Can automated bolus advisors help alleviate the burden of complex maths and lead to optimised diabetes health outcomes?

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Article points

1. The prevalence of type 1 diabetes in children and young people is increasing, with a significant proportion of this group having suboptimal glycaemic control.
2. Compounding the problem, many young people with type 1 diabetes believe their glycaemic control is acceptable; a fear of hypoglycaemia may result in avoidance behaviour, increasing blood glucose levels and the risk of long-term complications.
3. Integration of automated bolus advisors into blood glucose meters improves diabetes self-management without the need for mathematical calculations, reduces fear of hypoglycaemia and improves glycaemic control.

Key words

- Automated bolus advisor
- Avoidance behaviour
- Diabetes self-management

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Children and young people with type 1 diabetes face significant challenges to improve diabetes management. For young children their parents administer or oversee treatment, but by adolescence the responsibility is transferred; a crucial constant throughout each stage is the need to be able to calculate bolus insulin doses. Challenges to effective self-management include the complexity of bolus insulin calculation, poor numeracy and fear of hypoglycaemia. Automated bolus advisors integrated into blood glucose meters help overcome some of these challenges, improve self-care behaviour and reduce the risk of long-term complications.

The increasing public health burden of diabetes is driven by staggering statistics regarding the prevalence, financial cost to the NHS and wider society and associated comorbidities (Barnard and Lloyd, 2012). The predicted prevalence is expected to reach 552 million people worldwide by 2030 (International Diabetes Federation, 2011). These figures, however, tend to mask the overwhelming personal burden of type 1 diabetes for young people and their families.

Type 1 diabetes is usually diagnosed in childhood and adolescence. The incidence of type 1 diabetes has been increasing in children <15 years of age, trebling in Scotland over the past 30 years. The largest relative increase has been in those <5 years of age. It is predicted that the incidence will double between 2005 and 2020 in European children <5 years of age, with prevalent cases in young people <15 years rising by 70% (Patterson et al, 2009). Alarmingly, children and young people represent the most poorly controlled subgroup within the type 1 diabetes population (NHS Information Centre, 2010).

This article reviews the significant issues and challenges associated with type 1 diabetes among younger people, and discusses how the use of an automated bolus advisor can help alleviate the burden of intensive diabetes self-management.

Inadequate diabetes control

Large, controlled clinical trials have consistently shown that intensive management of glycaemia and other risk factors associated with diabetes can significantly decrease the development and progression of microvascular and macrovascular complications (Diabetes Control and Complications Trial Research Group, 1993; UK Prospective Diabetes Study Group, 1998; Nathan et al, 2005; Gaede et al, 2008; Holman et al, 2008). Despite advances in developing new medications, insulin delivery systems and glucose monitoring technology, a significant percentage of people with type 1 diabetes have suboptimal glycaemic control. Data from the most recent National Diabetes Audit (NHS Information Centre, 2010) showed that over 70% of adults with type 1 diabetes are not achieving HbA_{1c} targets of 58 mmol/mol

(7.5%); approximately 33% have extremely poor control, with an HbA_{1c} >80 mmol/mol (>9.5%). These findings are consistent with those reported previously (NHS Information Centre, 2010), reflecting persistent poor control.

Compounding the problem, approximately three-quarters of young people with diabetes believe their diabetes control is acceptable (Skinner et al, 2000), which is clearly inconsistent with the evidence. The National Diabetes Audit found that 80% of children aged 0–5 years are unable to achieve an HbA_{1c} <58 mmol/mol (<7.5%); this figure increases to 82% for 6–10-year-olds and 86% for 11–16-year-olds. Extremely poor control (an HbA_{1c} >75 mmol/mol (>9.0%)) was found in 31% of children aged 0–5 years, 35% of 6–10-year-olds and 48% of 11–16-year-olds (NHS Information Centre, 2010).

Self-management skills are learned during childhood and adolescence. For young children, most care comes from parents, who administer or oversee treatment (Anderson, 2004). Parents typically have sole responsibility for diabetes management tasks for their children up to the age of 8 years, when children begin to understand patterns of required behaviours; between the ages of 8 and 11 years children begin to take over some of those tasks. By adolescence, a negotiation occurs between parents and adolescents about the transfer of responsibility for diabetes, with the main burden of care being lifted off parents (Holmes et al, 2006). The one crucial constant throughout each stage is the need to be able to calculate insulin bolus doses. If the whole family is using the bolus advisor, this would result in consistency in management and understanding, with all parties working towards the same goals.

Challenges to effective self-management

Intensive self-management of diabetes is complex and time-consuming and creates a significant psychosocial burden on patients and their families (Snoek and Skinner, 2002). Significant challenges for effective diabetes self-management are outlined below.

Complexity of bolus insulin calculation

As noted above, the one crucial constant throughout each stage is the need to be able to calculate insulin bolus doses. Calculation of an insulin bolus dose is a complex process requiring knowledge of preprandial glucose level, grams of carbohydrate to be consumed, insulin sensitivity, insulin-to-carbohydrate ratio and active insulin "on board". Based on an average diet of three meals a day, with mid-morning and bedtime snacks, an intensive insulin regimen requires 35 calculations a week, totalling more than 1800 per year; this does not include correction boluses throughout the day or the addition of snacks. Because manual bolus calculations can be time-consuming, people are often unwilling to perform this task (Barnard et al, 2012). Instead, they often rely on empirical estimates when determining their insulin doses (Klupa et al, 2008). This can lead to mistakes that can result in severe clinical consequences.

Poor numeracy

The greater issue, however, is lack of mathematical competency, or numeracy, among many adults in the UK. A study by the National Research and Development Centre for Adult Literacy and Numeracy (Carpentieri et al, 2010) reported that 31% (6.7 million) of working-age adults (16–65 years) had poor or very poor numeracy skills. Given the complexity of the mathematical formulae and manipulations required to accurately calculate bolus doses, it is reasonable to speculate that poor numeracy among parents of children with type 1 diabetes is a contributing factor to poor diabetes control in this population.

Fear of hypoglycaemia

Adding to the burden of self-management is the underlying, debilitating fear of hypoglycaemia (Riddle, 2002; Cryer, 2004; 2008), which can result in poor adherence to insulin regimens and subsequent poor metabolic control (Wild et al, 2007). Fear of hypoglycaemia is a major contributing factor to people's unwillingness to intensify therapy, with one severe episode of hypoglycaemia being a strong deterrent from having another one. As such, a significant percentage of people with diabetes remain well above their glycaemic goals because they purposely decrease their insulin dosage or simply skip bolusing to avoid hypoglycaemia, which can lead to severe clinical consequences (Snoek and Skinner, 2002; Wild et al, 2007).

"Calculation of an insulin bolus dose is a complex process requiring knowledge of preprandial glucose level, grams of carbohydrate to be consumed, insulin sensitivity, insulin-to-carbohydrate ratio and active insulin 'on board'."

Page points

1. Behaviour to avoid hypoglycaemia, either conscious or subconscious, increases blood glucose levels and results in higher HbA_{1c} and increased risk of long-term complications.
2. Automated bolus advisors automatically calculate bolus insulin doses to cover carbohydrate intake and are now available integrated into blood glucose meters.
3. Use of an automated bolus advisor could reduce the burden of diabetes self-management without difficult mathematical calculations and improve blood glucose control and quality of life.

Parental fear of hypoglycaemia, anxiety and depression are reported to be common (Barnard et al, 2010). Parental fears include:

- Fear of hypoglycaemia and associated seizures, both during the day and at night.
- Anxiety associated with frequent blood glucose monitoring.
- Fear of "not being there" despite daily management being relentless.
- Fear that others, such as babysitters and teachers, will be unable to provide appropriate care for their child.

Experiencing hypoglycaemia and engaging in subsequent avoidance behaviours contributes to the problem. There is a paucity of evidence on behaviour to avoid hypoglycaemia, but there are some suggestions that higher than desirable blood glucose levels might be permitted in order to avoid hypoglycaemia (Barnard et al, 2010). It is likely that such avoidance behaviours could adversely affect glycaemic control, resulting in higher HbA_{1c}. Data indicate that a drop in HbA_{1c} of 1% is associated with an approximate 40% reduction in risk of long-term complications (Stratton et al, 2000); thus, for every 1% increase in HbA_{1c} there is a substantial increase in risk. Such behaviours can be either conscious or subconscious, with fear being a strong motivating factor to maintain such maladaptive coping despite the long-term risks.

Automated bolus advisor

Automated bolus advisors automatically calculate bolus insulin dosages to cover carbohydrate intake and address out-of-range blood glucose levels based on individualised insulin parameter estimates. Although this technology was first integrated into insulin pumps, automated bolus advisors have been integrated into blood glucose meters and are now available to people treated with multiple daily injections (MDIs). Use of these devices could help reduce the burden of diabetes self-management by eliminating the need to perform difficult mathematical calculations, reducing therapy burden, providing greater accuracy in insulin boluses and reducing risk of long-term complications. Research has indicated that use of automated bolus advisors is safe and effective in reducing postprandial glucose excursions and improving overall glycaemic control (Gross et al, 2003; Garg et al, 2008).

Barnard et al (2012) surveyed 588 people (aged 0–70 years) in the UK and Republic of Ireland who were treated with MDI therapy; the study objective was to assess attitudes and behaviours regarding insulin therapy after 4–12 weeks using an automated bolus advisor. Results showed that 76.7% of respondents reported that they currently use the bolus advisor to calculate insulin boluses for meals or snacks always or quite often. More than half of respondents indicated that their fear of hypoglycaemia was reduced (39.0%) or significantly reduced (13.0%), whereas 78.8% indicated that confidence in the insulin dose calculation improved (50.8%) or significantly improved (28.0%). Almost 90% of respondents indicated that the bolus advisor made bolus calculation easy or very easy compared with manual calculation.

It is noteworthy that >80% (n=456) of respondents reported improvement in their ability to act upon data from self-monitoring of blood glucose (SMBG). This perception is supported by the changes seen in SMBG frequency. After using the bolus advisor, the number of participants testing 4–5 times per day increased by 29%, from 257 to 331, whereas the number of participants testing >6 times per day decreased by 42%, from 189 to 133. This suggests that individuals are, in fact, willing to perform SMBG at optimal frequencies when they see the purpose and value of their testing.

These survey results suggest that use of a bolus advisor to aid in determining bolus insulin dosages may alleviate some of the fears and inconveniences associated with MDI therapy in people with type 1 diabetes. Most people surveyed reported that using the bolus advisor was easier than manual bolus calculation. Moreover, improvements included:

- A reduction in fear of hypoglycaemia.
- Increased confidence in bolus calculation.
- Improved ability to control blood glucose levels and achieve glycaemic goals.
- A sense of increased flexibility in lifestyle.
- Improvement in overall well-being.
- Parents reported increased confidence in their children's ability to manage their diabetes when at school or otherwise separated.

As stated earlier, automated bolus advisors have been commonly available in insulin pump therapy for a number of years. However, while insulin pump therapy is available to those that meet National

Institute for Health and Clinical Excellence criteria (NICE, 2008), it continues to be difficult to access in some areas, and many people are either not yet comfortable with this technology or prefer MDI. Integration of automated bolus advisors into blood glucose meters, in the author's view, enables most children and young people with type 1 diabetes to access and benefit from this technology:

- By helping people on MDI therapy safely and more effectively manage their diabetes.
- By reducing the burden of diabetes self-management.
- By contributing to improved diabetes control and quality of life.
- By reducing the risks of acute and long-term complications.
- By increasing self-efficacy associated with self-management of diabetes.

Conclusion

The factors contributing to poor glycaemic control in younger people with type 1 diabetes are multi-faceted and complex; however, because HbA_{1c} levels often increase with duration of diabetes, it is vital that effective diabetes management practices are initiated in families of young children with diabetes so that these can be reinforced throughout childhood and carried on into adolescence and adulthood.

Given the benefits of tight metabolic control, it is critical that healthcare providers utilise available technologies that not only facilitate effective glucose management but also address concerns about safety and lifestyle. Because inaccurate bolus calculations can lead to persistent poor diabetes control, tools that can help with removing the burden of such complex maths have the potential to significantly improve glycaemic control.

Use of automated bolus advisors has the potential to make bolus calculations easier, improve confidence in the accuracy of insulin bolus dosages and reduce fear of hypoglycaemia. Ongoing and future research will provide valuable data to help determine whether automated bolus advisor use improves clinical outcomes. ■

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