy resulted in higher insulin peaks after meals but also higher insulin levels between meals. Compare with the shaded area showing that the insulin level in non-diabetic individuals rises very steeply after a meal. In the early morning insulin pumps give higher insulin levels than multiple injections.

Advantages with insulin pump

- à 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.
- à Certain individuals need a higher level of insulin between meals which the insulin pump can provide.
- à The continuous supply of basal insulin will make you less dependent of the mandatory interval of not more than 5 hours between meals in multiple injection treatment.
- à You always have your insulin with you and 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 out with a group of people.
- à If the pump can be programmed for different basal levels you will have the advantage of adjusting the pump for the differing needs of basal insulin during the day and night.
- à The pump uses only short-acting insulin which ensures a more predictable insulin effect compared to intermediate- and long-acting insulin.
- à Possibility of adjusting the premeal doses in 1/10th unit increments.
- à The risk of severe hypoglycemia is usually reduced when using an insulin pump.
- à A small insulin depot will decrease the risk for unpredictable release of insulin during physical exercise.
- à During exercise a temporary basal rate can be used.

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.²⁵¹ Insulin absorption after a premeal dose will be constant for at least 4 days provided that the needle is inserted in an area free of lipohypertrophies.³¹¹

The total insulin requirement per 24 hours usually decreases 15 - 20 % after starting with insulin pump treatment^{58,105,377} and the glycaemic control

Disadvantages with insulin pump

- à A small insulin depot will make you very sensitive to an interruption in the insulin supply, risking the rapid development of ketoacidosis.
- à You must take more tests when using an insulin pump.
- à The insulin pump will be connected to you 24 hours a day. Some feel that this makes them more tied up to their diabetes.
- à The pump will be very obvious, for example when going to a public bath. Your diabetes will no longer be a secret disease. Often you will get curious questions about the pump, something that a person who has not fully accepted his/her diabetes fully might experience as uncomfortable.
- à The pump's alarm will trigger every now and then and you might need to stop your activities to change the needle or tubing at an inconvenient time.

often improves, resulting in a lower HbA_{1c}.^{58,105} 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 glycaemic control improves. The extra glucose that was earlier lost with the urine will now remain in the body and be transformed into fat instead.

The risk of severe hypoglycemia usually decreases with pump treatment,^{56,58,105} whereas the risk of ketoacidosis (diabetic coma) may increase according to some studies¹⁰⁵ while it decreases in others.⁵⁸ Ketoacidotic episodes usually occur early after initiating pump treatment when the patient is new to the method.²⁹¹ Some teenagers are frequently hospitalized due to ketoacidosis caused by interrupted insulin supply. Such episodes can drastically be reduced with an insulin pump that makes a continuous insulin supply possible.⁵⁰

The basal rate

Approximately 40 - 50 % of the daily insulin requirement is given as the basal rate (often close to 1 U/hour for an adult person) and the rest as premeal bolus injections.¹⁹⁶ After a change in the basal rate it will take 2 - 3 hours before the blood glucose level is affected.¹⁹¹ The basal insulin is absorbed

Insulin pump treatment will be easier if you: (adapted from ³⁹¹)

- à Are comfortable with the pump being constantly attached to your body and understand how it works
- à Regularly check your blood glucose, at least 2 - 3 times daily (including morning and evening).
- à Regularly perform urine tests for ketones: every morning, when ill or having nausea or when blood glucose is above 15 mmol/L (270 mg/dL).
- à Recognize symptoms of low blood glucose. Always carry glucose tablets.
- à Recognize early symptoms of ketoacidosis (diabetic coma). Always carry extra insulin and a pen or syringe to be able to treat this condition.
- à Have frequent contact with a diabetic clinic.
- à Persons living alone should have frequent contact with a close friend or relative.

twice as rapidly if the person has a thin subcutaneous layer (less than 10 mm in a lifted skin fold) compared to a thicker subcutaneous fat layer (more than 20 mm).¹⁹³

The body's insulin requirement is about 20 % lower between 1 - 3 AM compared to 5 - 7 AM.⁶³ If one uses a pump with the possibility of different basal rates you can administer a lower basal rate between 11 - 12 PM to 3 AM to avoid nighttime hypoglycemia.⁶³ 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 E/hour) between 3 and 7 AM.

The insulin sensitivity will increase when the blood glucose level has been lowered for some time (from a few days up to a week). To avoid hypoglycemia 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. With some pumps the basal rates are adjustable every hour and others can be set for different profiles for a longer

Daytime basal rate

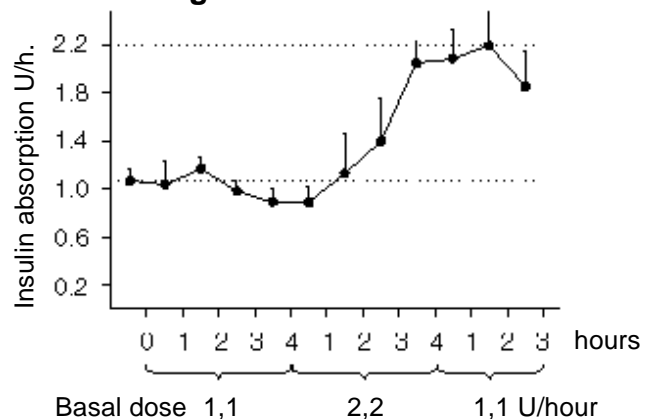
These guidelines apply to pumps with programmable basal rates. Make changes in basal rates in collaboration with your doctor and diabetes nurse.

It may often be appropriate 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. Change the basal rate profile *preceding* the meal (first check that the preceding meal's bolus dose was set correctly):

Blood test before meal	Measure
< 5 mmol/L < 90 mg/dL	Decrease the basal rate by 0.1 U/hour.
> 8 - 10 mmol/L > 144 - 180 mg/dL	Increase the basal rate by 0.1 U/hour.

Another way of adjusting your daytime basal rate is to skip breakfast (and the prebreakfast bolus) and adjust the basal rate to keep the blood glucose level constant until lunch.⁵⁷ Repeat the procedure with the other meals during the day.

Changes in the basal rate



When you change the basal rate it will take 2 - 3 hours before any effect will appear, e.g. an increased absorption of insulin into the blood stream. 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 blood stream for another 2 - 3 hours until the depot has decreased in size. The graph is from reference ¹⁹¹.

Nighttime 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 meal to reach a blood glucose level of about 7 - 8 mmol/L (126 - 144 mg/dL) at 10 - 11 PM.⁶³

Blood test at 3 AM and in the morning

Measure

< 6 mmol/L < 108 mg/dL	Decrease the basal rate after midnight and/or early in the morning by 0.1 U/hour.
> 9 - 10 mmol/L > 162 - 180 mg/dL	Increase the basal rate after midnight and/or early in the morning by 0.1 U/hour.

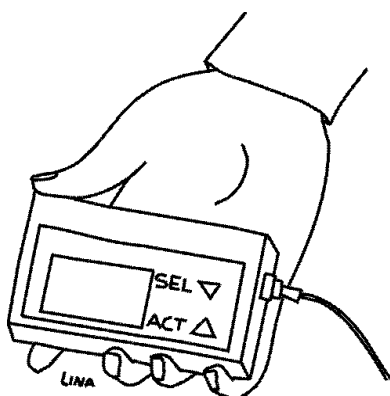
If your pump cannot be adjusted for different basal rate profiles you should adjust it to fit the nighttime need of basal insulin to reach a blood glucose level of 6 - 7 mmol/L (110 - 125 mg/dL) at 3 AM.⁶³

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

or shorter period of time. If you have a pump that can be programmed for only one basal rate you should adjust it according to your nighttime blood glucose values. You will then have to adjust the premeal bolus doses to fit the fixed basal rate.

Temporary change of the basal rate

On many pumps you can make temporary changes of the basal rate for one or several hours. This is



A modern insulin pump is small and handy. You will quickly learn how to use the different controls.

When should the basal profiles be changed? (adapted from ⁵⁷)

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 profiles once or twice in a month according to what your 24 hour blood glucose profiles show. Change the premeal bolus injections to adjust for temporary changes in diet or blood glucose readings. In the following situations it may be necessary to change the basal profiles:

- à Illness with fever and increased need of insulin.
- à Change in school or work activities with a new schedule or different physical activity.
- à Change in body weight with 5 - 10 % or more.
- à Pregnancy
- à Women may have different insulin needs during different phases of the menstrual cycle (see page 194).
- à Initiation of treatment with drugs that increase the need of insulin (such as cortisone).
- à Prolonged physical exercise (12 - 24 hours duration or more).

practical if, for example, you have problems with low blood glucose and repeated hypoglycemia for sustained periods despite extra food intake. It will usually help to decrease the basal rate or stop the pump completely for an hour or two. If your blood glucose is high at bedtime you can temporarily increase the basal rate by 0.1 - 0.2 U/hour for a couple of hours. If your blood glucose is low early in the night you can temporarily decrease the basal rate for a few hours. The temporary basal rate is very useful for prolonged exercise. For example, during a 5 hour bike ride, decrease the basal rate by 50 %. If you have exercised in the evening you should decrease the basal rate by 0.1 - 0.2 U/hour for the whole night.

Premeal bolus doses

Take a bolus dose 30 min before the meal when using regular insulin in the pump and just prior to the meal if using direct-acting insulin (Humalog).

Changing the basal rate

Since it takes 2 - 3 hours before a change in the basal rate will have effect, you must plan ahead.

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

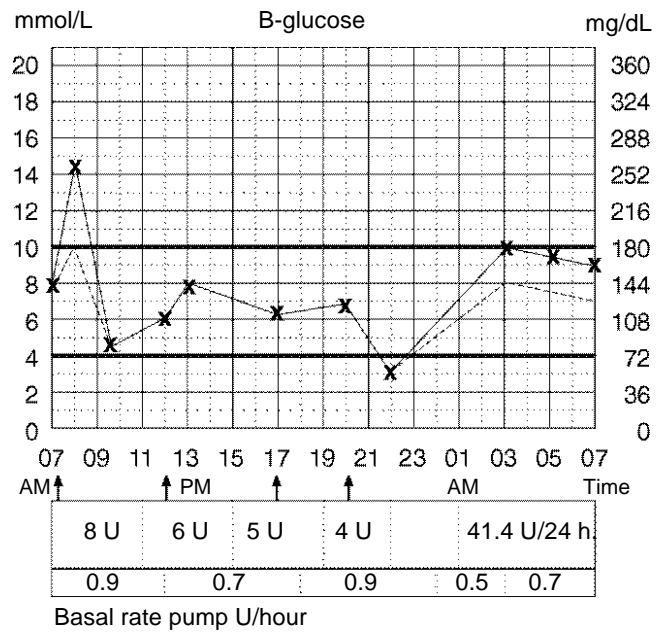
Ā If you want to quickly increase the effect of the basal rate (e.g. if you are ill with fever) you should administer an extra dose of insulin of the same size as 2 hours of the basal rate. You will then quickly increase the insulin depot resulting in a quicker absorption of insulin into the blood.

Ā If you want to quickly decrease the effect of the basal rate (e.g. if you are going to exercise) you should stop the basal rate for 2 hours and then start it again with a lower level. The insulin depot will then quickly decrease in size and the change in basal rate will soon have effect.

However, the timing also depends on what your actual blood glucose level is (see page 107). Adjust the doses up or down in the same way as when on multiple injections. 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, for example, you eat something extra.

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 a premeal bolus injections.¹⁰⁹ See example on page 109. Usually one unit will accommodate 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.

You will not be bound to maintaining an interval between meals (and insulin injections) of at most 5 hours as when on multiple injection treatment. The basal rate will probably make it possible to increase the time span between meals to 6 - 7 hours which might be an advantage if you have an irregular schedule.



Interpreting the 24-hour profile

It is best to take tests for a couple of days in a row to be sure that any one day was not just an exception. Start by looking at the evening meal since it determines what blood glucose you will have when going to bed. The dotted line shows what the blood glucose values might have been with the suggested changes.

Evening meal: The blood glucose after the meal is a bit low. Decrease the dose by 1 unit. Adjust the dose to have a blood glucose of about 8 mmol/L when you go to bed.

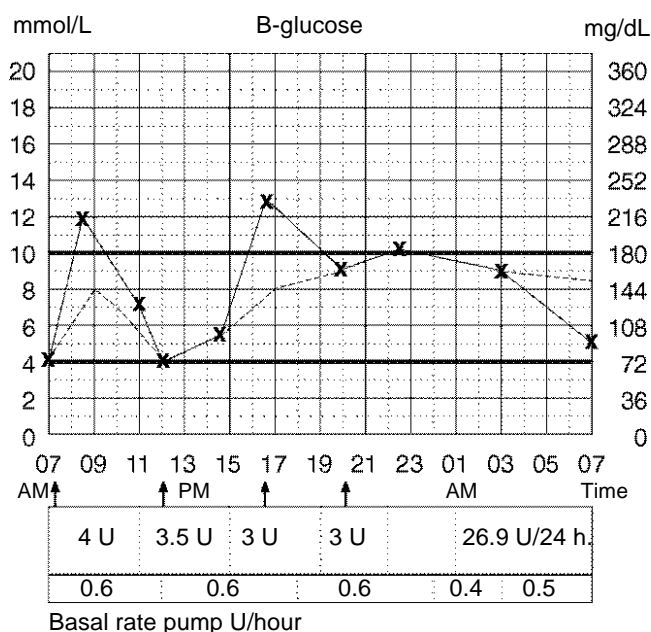
Night: Early in the night the basal rate needs to be increased slightly to 0.6 U/hour as the blood glucose is rising until 3 AM. The blood glucose level from 3 AM to 7 AM is stable so this rate does not need to be changed.

Breakfast: The blood glucose rises very quickly after breakfast. The insulin could have been given even earlier before breakfast to prevent the peak at 8 AM. An increased breakfast bolus dose or basal rate would increase the risk of hypoglycemia before lunch.

Lunch and dinner: No changes.

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

You should, however, be aware of eating and taking premeal bolus injections with intervals shorter than 5 hours as there will be a risk of overlapping insulin doses when using short-acting insulin in the pump. Try reducing the second premeal bolus by 1 or 2 units if the previous meal was only 3 - 4 hours earlier. You will not have this problem if you are using direct-acting insulin (Humalog) in the pump as the action profile of this insulin is considerably shorter.



Interpreting the 24-hour profile

See the previous profile for general interpretation.

Evening meal: No changes

Night: The blood glucose does not change early in the night. However, late at night it drops significantly, so reducing the basal rate to 0.7 U/hour is recommended.

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 premeal bolus dose is correct. However, as the blood glucose rises prior to dinner, the basal rate could be increased to 0.7 U/hour.

Dinner: No changes.

Change of insertion site

The most common site is the abdomen because the absorption of insulin is quickest here. With small children it is preferable to use the buttocks as well to be able to spread the injection sites, thereby decreasing the risk of lipohypertrophies (fat pads). 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 needle catching on the clothing and being pulled out.

Individual advice is needed on how often the needle should be replaced. We recommend the use of a soft

How many carbohydrates will one unit of insulin accommodate?¹⁰⁹

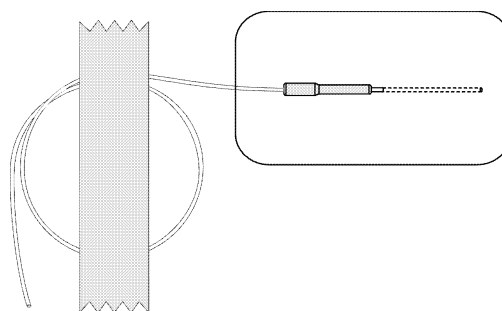
Example:	Carbohydrates (g)	Insulin units
Breakfast	60	6
Lunch	50	4
Dinner	55	5
Evening meal	35	3
Total	200	18

Quotient carbohydrates / insulin = 11.1 gram/unit

In this example of a 12-year old boy (38 kg, 84 pounds) one unit of insulin will accommodate 11 grams of carbohydrates without changing the blood glucose level.

teflon catheter, such as Sof-set[®], Clinisoft[®], PL Comfort[®], Disetronic[®] Tender or similar. Start by replacing it twice a week and then try to increase the number of days between replacements. You can often allow the needle to be in place for 4 - 5 days if your blood glucose readings are not raised. Smaller children usually need to replace it more often. The longer the catheter remains in one site, the greater the risk of developing lipohypertrophies (fat pads, see page 121) and infections. If you have problems with fat pads or redness of the skin you should replace the needle/catheter more frequently.

If the redness doesn't disappear quickly after replacing the needle you can accelerate healing by applying a dressing with warm soapy water for 20 minutes 4 times daily. You can also try an antibiotic ointment or hydrogen peroxide. If the redness increases or starts hurting, you might need antibiotic treatment. Contact your diabetes clinic or doctor.



Put the tubing in a sling and fix it with some adhesive to minimize the risk of pulling the needle loose if the tubing is pulled or jerked.

When do I replace the parts?

Teflon catheter	Start by replacing it twice a week. If there are no problems try using it 4 - 5 days before replacement.
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 needle/catheter 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 "no delivery" alarms.

Problems with irritation or infection of the insertion site can be prevented by careful hand washing, disinfection and needle/catheter replacement every second or third day. Use chlorhexidine in alcohol or similar agent for hand-washing. Don't use products containing skin moisturizers, since these may cause the adhesive to loosen more easily. If you are allergic to the adhesive, it can cause redness or itching (see page 103).

Insert the new needle or catheter before removing the old one. If you do it the other way around there is a greater risk that you will contaminate your hands on the old site, thereby increasing the risk of transferring bacteria to the new one. Insert the new needle/catheter at least 2 - 3 centimeters (one inch) away from the old one to avoid developing fat pads. The adhesive should not cover a previous injection site until it is completely healed. It is best to change sides on the abdomen (left/right) with each replacement.

If you have recurring problems with infected sites in spite of good hygienic routines, the bacteria might originate from your armpits or nostrils. Try washing your hands with a disinfection agent as well. If a culture reveals bacteria from the nasal cavity, antibiotic treatment may be necessary. Avoid inserting the needle in skin folds, close to the belly button or under the waist-line. Straighten your back before you apply the adhesive to avoid tight skin. Always check your blood glucose 3 - 4 hours after replacing the needle/catheter to make sure that it works properly.

Replacement of needle/catheter

- à If you replace the needle/catheter before taking a premeal bolus it will be flushed clean from possible tissue rests by the larger volume of fluid.
- à 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.
- à Start by washing your hands with soap and water.
- à Disinfect a skin area that is a little larger than the adhesive you are going to apply. Use chlorhexidine in alcohol or similar disinfectant. Use this for hand-washing as well if you have problems with skin infections.
- à Be careful not to touch the sterile needle.
- à Pinch a two-finger skin fold and insert the needle at a 45° angle (see ill. on page 102).
- à Apply the adhesive carefully. If it sticks unevenly don't try to move it. There is a considerable risk of removing the needle at the same time if you try to move the adhesive.
- à Withdraw the old needle after the insertion of the new one. Pull the adhesive from the side where the tip of the needle/catheter is located and it will come off more easily.

If you change to a new injection site in the evening you will find it more difficult to detect a blockage in the tubing which will cause the blood glucose to increase. Many pump users find it most convenient to replace the injection site when coming home from school or work. You will still have plenty of time to find out if something is wrong with the new injection site. If you replace the needle/catheter before taking a meal bolus dose the tubing will be flushed clean from possible tissue rests.

Insulin depot with a pump

The disadvantage of using an insulin pump is that the insulin depot will be very small, since only short-acting insulin is used. If the insulin supply is interrupted you will quickly develop symptoms of insulin deficiency like high blood glucose, nausea and vomiting (see "Depot effect" on page 62). This will be important if the pump is blocked or if you

High blood glucose and ketones?

If the blood glucose is higher than 15 mmol/L (270 mg/dL) and you have ketones in the urine, this indicates a blocked insulin supply.

À Take 0.1 U/kg (0.5 units/10 pounds) body weight of short-acting insulin (or preferably direct-acting Humalog) with a pen or a syringe. Don't use the pump as you are not sure if it works well.

À Measure blood glucose every hour. If it doesn't decrease the insulin dose of 0.1 U/kg (0.5 units/10 pounds) body weight can be repeated (every 1 - 2 hours with Humalog, every 2 - 3 hours with regular short-acting insulin).

À Check the pump by disconnecting the tubing and the needle. Activate a bolus dose. Insulin should immediately appear from the tubing. If it drops slowly you should give another bolus injection. If this dose also drops slowly it indicates a partially blocked tubing, e.g. caused by coagulated blood or crystallized insulin. Replace both the tubing and the needle.

À Replace the needle/catheter if the tubing works well. Check for signs of redness in the skin and of moisture close to the injection site indicating insulin leakage.

Other causes of a lack in insulin delivery:

à The connector between the tubing and the insulin reservoir can be broken.

à Hole in the tubing.
A cat bite in the tubing resulted in leakage which lead to ketoacidosis for a teenage girl.

à Air in the tubing is not dangerous as such but will give you less insulin.

à Squeezed or bent tubing, e.g. by a belt or tight jeans, will take several hours before the pump's blockage alarm is triggered.

intentionally turn it off, such as when sporting or swimming.

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 was used. The insulin depot for persons having a subcutaneous fat 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

Causes of ketoacidosis

à Insulin delivery is interrupted, such as a crack in the connector or a loose needle.

à Increased insulin requirements caused by intercurrent illness without the insulin dose being increased, e.g. a cold with fever.

à Inflammation or infection at the injection site (redness or pus).

à Decreased insulin absorption, for example caused by inserting the needle into a fat pad (lipohypertrophy).

à Decreased insulin potency, as after it has been frozen or exposed to heat/sunlight.

their depot.¹⁹³ From this follows that thin individuals will be more sensitive to an interrupted basal rate since their insulin depot is smaller.

Ketoacidosis (diabetic coma)

A small insulin depot will result in early insulin deficiency symptoms if something goes wrong with the pump or the tubing. 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 in the urine when you don't feel well.

If your blood glucose is above 15 mmol/L (270 mg/dL) and you have ketones in the urine you should take an extra dose (0.1 U/kg or 0.5 U/10 pounds body weight) of short-acting insulin (preferably direct-acting Humalog if available). The dose can be repeated after 2 - 3 hours if needed (1 - 2 hours with Humalog). Contact the hospital if you vomit or have nausea and are unable to drink.



Always use local anesthetic (EMLA[®]-cream) before replacing the needle/catheter when beginning with pump treatment with small children. Apply the cream 1½ - 2 hours ahead of time to get the full effect. Another alternative to lessen the pain is the Sof-serter[™] for automatic insertion of the Sof-set[®] catheter.

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

- à Blood glucose at least 2 - 3 times daily (including morning and before going to bed), preferably 4 - 5/day, especially if using Humalog in the pump.
- à 24-hour profile every week or every other week with readings taken before and 1 - 1½ hour after each meal and at night.
- à Before each meal when ill or not feeling well for some other reason.
- à Urine tests:
Glucose and ketones every morning. Ketones when having nausea, during illness or when the blood glucose level is high (> 15 mmol/L, 270 mg/dL).

More frequent home testing

Since there is a greater risk of insulin deficiency with a pump you must be willing to take more blood glucose tests. A minimum is 2 - 3 tests a day including morning and late evening. You must also be careful to check urine tests every morning and when not feeling well (ketones are a sign of insulin deficiency). A 24-hour blood glucose profile with tests before and 1 - 1½ hours after each meal is needed every week or every second week to adjust your doses correctly. You should also take night-time tests when compiling a 24-hour profile (at 2 - 3 AM and if needed at 5 AM as well).

Use a logbook in which you clearly document the pump's basal rate. We find it best to use a logbook where every entry is written on a blood glucose chart. This will enable you to visually observe patterns in your blood glucose readings (see charts on page 108). Make it a habit to check the pump daily for the total number or units delivered/24 hours and record this in your logbook.

Disconnecting the pump

Sometimes you will want to disconnect the pump for one reason or another. Some needle/catheter sets allow you to disconnect the tubing or between the needle and the tubing by using a rubber membrane as a one way valve. Remember to save the needle's sterile casing so that you can put it back on

IMPORTANT!!

When using an insulin pump you have a greater risk of ketoacidosis since you have a very small insulin depot.

Always check blood glucose and urine tests (ketones) when you have nausea or vomit!!! If the amount of ketones increases (e.g. from 2+ to 3+) this means that the insulin deficiency is increasing. You must then contact the hospital to discuss what to do next!

Be aware that insulin deficiency leading to increased ketone production immediately shows up in the urine. If you take extra insulin the production of ketones will stop. However, the excretion of ketones in the urine will continue for many hours but you will see that the concentration stabilizes and then decreases as the hours pass.

If you are the least bit doubtful or cannot get hold of someone who knows insulin pumps well, you should take an injection of insulin by pen or syringe and then go to the emergency ward.

Always bring extra insulin wherever you go even if you are only going to be away from home for a couple of hours!

again when you want to disconnect the tubing. Use self-sticking Velcro[®] to fix it onto the pump's leather case. If you have a so called Luer connection between the tubing and needle/catheter you should fill it with insulin before connecting. It is easiest to have the pump deliver a bolus dose, letting the drops fall into the Luer connector.

Pump alarm

Insulin pumps seldom malfunction. If one does, it will stop. 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, e.g. blocked tubing, an empty insulin container or low or flat batteries. 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 meal insu-

Causes of high blood glucose

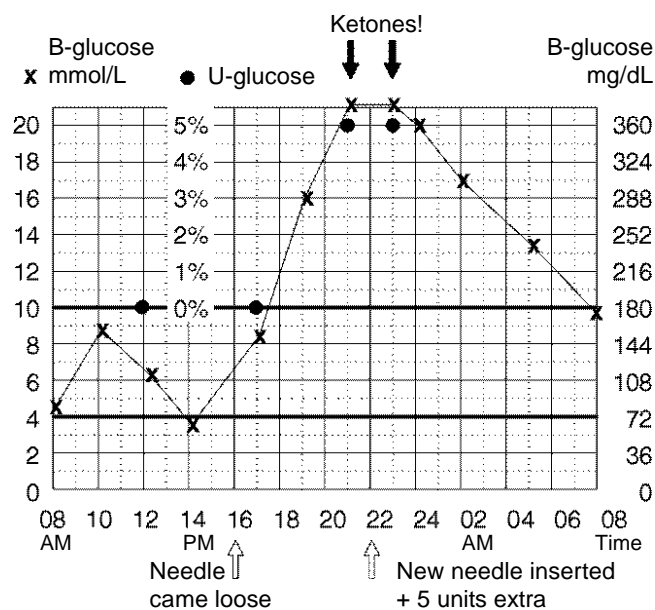
(adapted from ³⁷⁵)

- Ā The pump**
Basal rate too low
The pump has triggered an alarm and shut itself off
Other pump trouble
- Ā Insulin reservoir**
Wrong position in the pump
Empty reservoir
Leakage in the connection with the tubing
- Ā Tubing and needle/catheter**
Forgetting to fill the tubing when replacing
Leakage in connections
Adhesive and needle is loose
Air in the tubing
Blood in the tubing
Needle/catheter has been in place too long
The tubing was replaced in the evening without giving a bolus dose to build up the pressure.
Bent/squeezed tubing
Blocked needle/catheter
- Ā Injection site**
Redness, irritation / infection
Fat pad at the injection site
Placement close to waist band
- Ā Insulin**
Cloudy insulin
Expiration date passed
Exposed to heat / sunlight

lin or forgot to push one of the buttons before going to bed.

“No delivery alarm”

The pump alarm will be triggered if there is an increased resistance when pumping insulin. It cannot tell where that the blockage is in the system. It may be that the insulin reservoir is empty, the plunger may be sluggish or the tubing or needle blocked. The tubing can be bent or squeezed, for example by a belt buckle. If the “no delivery” 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



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 the patient was feeling nauseous. He checked for ketones and discovered that something was wrong. When he checked the needle it was loose and the insulin was not entering his body. He gave himself 5 extra units 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 needle/catheter. Give a bolus dose and see if insulin comes out from the tip. Bend the catheter and give another bolus dose. The pump should now give a blockage alarm. Check the tubing and connections for leakage. Replace the needle/catheter and check the blood glucose level frequently to make sure that it decreases. Take an extra injection (with a pen or syringe) of 0.1 U/kg (0.5 units/10 pounds) body weight if you have ketones in the urine and check your blood glucose once again after 1 - 2 hours. Repeat the dose if necessary.

out and try careful massaging of the infusion port and catheter under the skin. If you haven't disconnected the tubing there is no need to take extra insulin other than the remaining premeal dose if the pump now works without alarm (assuming that the blood glucose level is not raised).

If the needle 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 pump alarm in your pump. It may also depend on which tubing you have and how long it is. test it by pushing the needle into a rubber cork or pinch the end of the catheter. If you

Stopped pump

Time that the pump has been stopped	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 2 - 4 hours. Check your blood glucose when you connect the pump and take an extra bolus dose if needed.
> 4 hours	Dose before disconnecting as above. Using a pen injector or syringes, take extra short-acting insulin every 3 - 4 hours corresponding to the missed basal rate. Take the premeal bolus dose with the pen or syringe.

then give a bolus dose you will see how many units are pushed into the tubing before the alarm is triggered.

If your pump for example has given 4.3 units of the meal bolus dose when the alarm goes off and you know that 2.6 units are needed to build up pressure to trigger the alarm, you will have only received $4.3 - 2.6 = 1.7$ units of the bolus dose.

For smaller children we often use insulin of 40 U/ml. You must then remember 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 alarm for a block in the tubing even after you have replaced both the tubing and the needle. 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, e.g. motor problems. If the pump works well without the reservoir the reason may be that you have reused it. When doing so the silicon on the plunger wears off, and this may result in a “no delivery” alarm.

Occlusion alarm (“no delivery”)?

- À** 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 pre-meal bolus, take the remaining portion.
- No alarm Ë OK, no problems
Alarm Ò
- Â** Disconnect needle/catheter from tubing. Start a bolus dose with the pump.
- No alarm Ë Replace needle/catheter
Alarm Ò
- Ã** Disconnect tubing from insulin reservoir. Start a bolus dose with the pump.
- No alarm Ë Replace tubing
Alarm Ò
- Ä** Remove the insulin reservoir from the pump and start a bolus dose.
- No alarm Ë Replace reservoir
Alarm Ò
- Å** Something is wrong with the pump. Contact the pump dealer and deliver insulin with a pen or syringe.

Leakage of insulin

The pump can't alarm if there is an insulin leakage. It will only trigger if the motor runs against resistance. Insulin can be disposed outside the injection site if the needle has been retracted. Often this can be only 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 if there is a leakage.

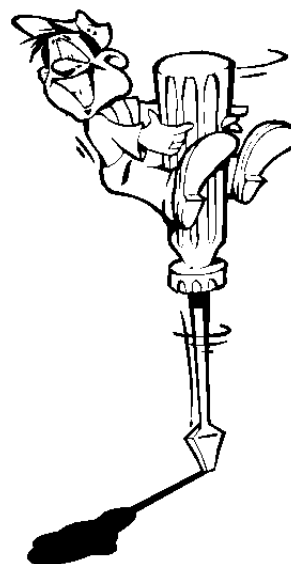
The tubing connector on the pump end can crack, causing leakage, especially if you are too rough when connecting it. Feel the connector with your fingers. If there is a leakage you can often detect the smell of insulin.

Air in the tubing

When you connect the tubing to the pump there is always a risk of air entry, especially if you fill it with cold insulin. Air will come out of the solution when the temperature rises. Always make sure that

Problems with the pump?

Problem	Measure
Infection/irritation at the injection site	Wash hands and skin with chlorhexidine in alcohol. Replace needle/catheter more frequently.
Blocked needle or catheter	It can be bent or blocked by coagulation or insulin crystals. Replace it.
Blocked tubing	Can be caused by precipitation of insulin. Disconnect the needle and tubing and give a bolus dose. Replace if the alarm is triggered.
Blood in the tubing	Disconnect the tubing from the needle and give a bolus dose. The pump will then trigger the occlusion alarm if it is blocked.
Air in tubing?	See text on page 114.
White spots on the inner layer of the tubing	Many kinds of tubings are made of 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/catheter come loose? Is there a bent catheter? Replace the needle/catheter.
Moisture under the adhesive	This indicates insulin leakage. Replace the needle/catheter.
Adhesive comes off	Wash the EMLA [®] - cream off carefully with water. Don't use disinfectant with skin moistener. Let the skin air dry before you apply the adhesive. 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 rests of adhesive	Wipe off with medical benzine.
Sore skin from plastic wings	Apply a piece of tape beneath the hard plastic.
Scars in the skin from old catheters	Caused by an infection of the insertion site. Replace needle/catheter more frequently.
Redness of the skin at the needle tip	Can be caused by insulin allergy. See page 122
Nothing works	Try running the pump with both insulin and tubing removed.



An insulin pump needs to be looked after, and tubing and batteries need to be replaced. When the alarm triggers you must know how to deal with it. You will be the "first line pump mechanic" and will probably find it easier if you are technically oriented. However, this is not a requirement.

the insulin is at room temperature before refilling the reservoir. Introducing air into the subcutaneous tissue is of no concern, but you will miss the corresponding amount of insulin. The alarm will not be triggered since the pump's microcomputer 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 meal bolus dose you can compensate with a little extra insulin. Five to seven cm (1 - 1½ inch) of air in the tubing usually correspond to 1 unit of insulin. To find out the exact dimension of your pump tubing give a bolus dose of 1 unit when replacing the tubing. Make a mark on the tubing with a felt tip pen corresponding to 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 needle in the skin. Give an extra bolus dose "into the air" to purge the air in the tubing and fill it with insulin once again.

Infusion sets with soft cannula

Brand	Length cm	inches
PL Comfort [®]	60, 80, 110	24, 32, 43
Clinisoft [®]	55, 80, 110	22, 32, 43
Sof-set [®]	61, 107	24, 42
Disetronic [®] Tender	30, 60, 80, 110	12, 24, 32, 43

For most tubes, 5 - 7 cm (2 - 3 inches) contain approximately 1 unit of insulin. The Sof-set[®] needle can be used with an automatic inserter (Sof-serter[™]) that lessens the pain.

Intercurrent illness and fever

When you are ill, especially with fever, your body will increase its insulin requirements, often by 25 % for each degree celsius of fever (see page 177). It is advisable to start by increasing the basal rate. Start by a 10 - 20 % increase when you notice that your blood glucose is rising. You will probably also need to increase the meal bolus doses according to your blood glucose readings. It is important that you test your glucose level before each meal when ill and preferably 1 - 1½ hours after the meal as well. Most often you will also need to check the blood glucose levels in the night.

Doses without the pump

It is very important that you always carry extra insulin wherever you go in case of pump malfunction. Check to see that the insulin has not expired. You should have written down what doses to begin with if you temporarily need to use a pen or syringes.

À Use the old doses

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

À Intermediate-acting insulin at bedtime

Look at the pump doses. The breakfast dose with a pen will be the sum of the pump pre-breakfast dose and the basal rate between breakfast and lunch. If you have a high basal rate (>1.5 - 2 U/hour) start by only counting 1 - 1.5 U/hour when calculating the dose with pen or syringes.

The bedtime dose of intermediate-acting insulin (Insulatard, Humulin NPH, Isuhuman Basal) is calculated by adding the basal rates between 10 PM and 8 AM (see example on page 117). You can also use short-acting insulin (*not* Humalog) during the night, giving two doses, at 10 PM and 3 AM corresponding to the sum of the basal rates during the night.

À Long-acting basal insulin

The most logical choice is to replace the basal dose in the pump with long-acting insulin (Ultratard, Ultralente) and to use the same bolus doses (and type of insulin) before meals as when using the pump. Take the total basal dose during 24 hours, add 10 - 20 % and divide into 2 equal doses that you take with breakfast and dinner (around 5 - 6 PM).

Being admitted to the hospital

If you are admitted to the hospital in an acute situation you will often find that there is no staff available who are familiar with the pump. If you have problems with the pump it is usually best to begin injecting insulin with a pen or syringes until the daytime staff arrives. If you vomit or have signs of ketoacidosis the best treatment is intravenous insulin (see page 57).

Physical exercise

When physical active you can disconnect the pump for 1 - 2 hours time without taking any extra insulin. If your exercise lasts longer than 2 hours you will probably be better off by keeping the pump connected and using the temporary basal rate. Try half the basal rate while exercising and for an hour or two following. You may need to lower the basal rate even more — but the only way to know for sure is to try it yourself.

If the time of exercise is within 1 - 3 hours after a meal you can try taking half the meal bolus dose or

Insulin pump and illness

- à Continue with your ordinary meal bolus doses, increasing them by 1 - 2 U if necessary.
- à Increase the basal rate by 0.1 - 0.2 U/hour if the blood glucose continues to be high.
- à Never discontinue the basal rate completely even if you have problems with hypoglycemia.
- à Check your blood glucose every 2nd to 4th hour. Check for ketones in the urine frequently. Keep good records in your logbook.
- à Take extra insulin (1 U/10 kg or 0.5 U/10 pounds body weight), preferably Humalog, if your blood glucose is high and you have ketones in the urine. Give another 1 U/10 kg (0.5 U/10 pounds) every 2nd hour until the blood glucose is below 10 mmol/L (180 mg/dL) and the level of ketones in the urine is decreasing.
- à Give the extra insulin with a pen or syringe. The reason for the high blood glucose may be pump malfunction.
- à 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 the urine you will lose extra fluid. Drink glucose-free fluids when the 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 are nauseous, try to drink small volumes (a couple of mouthfuls) at a time.

Call the hospital

- à the first time you become ill after having started with the pump.
- à if you have nausea that prevents you from eating for more than 6 - 8 hours.
- à if you have vomited more than once during a 4 - 6 hours period.
- à if the blood glucose level has not been lowered or the ketones in the urine have not decreased after the second extra dose of insulin.
- à if your general well-being is worsening.
- à if you are in the least uncertain as to how to handle the situation.

AM	PM	AM	Time			
↓	↓	↓	Pump			
7 U	5 U	5 U	4 U	42 U /24 h.	Premeal bolus dose	
0.9	0.8	1.0	0.7	0.9	Basal rate pump U/h.	
↓	↓	↓	↓		Pen/Syringe	
11 U	9 U	9 U	6 U	8 U	43 U /24 h.	Premeal bolus dose
Reg.	Reg.	Reg.	Reg.	NPH		
7+	5+	5+	4+	1.0 x 2	Calculation	
0.9x5	0.8x5	0.8x2+ 1.0x2	1.0x2	0.7x3+ 0.9x4		

Intermediate-acting bedtime insulin

Sometimes you must use an insulin pen or syringes for a while, e.g. if something is wrong with the pump. 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 previously when on multiple injections.

7 U	5 U	5 U	4 U	46 U/24 h.
12U UT		13U UT		

Long-acting basal insulin (Ultratard = UT)

Basal rate in pump 21 U+20% = 25U divided in 2 doses

Another alternative is to replace the basal rate in the pump with a long-acting insulin (Ultratard, Ultralente) given twice daily and continue using the same bolus doses (and the same type of insulin, short-acting or direct-acting) before meals as with the pump. You will probably need to increase the amount of basal insulin by 10 - 20 %.

even skipping it if the exercise is particularly strenuous. However, you will then probably need to keep the pump connected to get the basal rate during the entire time of the exercise.⁴¹⁹

Don't forget to refill your glucose storages after exercise (see page 169). After strenuous exercise (e.g. a ball game or skiing) you must decrease the basal rate by 0.1 - 0.2 U/hour during the night to avoid hypoglycemia. Try this out yourself and note the blood glucose tests in the logbook for future reference if faced with a similar situation.

Nighttime pump?

Some feel that the pump has obvious advantages during the night but that multiple injections are bet-



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 to take the bolus dose but since the insulin can't be allowed to freeze, you must protect it from low temperatures.

ter during the day. If you look at the insulin level in the blood it will be slightly higher at night and especially early in the morning, when using a pump (see figure on page 104). This is an advantage. During the day, in between meals, the insulin level is slightly higher with a pump, which is not desirable since it will increase your need to eat snacks and that can contribute to a weight gain.

You should not hesitate to try connecting the pump in the evening, letting it stay in place during the night, and disconnecting it in the morning. During the day you can use a pen injector or syringes for premeal bolus doses. Talk to your diabetes doctor if this sounds appealing.

Is the pump disturbing?

You must carry your insulin pump 24 hours a day. "How do you sleep with it?" many ask. You will be surprised how quickly you get used to wearing the pump at night. Some people who lie quite still put the pump besides 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 belt or in a pajama pocket. "What do you do with the pump when having intercourse?" was the first question my friends asked me, an 18 year old girl told us. It is easiest to disconnect it for a while if it is disturbing. Making love is also physical exercise and you might do quite well with a little less insulin for a while.

Will I gain weight when I start with the pump?

There is always a risk of gaining weight when your blood glucose improves since you lose less glucose into the urine. You should therefore try to reduce

When should I disconnect the pump?

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

your calory intake when starting with a pump. If you have frequent hypoglycemias you will risk weight gain since you will frequently need to snack. If you start enjoying extra "freedom" like candy and chips you will also gain 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 still have the basal rate to ensure your basal insulin requirements.

Taking a bath or shower

Most pumps can stand some water but you must disconnect them when taking a bath. When taking a shower there is a shower protector to put over the pump, but many prefer to simply disconnect it for a short while. You should also disconnect the pump if you have a sauna since insulin can't take the heat. The heat in a sauna will cause previously injected insulin to be absorbed much more quickly (see page 64). There is a protective waterproof case available which can be used, for example on the beach.

Travel tips

Don't forget to adjust the pump's clock if you travel across time zones. Change the clock to the time of arrival when you get on the plane. Measure blood glucose before each meal and make necessary adjustments of the bolus dose. Always bring extra insulin and an insulin pen or syringes wherever you go. 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. See page 205 for further travel tips.

Pregnancy

Using an insulin pump is an excellent method to obtain blood glucose values close to those of a per-

son without diabetes. With a close to normal blood glucose, the risk of complications during pregnancy decreases to the same levels as for non-diabetic women (see page 191). During the later part of pregnancy it might be difficult to have the pump needle on the distended abdomen. You can instead try 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 needle 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 ketones in your urine. Adding a bedtime dose of intermediate-acting insulin (0.2 U/kg) in addition to the normal basal dose delivered by the pump has considerably decreased the risk of ketoacidosis.²⁸²

Humalog in the pump?

As direct-acting insulin (Humalog) acts more rapidly when taken prior to a meal and more closely mimics the non-diabetic insulin response, it seems logical to try it when using an insulin pump. In a Canadian study regular short-acting insulin and direct-acting insulin were used in insulin pumps during a 3 month double-blind cross-over study.⁴³⁸ All bolus doses were given immediately before the meals. HbA_{1c} was significantly lower (7.7 % compared to 8.0 %) when using direct-acting insulin but there was no difference in the frequency of hypoglycemia.

One problem when using insulin with an even shorter duration is that your body's depot of insulin

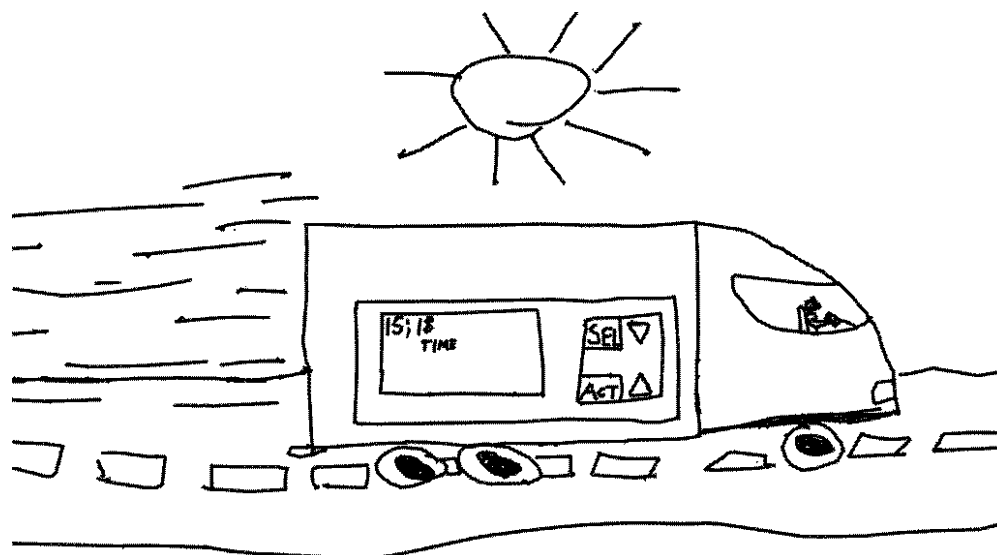
will decrease considerably as well. This implies that insulin deficiency symptoms will arise quickly if the pump fails.

In a German study the pump was stopped in the morning in 7 patients.³¹⁶ A deterioration in control was defined as an increase in blood glucose of more than 8.3 mmol/L (150 mg/dL), an increase of more than 2.2 mmol/L (40 mg/dL) in 15 min., appearance of ketones in the urine or symptoms of insulin deficiency.

When the subjects used regular short-acting insulin the deterioration occurred at a mean of 386 min (range 135 - 510 min) while the mean was 251 min (range 45 - 380 min) when direct-acting insulin was used. In other words one can compare a pump stoppage of about 4 hours with direct-acting insulin compared to about 6 hours with regular short-acting insulin. However, notice that variability is great, meaning that the individual differences are considerable.

Some patients have already tested direct-acting insulin in their pumps and many like it. However, if you develop symptoms shortly after the pump stops you are probably better off using regular short-acting insulin.

When using direct-acting insulin in the pump you may need to lower the bolus doses since the bolus doses of regular insulin you previously used supplied part of the basal insulin, overlapping with the next meal as well. To compensate for this you may need to increase the basal rate instead.



An insulin pump will enable you to fine tune your insulin doses and will give you more "horsepower under the hood" to take care of your diabetes. However, it will demand greater knowledge and attention to make it work well just like a stronger and faster car. If you use it correctly an insulin pump is a very good tool and a powerful support on your long diabetes journey.

The onset of action with a premeal bolus dose of Humalog may be too rapid in certain situations, like when eating a meal that digests slower (like pasta or pizza), or a longer dinner with many courses like when on conference. You can try by taking the bolus dose after the meal. If you have a pump that can deliver the dose more slowly (“square wave bolus”) this is an ideal solution in these situations. You can use it even if you have problems with gastroparesis (slower emptying of the stomach due to diabetic neuropathy, see page 216) (see the diet chapter on page 147 for further advice on the use of Humalog).

Side effects of insulin treatment

Pain

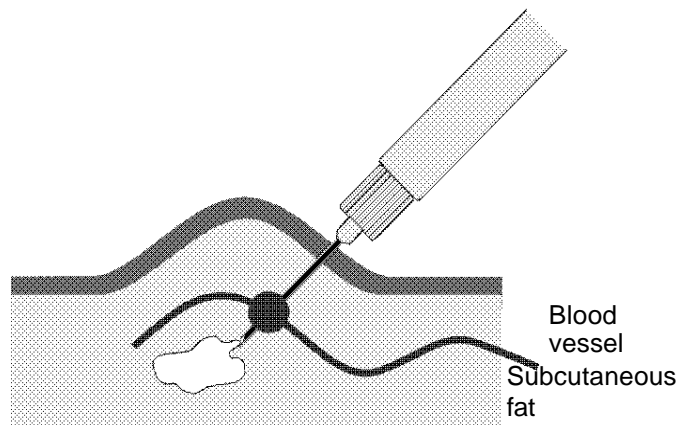
If an injection is extra painful you have probably hit a nerve or a tactile organ (see ill. on page 91). If you can stand the pain you can readily inject the insulin, otherwise you must pierce the skin once again.

Insulin leakage

It is not uncommon for a drop of insulin to come out on the skin after withdrawing the needle. Two to three drops from a pen needle contains approximately one unit of insulin (100 U/ml). In one study on children and adolescents with diabetes 68% encountered leakage of insulin after injections during one week. Twenty-three percent of the injections were followed by leakage of up to 18% of injected dose (2 units of an intended dose of 11 units).³⁷⁹ It may be difficult to avoid insulin leaking, but the risk is smaller if you lift a skin fold and inject at a 45° angle (even if you use an 8 mm needle). Try to inject more slowly. You can also try to withdraw the needle halfway and then wait 20 seconds before withdrawing it completely. Earlier the standard advise was to stretch the skin sideways when injecting to avoid this problem, but this is not a good idea because you instead risk an intramuscular injection.

Blocked needle

Sometimes the needle will be blocked when you inject long- or intermediate-acting insulin. This can be caused by the crystals in the insulin that aggregate. It seems to depend on how quickly you inject the insulin. Try injecting more slowly or even more rapidly. The risk increases when reusing the needles as remaining insulin may crystallize inside the needle barrel.



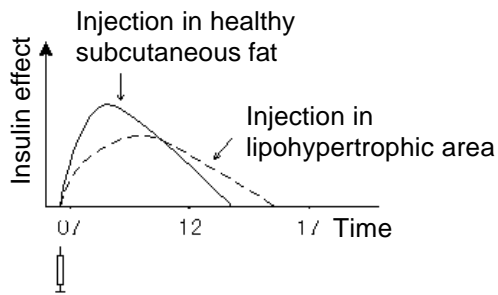
If you penetrate a superficial blood vessel with the needle there may be a bleeding. A bleeding under the skin will feel like a small bubble, which is often bluish in color.

Bruises after injections

If you penetrate a superficial blood vessel in the subcutaneous fat a small bleeding may arise. The blood vessels in the subcutaneous fat however are so small that there is no risk that insulin will be injected directly into the vessel. It will feel like a small bubble under the skin that sometimes is bluish in color. Such a bleeding is quite harmless and is absorbed completely after some time.

Fat pads

Fat pads (lipohypertrophies) contain both fibrous and fat tissue.⁴⁰¹ They are caused by insulin's effect of stimulating growth of fat tissue. This is a common problem when you don't vary your injection sites frequently enough. A child usually wants to prick the skin where it hurts the least, resulting in injections too close together. It is important to carefully explain this and to help find a system for rotating the injections sites effectively. Younger children (less than 10 - 12 years of age) should have a parent helping them with 1 - 2 injections per day and then preferably inject at places that the child might have difficulties in reaching, such as the buttocks (see "Where do I inject the insulin?" on page 92).



Insulin will be absorbed slower if you inject in an area with fat pads (lipohypertrophy).

Reusing needles causes blunting which increases the microtrauma of repeated injections. This may contribute to increased lipohypertrophy by build-up of fibrous tissue from the release of local growth factors.³⁸¹

Injections in fat pads will usually result in a slower absorption of insulin.^{245,436} An area with lipohypertrophy should be left alone for a couple of weeks. One way to accomplish this can be to use an indwelling catheter (Insuflon, see page 101) with which the injection sites can be actively rotated. Another way is to use a guide with a rotation scheme, designed with holes or sectors for different days of the week.¹⁵⁴

Remember that insulin will have a quicker action of you inject it in an area free from lipohypertrophy. You may have to lower the dose to avoid hypoglycemia.

Redness after injections

Redness, sometimes with itching, that occurs immediately or within hours of an insulin injection can be due to an allergy towards the insulin or a preservative. This type of reaction will usually subside after some years as you continue with insulin treatment.³¹⁷ Inform your doctor if you have prob-



Insulin causes the subcutaneous tissue to grow if you often inject into the same spot. You will get a "fat pad" (lipohypertrophy) in the skin that feels and looks like a bump.

lems with redness after injections. There is a special skin test available to find out if you are allergic to the insulin or the preservative. There is often an increased level of insulin antibodies in the blood (see below) as well. If problem with redness continue, adding a small amount of cortisone to the insulin usually has a good effect.²⁶⁶ A generalized allergic reaction after insulin injection is very rare.⁸³

Allergy towards nickel in pen and syringe needles can cause redness after injections. The needles are covered with a layer of silicone lubricant. If you are allergic to nickel you should not use the needles more than once as the silicone layer wears off and the nickel will come in closer contact with the skin. Needles on syringes have a thicker silicone layer since they need to penetrate the rubber membrane of the bottle when drawing up insulin, thereby being more appropriate if you have a nickel allergy. You can take a skin test to see if you are allergic to nickel. You will usually react to nickel in other materials as well, for example ear-rings, belt buckles or wrist watches.

EMLA[®]-creme (a topical anesthetic used for venepuncture or when replacing indwelling catheters) can cause an allergic redness that looks very much like an allergy against the adhesive.

Insulin antibodies

The body will produce antibodies against foreign substances. Insulin antibodies with porcine and bovine insulin were common. With the use of human insulin it is not common to have high enough levels of antibodies to cause problems. Insulin antibodies work by binding insulin when there is a high level of free insulin, e.g. after a meal bolus injection.¹⁷ When there is a low level of free insulin, e.g. during the night, they release insulin.¹⁷ In this way the insulin concentration in your blood will be levelled off in an unfortunate manner. When you want a high level of insulin after a meal it will be lowered (resulting in high blood glucose) and when you want a low level in the blood during the night you will instead have too much insulin (resulting in hypoglycemia). One can say that with high levels of insulin antibodies you will produce long-acting insulin on your own.

One possible method to lessen these problems is to give a fairly large dose of short-acting insulin in the morning to "saturate" the insulin antibodies. During the day you give smaller and smaller doses of short-acting insulin prior to meals. At bedtime give only a small dose of insulin to lessen the risk of nighttime hypoglycemia.

Switching to direct-acting insulin (Humalog) substantially decreased the level of antibodies and problems with early morning hypoglycemia in a case report.²⁴⁷ Apparently, the structural differences between regular short-acting and direct-acting insulin molecules prevented Humalog from binding to the human insulin antibodies.

You can measure how much of the total amount of insulin which is bound to antibodies with a blood test. Normally this level is approximately 6 % but we have seen values above 90 % in cases where the patient has had especially difficult problems. Insulin antibodies can be very troublesome but usually the negative effects will slowly subside after several years even if you have measurable levels of antibodies.

Lipoatrophy

Lipoatrophy is manifested as a cavity in the subcutaneous tissue. The reason for its development is somewhat unclear. Lipoatrophy usually does not appear in areas where you have given very frequent injections. It is instead believed to be an immunologic reaction towards insulin in which subcutaneous tissue is broken down.³¹⁷ Patients with lipoatrophy often have high levels of insulin antibodies. You can treat the cavities by injecting insulin along the edges. This will cause the formation of new “fat pads” and eventually the cavities will disappear.

Insulin edema

Sometimes you can get a local or generalized edema when you quickly improve the glycemic control. This is caused by a temporary accumulation of fluid in the body and usually subsides spontaneously over a period of days to weeks with continued good glycemic control.³⁶⁶ In severe cases, ephedrine has been used successfully.²⁰⁴