Advances in diabetes care: Technology

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The past decade has seen significant advances in the therapies available to manage both type 1 diabetes and type 2 diabetes. In particular, the sophistication of medical devices available to manage these conditions has advanced significantly. Leaving aside the broader development of information systems and databases, this review provides an overview of how diabetes-specific technology has developed and what may be appearing in clinical practice in the near future.

Insulin pump therapy

Insulin pump therapy, or continuous subcutaneous insulin infusion (CSII), involves the use of a mobile phone sized infusion pump, which delivers insulin continuously via a subcutaneous cannula with additional bolus doses as needed for meals or correction of high blood glucose levels.

CSII is currently an insulin delivery system that still cannot think for itself, so users have to be able to control and instruct the pump (with the single exception being the insulin pump with the low glucose suspend function described below). In broad terms, CSII fits into the increasing focus on teaching people with diabetes how to use flexible insulin self-dosing (as opposed to fixed insulin doses), whether delivered by pump, pen or even syringe. The aim is to mimic the release of insulin from the non-diabetic pancreas, which varies according to diet, exercise, activity, illness, stress and circadian rhythms.

Clearly these principles apply not just to people with type 1 diabetes but also to many with insulin-treated type 2 diabetes. However, at present in the UK, CSII is restricted almost completely to people with type 1 diabetes, although a number of current insulin pump manufacturers are considering the development of simple (and presumably cheaper) CSII devices aimed at people with type 2 diabetes. CSII use in the UK is estimated to have increased markedly since the publication of the original NICE Health Technology Assessment in 2003 (updated in 2008 [NICE, 2008]) from less than 1% to just over 5% of type 1 diabetes at present. This means that many practices will have people with type 1 diabetes using CSII and others may be asked by patients for advice about, or access to, CSII. Common fallacies about CSII are that it is an easy and needle-free option. In fact, using CSII effectively and safely requires a significant level of engagement with frequent self-monitoring of blood glucose, although the potential rewards are great for those who are motivated.

What advantages does CSII offer? First, small amounts of insulin can be delivered far more accurately than with insulin pens, with the most sensitive pumps being able to deliver insulin in 0.025 unit/hour increments. Second, background or basal insulin can be adjusted more easily than with injections. For example, many people will programme a number of predetermined steps in basal insulin throughout a 24-hour period reflecting circadian changes in insulin sensitivity. Additionally, users can set "temporary basal rates"– for example, reducing insulin delivery for exercise or increasing with stress or illness.

Another major advance in the past decade has been in the inbuilt software present in most current insulin pumps allowing calculation of insulin bolus doses. For example, the carbohydrate content and blood glucose values can be entered into the pump at mealtimes and the pump will calculate an insulin dose based on that person's insulin–carbohydrate ratio and a correction factor based on the current blood glucose, the target value and an individual's insulin sensitivity. Most insulin pumps can also now allow for recent insulin doses by modelling the amount of insulin likely to remain in the system, an important feature that can help protect against the inclination of some people to give frequent and repeated correction doses of insulin, carrying a danger of overshoot hypoglycaemia. Finally, some or all of the bolus dose can be delivered over an extended time period, a feature useful for large or slowly absorbed meals.

In the past few months, the first of a new generation of small insulin pumps has been launched in the UK. The OmniPod® (Insulet Corporation, Massachusetts, USA) is a "patch pump" with a relatively low profile "pod" attached

direct to the body with a wireless personal digital assistant-type controller remotely used to control insulin delivery. This device has been popular in the USA where it has been available for some time as an alternative to the traditional insulin pump and the next 2–3 years will almost certainly see a number of other small pumps with similar controllers becoming available.

Finally, insulin pump data can be downloaded allowing users to examine patterns of glycaemia and insulin dosing retrospectively. In theory, connectivity could allow real-time flow of information – for example, to parents of children with diabetes – although clearly within the UK, there are particular concerns and limitations on the flow of personal data.

Monitoring of blood glucose

Although less widely used than CSII, continuous glucose monitoring (CGM) has also evolved over the past decade. Real-time CGM devices consist of an implanted subcutaneous sensor with a wireless link to a receiver. In some cases, where people are also using CSII, the pump device can act as the receiver, displaying blood glucose levels. CGM was originally used as a blinded non-real-time device, allowing healthcare professionals to download and analyse glycaemic trends retrospectively. Current devices allow glucose levels to be viewed in real time and to set alarms where values fall above or below pre-set values, or even using predictive modelling to sound an alarm before glucose deviates outside set limits. These alerts are particularly popular when used as hypoglycaemia alarms.

As indicated earlier, even where insulin pumps are used as receivers, they do not currently use blood glucose data to alter insulin infusion rates, with one exception. The Paradigm® Veo™ insulin pump (Medtronic MiniMed, Northridge, California) has a low glucose suspend feature, where the pump will temporarily switch off insulin delivery if the user fails to respond to hypoglycaemia alarms.

CGM devices are not infallible and do not replace finger-prick capillary blood glucose monitoring. All three devices currently available in the UK need calibrating against capillary glucose. Considerable efforts have gone into trying to develop a genuinely reliable non-invasive blood glucose monitor using a variety of imaginative technologies, but none currently appear clinically viable, at least in the near future.

CGM is sparingly used in the UK with no current NICE guidelines to guide clinical use or NHS funding and nearly all NHS-funded use is in people with type 1 diabetes. In part, the low level of current use of CGM is because evidence is just starting to accrue for the efficacy of CGM to improve glycaemic control, either in combination with CSII or with injections. It seems likely that NICE will consider this at some point in the next 2–3 years. Likely near-term advances in CGM will involve a continuation of trends over the past few years – smaller and more reliable devices requiring less calibration, and with longer life spans (current sensors last 4–7 days).

For intermittent finger-prick glucose monitoring, devices have already evolved significantly in terms of size, reliability, speed of action, ability to use alternate sites and volume of blood required. The author speculates that future refinement is likely now to focus on connectivity and software. Many meters can already be uploaded to a computer, although the way in which data are then displayed, allowing patterns to be identified, varies significantly in usefulness. Recent developments are meters that link wirelessly to insulin pumps and a "USB" meter for easy uploading of data. Learning from the utility of bolus calculating software in insulin pumps, the Accu-Chek® Aviva Expert meter (Roche Diagnostics, Burgess Hill) can perform similar calculations to suggest bolus insulin doses, except they are to be delivered by pen or syringe rather than CSII.

Closed loop insulin pumps

Finally, the "holy grail" of CGM and CSII is that the devices become linked together to create an "artificial pancreas" or closed-loop insulin pump system. A full review is outside the remit of this article but many people will have stumbled across information about these studies and may approach primary care teams asking about progress. As a brief summary, overnight closed-loop CSII has been tested successfully in Cambridge in children and adults with type 1 diabetes (Hovorka et al, 2010). Full 24-hour systems may need more complex solutions to cover activity and carbohydrate intake but semi-automated systems may offer a useful intermediate step towards this goal. When patients ask, the author counsels cautious optimism, but it is also worth emphasising that these exciting systems are still in clinical trials. ■

Hovorka R, Allen JM, Elleri D et al (2010) Manual closed-loop insulin delivery in children and adolescents with type 1 diabetes: a phase 2 randomised crossover trial. *Lancet* **375**: 743–51

NICE (2008) *Continuous Subcutaneous Insulin Infusion for the Treatment of Diabetes Mellitus. Review of Technology Appraisal Guidance 57.* NICE, London