

In this article...

- How to treat and manage type 1 diabetes
- What the history of insulin is and how it works in the body
- Different treatment options available to people living with type 1 diabetes

Type 1 diabetes: treatment, management and the use of insulin



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Key points

Insulin is an essential treatment for the management of type 1 diabetes

Having an understanding of different types of insulin can ensure the right insulin is administered at the right time

Insulin can be administered either by injection or insulin pump

There is currently no cure for type 1 diabetes but research is striving to find one

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Abstract It is vitally important to manage type 1 diabetes well to improve the individual's quality of life and reduce the risk of complications. This article, the second of two on type 1 diabetes, aims to enable readers to understand how to monitor blood glucose and administer insulin. Normally, a long-acting basal insulin and a short-acting bolus insulin are used to manage diabetes. As insulins vary in their durations of action, this article provides details of different insulins and their indications. It also considers injection sites, insulin pumps and continuous glucose monitoring.

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The treatment for type 1 diabetes can appear complex, with many different options available. Providing a person who is living with type 1 diabetes with the correct treatment can not only avoid life-threatening consequences, but also greatly improve quality of life and prevent long-term complications. This article explores the treatment options for type 1 diabetes, focusing on insulin and how it can be administered. This is important, as nurses often lack confidence with insulin management and seek greater understanding of the different types of insulin and when they should be given.

Treatments for type 1 diabetes

The main treatment for type 1 diabetes is insulin. Without insulin, people living with type 1 diabetes could experience life-threatening consequences. Some people living with type 1 diabetes may have other medications in addition to insulin, such as metformin or a sodium-glucose cotransporter-2 (SGLT2) inhibitor – treatments that are typically used in the care of type 2 diabetes. However, these treatments should not replace insulin and they are often initiated under diabetes specialists.

What is insulin?

Insulin is a polypeptide hormone that is produced by pancreatic beta cells. As discussed in the first article in this series, people living with type 1 diabetes do not produce any insulin. Insulin allows the uptake of glucose, which is released from the liver and from food – particularly carbohydrates – into blood cells for the body to maintain a normal blood glucose level and for the individual to have energy.

History of insulin

Insulin was first discovered in 1921 by Frederick Banting, Charles Best and John Macleod at the University of Toronto in Canada. They had been researching how to remove insulin from the pancreas of dogs, which was then further explored by taking insulin from cattle (Quianzon and Cheikh, 2012). In 1922, a 14-year-old boy named Leonard Thompson became the first person to be administered with animal insulin – within a short period of time, he had normal blood glucose levels (Greenhill, 2021).

Pharmaceutical company Eli Lilly began the production of animal insulin, and other pharmaceutical companies later developed

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a variety of slower-acting insulins. Animal insulin from cattle and pigs was used for many years, but many people had allergic reactions to it. For this reason, synthetic 'human' insulin was created in 1978 (American Diabetes Association, 2019).

Different types of insulin

Insulin can be broadly categorised into three main groups:

- Short-acting (including soluble and rapid-acting);
- Intermediate-acting;
- Long-acting.

Insulin terms used in diabetes care

It is important to be familiar with the terms used in clinical practice, as often you may hear "the patient is on a basal-bolus regimen" or "you need to give the bolus-basal insulin". Key terms to be aware of include:

- Bolus insulin – this is rapid-acting insulin that is given with meals or used as a correctional dose to reduce an elevated blood glucose level;
- Basal insulin – this is long-acting insulin. This type of insulin should never be omitted;

- Basal-bolus regimen – this is when a person is taking both basal and bolus insulin. This is the most common treatment regimen in type 1 diabetes.

All of this can be confusing, so we will discuss the different types of basal and bolus insulin in more depth.

Analogue insulin

Analogue insulin is made in a laboratory and created by growing insulin proteins with *E coli* bacteria. Available in two main forms – rapid-acting insulin and long-acting insulin – it can also be pre-mixed.

Table 1. Insulins commonly used to treat diabetes

Insulin type	Brand names	When to give	Onset	Peak	Lasts for	Insulin action profile over 24 hours
Rapid-acting analogue	<ul style="list-style-type: none"> • NovoRapid® • Humalog® • Apidra® • Fiasp® 100 units/ml	Immediately before, with, or up to 15 minutes after food	15-30 minutes	15-30 minutes	4 hours	
Short-acting soluble	<ul style="list-style-type: none"> • Actrapid® (used in insulin infusions) – 100 units/ml • Humulin® S – 100 units/ml • Humulin® R 500 units/ml – off licence 	20 minutes before food	30 minutes	30 minutes	6-8 hours	
Intermediate-acting isophane	<ul style="list-style-type: none"> • Humulin® I – 100 units/ml • Insulatard® – 100 units/ml 	Before bed or 30 minutes before food	30 minutes to 2 hours	30 minutes to 2 hours	12-16 hours	
Long-acting analogue	<ul style="list-style-type: none"> • Lantus® (glargine) – 100 units/ml • Levemir® – 100 units/ml 	Any time of day, but always same time of day, OD or split BD	1-2 hours	2-4 hours	18-24 hours	
Analogue insulin mixtures	<ul style="list-style-type: none"> • Humalog® Mix25 – 100 units/ml • Humalog® Mix50 – 100 units/ml • NovoMix® 30 – 100 units/ml 	Immediately before, with, or up to 15 minutes after food	15-30 minutes	1 hour	8-16 hours	
Soluble insulin mixtures	<ul style="list-style-type: none"> • Humulin® M3 – 100 units/ml 	20-30 minutes before food	30 minutes	1-2 hours	10-14 hours	
Super long-acting analogue	<ul style="list-style-type: none"> • Toujeo® – 300 units/ml • Insulin degludec – 300 units/ml 	Any time of day, but always the same time of day, OD	<ul style="list-style-type: none"> • Toujeo: 6 hours • Degludec: 30 minutes to 1.5 hours 	No peak	36 hours	<p>Toujeo ▶36hrs</p> <p>Degludec ▶36hrs</p>

OD = once daily; BD = twice daily



Examples of rapid-acting analogue insulin are:

- Humalog®;
- NovoRapid®.

Examples of long-acting analogue insulin are:

- Lantus® (insulin glargine);
- Levemir® (insulin detemir).

Human insulin

Human insulin is made in the same way as analogue insulin and is available in two forms:

- Short-acting insulin;
- Intermediate-acting insulin.

An example of short-acting human insulin is Actrapid®, which is most commonly used in insulin infusions to treat conditions such as diabetic ketoacidosis (diabetes.co.uk, 2023).

Neutral protamine Hagedorn insulin

Neutral protamine Hagedorn (NPH) insulin is an insoluble intermediate-acting insulin made in the same way as human insulin. It is not as long-acting as others and is commonly used for type 2 diabetes. Examples of NPH insulin are Humulin® I (Isophane®) and Insulatard®, which are used frequently in gestational diabetes (Saleem and Sharma, 2023).

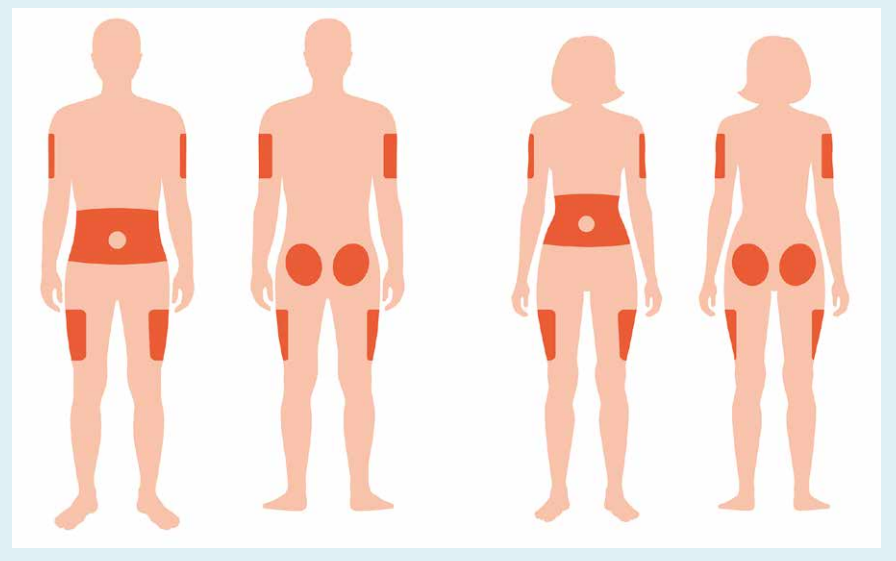
Animal insulin

Animal insulin was the first insulin that was administered to humans. Despite the fact that it was widely used for a long time, it is no longer initiated for people with type 1 diabetes; however, there may be a few individuals who still take animal insulin and do not wish to change. Animal insulin is still included in the *British National Formulary*.

Insulin preparations

Insulin comes in units. Historically, it came in a single strength and would be seen in preparation U-100, which is 100 units per ml. These days, different insulins may have different strengths – for example, U-300 (300 units per ml) or U-500 (500 units per ml). It is essential to check the strength of the insulin prescribed and when it is to be administered. Table 1 provides an overview of some common types of insulin that are used to treat diabetes.

Fig 1. Insulin injection sites



“Injecting insulin into subcutaneous fat allows the insulin to absorb as expected”

How do we choose the right insulin?

The National Institute for Health and Care Excellence (NICE) (2022) stipulates very clear guidelines on what insulin to initiate. However, with this in mind, an individualised insulin plan should be made and discussed with the patient. At diagnosis of type 1 diabetes, NICE (2022) recommends initiating twice-daily basal insulin detemir (Levemir®) with a rapid-acting bolus insulin (Humalog®/NovoRapid®).

In some cases, a person living with type 1 diabetes may not want to have a twice-daily basal insulin, so a once-daily basal insulin (Lantus®) should be initiated. The type of insulin may change as the person continues on the journey with type 1 diabetes. This can be for a number of reasons, including frequent episodes of hypoglycaemia or hyperglycaemia (NICE, 2022).

It is advised not to start a person on a mixed insulin at diagnosis of type 1 diabetes. This would only be considered in exceptional circumstances, for example, in someone with complex needs (NICE, 2022).

Additional medications in type 1 diabetes

Metformin

Metformin is an oral medication typically used as first-line treatment for type 2 diabetes. It is a biguanide-class drug that is used to reduce the amount of glucose released by the liver, and it reduces insulin resistance by enabling cells to take in

insulin. Metformin does not cause hypoglycaemia by itself, but this may occur if the drug is taken in combination with insulin. It would be advised to reduce the insulin dose, but never stop the insulin.

Metformin is used in type 1 diabetes if the person is living with overweight or obesity (body mass index (BMI) >25) and struggling to optimise blood glucose levels with additional doses of insulin (*Drug and Therapeutics Bulletin*, 2018). Metformin is not licensed for use in type 1 diabetes and should be initiated by a diabetologist.

SGLT2 inhibitors

SGLT2 inhibitors are a newer medication typically used to treat type 2 diabetes. SGLT-2 inhibitors help to excrete excess glucose, which would normally be reabsorbed, out of the kidneys and into the urine. This, in turn, lowers overall blood glucose levels and improves diabetes control. There is also evidence that SGLT-2 inhibitors help to reduce cardiovascular risk (Padda et al, 2023).

SGLT-2 inhibitors can have a positive impact on overall diabetes control and weight, but should be carefully considered when initiating for a patient with type 1 diabetes to avoid adverse events. SGLT-2 inhibitors are not licensed for use in type 1 diabetes and should be initiated under the care of diabetes specialists (Evans et al, 2020).

How is insulin administered?

Insulin is usually administered subcutaneously and should be injected into an area of the body with lots of subcutaneous fat. A common place to inject is the abdomen; Fig 1 shows common injection

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sites. However, insulin can also be administered via an insulin pump or an insulin infusion; both methods are discussed later in this article.

Injecting insulin into subcutaneous fat allows the insulin to absorb as expected; injecting it into muscle will affect the rate of absorption. Other factors that can contribute to the rate of absorption can be insulin resistance, the dose of insulin and exercise (Donnor et al, 2023). For people living with diabetes, the absorption of insulin can change from day to day, as explained in the *British National Formulary* (bnf.nice.org.uk/treatment-summaries/insulin).

Most people living with type 1 diabetes will administer the insulin themselves, and will be taught how to do this at diagnosis; this is discussed later in this article. In some circumstances in which a patient is unable to administer insulin – for example, with older people or people living with complex needs – insulin may be administered by a district nurse or a caregiver. This needs to be assessed at the time of initiating insulin to ensure safety and care delivery.

Insulin should be injected at a 90-degree angle. With people who have very little subcutaneous fat, you may need to pinch the skin to raise it; this avoids insulin being injected into the muscle. The risk of injecting insulin into the muscle is reduced when using smaller insulin needles or injecting into fatty tissue, such as the abdomen, where people tend to have a higher fat store (Curtis and Moutter, 2017).

Insulin pens/cartridges/vials

Insulin usually comes in a pre-filled pen or cartridge for individuals to use. A pre-filled pen is disposed of once finished. An insulin cartridge will have the same amount of insulin as a pre-filled pen, but the person living with diabetes will have a reusable pen into which they can insert the insulin cartridge. A small needle (usually 4mm or 5mm) is applied to the insulin pen, the units of insulin are dialled up on the pen and then administered.

It is essential that insulin is not drawn up from an insulin pen as this can lead to an insulin overdose; it should only be drawn up from a vial. There is a risk of severe harm and death if insulin is drawn up from pen devices (NHS England, 2019).

Insulin can also come in a vial. This is commonly used in hospital settings or for individuals who use an insulin pump. The insulin preparation remains the same in either a pen, cartridge or vial. When using

Fig 2. Lipohypertrophy in leg



insulin from a vial, it is essential to use an insulin syringe to ensure you have the correct number of units. You should never use an insulin syringe to draw up insulin from an insulin pen (Diabetes UK, 2016).

Lipohypertrophy

It is essential for people injecting insulin to rotate the injection sites to avoid lipohypertrophy (Fig 2). This occurs when insulin is administered in the same place repeatedly. Insulin starts to build up under the surface of the skin and forms small hard lumps. When the area is avoided, these lumps can disappear but, in some severe cases, lipohypertrophy can leave long-term damage to the skin and make insulin absorption unpredictable in that area. Lipohypertrophy affects an estimated 25-30% of people living with type 1 diabetes (Kadiyala et al, 2014).

Lipohypertrophy is not always as obvious and easy to detect as you might think. However, it is important to be aware of lipohypertrophy whenever insulin is being administered because it can affect absorption and so may not have the desired effect on blood glucose levels. There is no expectation for a ward nurse to check for lipohypertrophy, but it is good practice to do so and, if concerned, seeking specialist advice would be wise.

Calculating insulin doses

People living with type 1 diabetes will have variable insulin doses throughout the day. Typically, the long-acting insulin dose remains the same unless the person is exercising or unwell. People living with type 1 diabetes cannot live without insulin. It is essential to monitor blood glucose levels to administer the right amount of insulin and titrate it safely.

NICE (2022) recommends initiating twice-daily basal insulin at diagnosis of type 1 diabetes, along with a bolus insulin with meals. In clinical practice, it is unlikely that you will be required to work out insulin doses, but having insight into

how they are calculated can be helpful to understand that there is a general formula specialists follow to ensure the regimen is safe. The total daily dose of insulin is calculated by using a formula of 0.4-1.0 units per kilogram (kg) (American Diabetes Association, 2021). For example:

- If the individual weighs 60kg, the total daily dose of insulin would be 0.4 units x 60kg = 24 units. This would then be split half and half, so 12 units are basal insulin and 12 units are bolus insulin;
- If the person was prescribed a twice-daily basal insulin of 12 units, this would be split to six units in the morning and six units in the evening;
- The bolus insulin would be split with the view of having three meals a day, so four units with each meal.

The insulin doses are titrated up or down, based on the individual's blood glucose levels. These can be affected by illness, exercise and carbohydrate intake. Other contributions can include pregnancy, menstrual cycles and stress.

Note that when prescribing insulin, no abbreviations should be used. Insulin should always be prescribed in units.

Insulin pumps

An insulin pump is a small electronic device that administers insulin continuously into the subcutaneous tissue. Insulin pumps are an alternative way of administering insulin and are offered to people living with type 1 diabetes. It is the patient's choice if they wish to use insulin pump therapy. The patient will discuss their treatment choices with their specialist team.

It is uncommon for adults to have insulin pump therapy immediately after diagnosis of type 1 diabetes. Usually, pump therapy is discussed 6-12 months after diagnosis. This is to ensure they have the right amount of knowledge and insulin doses. There are a wide variety of insulin pumps available for people with type 1 diabetes – they can choose if they would like an insulin

Fig 3. Examples glucose monitoring



3a. Flash glucose monitoring



3b. Continuous glucose monitoring

pump, then select different models based on preference (Diabetes UK, nd).

Insulin pumps administer rapid-acting insulin. Individuals using an insulin pump generally do not need to use insulin injections unless the pump fails. There are two different types of insulin pumps:

- A tethered pump, which has a small tube connected to the cannula and pump. This kind of pump is attached to the skin with a small cannula that sits in the subcutaneous layer;
- A patch pump, which sits directly on the skin.

Insulin pumps stay attached continuously. They should only be removed for a short period of time (not longer than 1 hour), for example, while washing or

exercising. The insulin doses are programmed into the pump and controlled by the person using it.

Insulin pump therapy can have a very positive impact on a person living with type 1 diabetes. It reduces insulin injections and allows the person to manipulate the insulin via the pump, depending on what they are doing. When using an insulin pump, insulin delivery can be suspended, spread over longer periods of time or given in frequent doses without having to be injected.

However, the person is relying on technology to deliver the insulin. If a pump breaks or is removed for too long, there will be no insulin circulating in the body, which could lead to diabetic ketoacidosis if not

identified. It is essential that the patient always has some spare supplies – such as batteries, cannulas and insulin – with them to avoid harm. If a patient is in hospital and unable to manage their pump, they may be switched back to insulin injections temporarily, until they are better and able to manage the pump again.

Carbohydrate counting

Patients living with type 1 diabetes should be offered training in carbohydrate counting as part of a structured education programme. Carbohydrate counting allows the patient to give amounts of rapid-acting insulin that are as accurate as possible with each meal they have. This can avoid hyperglycaemia and hypoglycaemia. It can also allow more freedom for people living with type 1 diabetes to eat and drink whatever they wish without restriction. This can be challenging, but there are lots of resources available to support carbohydrate counting, such as accurate information on food packets and further nutrient information in restaurants.

If a patient does not carbohydrate count, it may mean they give inaccurate insulin doses resulting in suboptimal control over a longer period. Carbohydrate counting can also reduce the fear of not giving the correct amounts of insulin and empowers the person living with type 1 diabetes if they wish to exercise, party or manage illness when blood glucose levels can change.

Carbohydrate counting education is delivered by a specialist dietitian or nurse. Dose Adjustment for Normal Eating (DAFNE) is a structured education programme widely used across the world. The aim of this course is to support people living with type 1 diabetes to learn and develop skills in carbohydrate counting to give the right amount of insulin to sustain optimal blood glucose levels and lead as normal a life as possible. The DAFNE course is available to all individuals aged >17 years and can be delivered face to face, in a small group or virtually.

Continuous glucose monitoring

Blood glucose monitoring has developed significantly in recent years. Continuous glucose monitoring (CGM) or flash glucose monitoring (Fig 3) have become more widely available for people with diabetes.

CGM involves a small device that sits in the subcutaneous layer and measures interstitial glucose, which is found in fluid between the cells (National Institute of Diabetes and Digestive and Kidney Diseases, 2023). This allows the individual to

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“Carbohydrate counting can reduce the fear of not giving the correct amounts of insulin”

see their blood glucose levels in real time and make more informed decisions on their diabetes management. CGM can be used alone or with an insulin pump. The device is waterproof and sits on top of the skin for up to two weeks before needing to be changed. A person wearing a CGM device may see the blood glucose results on their mobile phone or insulin pump.

The person using flash glucose monitoring will scan the device with a monitor or their mobile phone, which will show them the result.

People who use CGM or flash glucose monitoring still need to have a blood glucose monitor to ensure readings are accurate or in case the CGM/flash glucose monitor breaks. Some flash glucose monitors and CGM devices also have an alert function if the blood glucose is trending down or the blood glucose is less than 4mmol/L. This is a great feature for people with little or no awareness of hypoglycaemia.

In 2022, NICE updated its CGM guidance so all people living with type 1 diabetes should be offered a choice of CGM or flash glucose monitoring (NICE, 2022).

Living with type 1 diabetes

When a person is diagnosed with type 1 diabetes, they are usually diagnosed and given treatment in a hospital setting. They will be seen by a team of diabetes specialists – usually a diabetologist, a diabetes specialist nurse and specialist dietitian.

Typically, the patient will be seen by a diabetes specialist nurse, who will:

- Show them how to check their blood glucose level;
- Give them a blood glucose meter;
- Teach them how to administer insulin;
- Ensure they can do this before they leave the hospital;
- Teach them about the different types of insulin and when they should be given, along with the doses they need to have.

They will be discharged home with a supply of insulin, insulin needles and a sharps bin. Once discharged from hospital, the patient will be seen in an outpatient setting, where they will be offered type 1 diabetes education and have continued follow-up to optimise their diabetes control.

The patient’s GP will also support them by ensuring they have their prescription, and their eyes and their feet checked.



Insulin passports

Insulin passports should be offered to all people using insulin. An insulin passport will have:

- An up-to-date record of the type of insulin the patient is prescribed;
- The current dose advised.

This can be helpful for everyone involved in the care of the patient, including the person themselves. Insulin passports can be given out by healthcare providers, as explained in the *British National Formulary* (bnf.nice.org.uk/drugs/insulin).

Is there a cure for type 1 diabetes?

There is currently no known prevention for type 1 diabetes, but there is ongoing research on the immune system to stop antibodies from attacking beta cells (Diabetes UK, nd). There is also ongoing extensive research into finding ways to cure type 1 diabetes. The Juvenile Diabetes Research Foundation (JDRF) strives to invest in research for type 1 diabetes. The production of antibodies that prevent the production of beta cells must be stopped and restoration of the islet cells needs to happen for a person to be able to live without type 1 diabetes (JDRF, nd).

To date, there is a new drug called teplizumab-mzwv (Tzield®), which was approved by the US Food and Drug Administration (FDA) in 2022 for use in delaying the onset of type 1 diabetes for people at risk of developing it (Keam, 2023). To identify whether someone is at risk of developing diabetes, they would need to have a blood test to show that there are positive antibodies for type 1 diabetes. If the person already has an established diagnosis of type 1 diabetes, they would not be eligible for this drug (JDRF, 2022).

People living with type 1 diabetes can apply to be part of ongoing clinical trials; Diabetes UK has a webpage (diabetes.org.uk/clinical-trials) that gives details of clinical trials.

Conclusion

Over the years, the management of type 1 diabetes has come a long way to make it easier for people to improve their quality and longevity of life. Despite there still being limited treatment options, having insight into the available treatments to manage and optimise care can support the care that nurses provide.

Type 1 diabetes can be a challenging long-term condition, which, in the absence of insulin, can be life-threatening. Nurses who understand how insulin is prepared, prescribed and administered can help reduce levels of harm in clinical areas and benefit patient care. **NT**

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