Pumping up a new revolution of diabetes management: insulin pumps and emphasis on psychological aspect of diabetes care

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Case
Ms A is a 17-year-old Pasifika female, with known type 1 diabetes mellitus (T1DM) diagnosed three years ago. She presented to the Emergency Department with a one day history of abdominal pain, vomiting, and reduced appetite. She denied polydipsia, polyuria, infective, coryza, or urinary symptoms.

Ms A has had multiple hospital admissions with diabetic ketoacidosis (DKA), averaging once a month in the past year. She reported poor adherence to her insulin regimen and does not check her capillary blood glucose (CBG) levels regularly despite owning a CareSens Glucometer. Her prescribed insulin regimen includes 70 units of Lantus once daily and 16–20 units of Novorapid thrice a day pre-meals. Her HbA1c had been persistently elevated for a year (between 130–161 mmol/mol), with the most recent result being 137 mmol/mol. She reported poor attendance at Diabetes Clinic follow-ups and described frequent nocturnal hypoglycaemia and episodes of hypo- and hyper-glycaemia on the occasional CBG level checks that she performs.

On systems review, she also reported low mood and previous suicidal ideation but with no plan or intent.

She is a non-smoker and does not drink alcohol. She lives with her parents, four siblings, and grandparents. She described her family as being supportive, in fact often "overly supportive". She reported high CBGs as a source of tension between herself and her mother, who was her main caregiver. Ms A felt frustrated and pressured to eat at stipulated times to balance the insulin. She usually does not take breakfast and snacks very frequently. Recently, she left school due to frequent absenteeism and bullying.

She has a family history of type 2 diabetes mellitus (both maternal grandparents). She did not take any other medications and has no known drug allergies.

On assessment, her body mass index was 30.1 kg/m² and Glasgow Coma Score was 15/15. She was tachypnoeic (respiratory rate of 24/min), tachycardic (heart rate of 110/min regular), afebrile, and normotensive with blood pressure of 127/97.

Tongue and mucous membranes were dry, and she had a capillary refill time of three seconds. She had generalised tenderness on abdominal palpation, bowel sounds were active, and there was no guarding or peritonism. Physical examination was otherwise unremarkable.

Investigations
Significant investigation results revealed an increased anion gap metabolic acidosis as follows.

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Result</th>
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<tbody>
<tr>
<td>Venous blood gas pH</td>
<td>7.14 (↓)</td>
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<tr>
<td>Bicarbonate (HCO₃⁻)</td>
<td>7 mmol/L (↓)</td>
</tr>
<tr>
<td>Glucose</td>
<td>290.0 mmol/L (↑)</td>
</tr>
<tr>
<td>Partial pressure of carbon dioxide (pCO₂)</td>
<td>3.1 kPa (↓)</td>
</tr>
<tr>
<td>Partial pressure of oxygen (pO₂)</td>
<td>4.5 (↓)</td>
</tr>
<tr>
<td>Potassium (K⁺)</td>
<td>5.1 mmol/L</td>
</tr>
<tr>
<td>Base excess</td>
<td>−21 mmol/L (↓)</td>
</tr>
<tr>
<td>Lactate 1.6 mmol/L</td>
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Significant investigation results revealed an increased anion gap metabolic acidosis as follows.

Midstream urine dipstick & microscopy
- Ketones large amounts (↑)
- White blood cell count (WBC) 10 x10⁶/L
- Red blood cell count 9 x10⁶/L

Beta-hydroxybutyrate 6.62 mmol/L (↑)

Full blood count
- Haemoglobin 164 g/L (↑)
- WBC 9.3 x10⁶/L
- Neutrophils 6.4 x10⁹/L

Urea + electrolytes
- Sodium 130 mmol/L (↓)
- K⁺ 5.3 mmol/L (↓)
- HCO₃⁻ 8 mmol/L (↓)
- Creatinine 51 umol/L
- C-reactive protein 1 mg/L

Beta-human chorionic gonadotrophin (hCG) <2 U/L

Echocardiogram
- Sinus tachycardia 110 beats per minute, no acute ST segment changes

Chest x-ray
- No abnormality detected

Abnormal results are bolded

Problem List
1. Diabetic ketoacidosis (DKA) secondary to poor adherence to insulin regime with underlying psychosocial stressors
   - The diagnosis of DKA is characterised by a biochemical triad of hyperglycaemia, ketonemia, and metabolic acidosis with rapid onset. Echocardiogram and septic screen including a chest x-ray and midstream urine ruled out an infective precipitant.

2. T1DM with persistently suboptimal glycaemic control (multifactorial)
   - Low mood and previous suicidal ideation secondary to complex psychosocial stressors both at home and at school
Discussion
T1DM is one of the most common chronic childhood illnesses. It is characterised by insulin deficiency resulting from the destruction of pancreatic beta cells. As of 2014, there are approximately 15,000–20,000 New Zealanders with T1DM, which is approximately 5–8% of all New Zealanders with diabetes.1 Individuals with T1DM are often diagnosed in childhood/adolescence. Subsequently, their need to depend on insulin for survival for the rest of their lives presents unique challenges to the individual, their family, and the healthcare providers involved in the management and monitoring.

The following discussion aims to review some of the existing diabetes technologies and address the understudied psychological aspects of diabetes management in adolescents, with a special focus on our case patient.

1. INTENSIVE DIABETES THERAPY
Ideally, intensive diabetes therapy via insulin replacement therapy should be started immediately following diagnosis (Grade 1A).2 This necessitates frequent daily CBG checks so that meals and physical activity can be coordinated with matching levels of insulin replacement. The overarching goal of glycemic management is to minimise development and progression of micro- and macro-vascular complications of DM.3,4 However, this goal elusive due to the translational hurdle of mimicking minute-to-minute variation of normal physiologic basal-bolus insulin secretion which requires strict adherence to prescribed insulin regimen – this was the main challenge for our care plan.

More recently, an improved understanding of pharmacokinetics and pharmacodynamics of insulin products has paved the way for the development of enhanced insulin delivery and glucose monitoring methods. Two such technological advances that will be discussed in further detail include capillary glucose monitoring (CGM) and continuous subcutaneous insulin infusion (CSII).

1.1. Capillary glucose monitoring
CGM is a relatively new device developed to facilitate glycemic control. For years, physicians used standard self-monitoring capillary blood glucose measurements (e.g. finger-prick testing) to guide insulin therapy. However, this is of limited benefit as it only offers cross-sectional “snapshots” of continuous variation in CBG.

Improved models of CGM provide real-time feedback regarding glucose concentration. As illustrated in a randomized controlled trial comparing CGM and conventional glucose monitoring, a substantial reduction in HbA1c was noted in the CGM group.1 Although the real-time feedback feature enables delicate control of insulin administration, these clinical benefits will only be gleaned by highly educated and motivated patients. Relating this back to our case patient, the CGM device might still not be able to address the core issue of non-adherence to prescribed insulin regimen.

1.2. Continuous subcutaneous insulin infusion
Insulin pumps are increasingly utilised in the management of T1DM in the paediatric population, with their efficacy being proven in several large clinical studies.6,7 CSII is a device that delivers a combination of basal insulin and pre-meal bolus through a subcutaneously-inserted catheter that requires replacement every 2–3 days (Figure 1).

Studies have shown that insulin delivery via a pump is generally preferred over the conventional multiple daily injections (MDI) approach.8 MDI regimens can necessitate up to 6–7 injections daily, which may be a barrier for some patients. In contrast, pumps have been shown to facilitate enhanced glycemic control (as reflected by reduced HbA1c and hypoglycaemic events)9,10 while permitting increased flexibility (with meal times and socialisation) and improved quality of life.11,12 Other reported benefits include reduction in long-term diabetic complications.13 However, similar to the MDI approach, pump therapy requires frequent CBG testing and carbohydrate counting knowledge. Pump usage competency and commitment are prerequisites to attaining benefits of pump therapy because ultimately, pumps are mere tools – they can only be as good as one’s ability to use them. Specific to our case patient, even though her suboptimal diabetes control would make her a potential candidate for pump therapy (according to the position statements by the American Diabetes Association and European Society for Paediatric Endocrinology),14 she would not have met the PHARMAC criteria (Table 1) for a funded pump (either Animas or Medtronic) in New Zealand.15

To qualify for a PHARMAC-funded pump, one of the following criteria must be met:

- Either
  - Unpredictable and significant variability in CBG including significant hypoglycaemia affecting one’s ability to reduce HbA1c
  - Four severe recurrent and unexplained hypoglycaemic episodes over a six month period either due to hypoglycaemic unawareness or to nocturnal hypoglycaemia

Table 1. PHARMAC criteria for a funded pump in New Zealand

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<th>Criteria</th>
<th>Description</th>
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| 1. Ingestion of insulin as per CGM results. The STAR 3 trial demonstrated clinical benefits including a reduction in glycemic variability and HbA1c levels with sensor-augmented insulin pump therapy compared to the standard MDI regimen.16 Unfortunately, these pumps are not yet funded in New Zealand.

2. EMERGING THERAPIES
The development of an “artificial pancreas” has been hailed as a possible future solution to T1DM. An automated “closed-loop” insulin pump would allow CBGs to be automatically measured and used to determine the amount of insulin administered.

Short-term pilot studies have reported near-normal glucose levels and a reduction in nocturnal hypoglycaemia,17,18 Close-looped pumps have great potential to benefit patients with T1DM, including our case patient. However, large-scale randomised trials are still needed to confirm evidence of clinical efficacy.19
3. DISADVANTAGES OF PUMP THERAPY
Notable disadvantages regarding choice of insulin regimen include the high cost of pumps and superficial infection at port sites. Pump failure can also result in life-threatening complications such as DKA. Therefore it is still essential for TIDM patients to be equipped with the skills of CGM testing and carbohydrate counting, such that they are able to troubleshoot and self-administer insulin during periods of pump failure.

In the context of our case patient, this highlights the importance of engaging and empowering adolescent patients to be involved in self-management of their TIDM, as there is currently no perfect solution that would completely negate the need to learn carbohydrate counting and self-administration of insulin.

4. DIABETES EDUCATION AND ONGOING MANAGEMENT
It is not uncommon for patients with TIDM to experience significant stress associated with various self-care responsibilities. This is especially so during adolescence when independence and self-assertiveness are predominant traits. Although it has been shown that shared parent-child responsibility is associated with improved diabetes control, other studies have shown that conflict over child’s diabetes management and poor parent-adolescent communication skills can lead to poor outcomes. This highlights the importance of determining an appropriate degree of parental involvement by incorporating structured age-appropriate psychosocial support into routine adolescent diabetes care.

In view of the complex psychosocial background of our case patient, it would be beneficial to pay more attention to the patient’s perspective around diabetes-related psychological burden. Her clinic follow-up records revealed increasing non-adherence with insulin regimen due to a multitude of psychosocial stressors: frequent absenteeism, bullying, non-adherence to recommended frequent CBGs checks, and “frustration at her T1DM diagnosis” that requires frequent regular follow-ups and a huge amount of effort on her part to monitor and self-administer insulin.

Conclusion
Comprehensive management of these psychosocial issues, on top of intensive self-care training to equip both patient and family with necessary skills and knowledge to manage their condition pharmacologically, can help the adolescent stay committed to the shared-care plan, which may include using enhanced diabetic technologies.

References


About the author
Dr Isabel, MBChB, has recently completed her post-graduate year one medical & surgical training as a junior doctor. She was a Trainee Intern at the South Auckland Clinical School (Middlemore Hospital), University of Auckland at the time of authorship. This article was
written during her General Medicine clinical rotation in her final year of medical studies. It was awarded the ‘W E Henley Prize in Clinical Medicine’ and ‘David Scott Prize’ in 2018 by the University of Auckland and Middlemore Foundation respectively. Isabel has a keen interest in the multidisciplinary care of youths with diabetes and desire to contribute to existing literature on diabetes care. Outside of medicine, she is a competitive swimmer and triathlete who also enjoys expressing herself through arts and playing the piano.

Acknowledgements

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Patient consent

Obtained for both case write-up and photo of insulin pump in Figure 1.

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