A day in the life of a diabetic diver: the Undersea and Hyperbaric Medical Society/Divers Alert Network protocol for diving with diabetes in action

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Abstract

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Some people with well-managed insulin-dependent diabetes can dive safely. Those cleared to participate should control tightly the variables that impact blood glucose levels, including activity, timing, food and insulin. Honest self-assessment is critical. A diabetic diver should cancel a dive if seasick, unusually anxious, or following significant high or low blood glucose levels in the preceding 24 hours. The diver should enter the water with a blood glucose level above 8.3 mmol·L^{-1} and below 14 mmol·L^{-1} with a stable or rising trend in blood glucose established with glucose tests at 90, 60, and 30 minutes prior to a dive. The diver should carry emergency glucose at all times and brief dive buddies about hypoglycaemia procedures. This is a personal account of the author's experience diving with type 1 diabetes and details how the UHMS/DAN recommendations are put into practice on dive days. Key elements of the self-assessment process, long- and rapid-acting insulin adjustments, meal timing, responses to blood glucose trends, handling hypoglycaemia and approaching multi-dive days are described. Some considerations for people using insulin pumps are also briefly discussed.

Key words
Scuba diving; health status; exercise; blood glucose level; endocrinology; safety

Introduction

Many people with well-managed insulin-dependent diabetes mellitus (IDDM) are highly self-aware, disciplined and able to manage risk; traits that set them in good stead to be excellent divers. Indeed, dive medicine bodies recognise that "*some individuals with insulin-requiring diabetes may be able to dive with an acceptable level of risk.*"[1] The Undersea and Hyperbaric Medical Society (UHMS) and Divers Alert Network (DAN) provide a comprehensive series of recommendations for selection and surveillance, scope of diving, and glucose management on the day of diving. The proceedings of the meeting through which the guidelines were developed includes individual papers, discussion, and the consensus guidelines.[2] An executive summary including the 19-point guidelines can be found in the proceedings and was reprinted in this journal.[3] The guidelines have been adopted by a number of dive medicine bodies, including the South Pacific Underwater Medicine Society (SPUMS).[1]

Medical evaluation to ensure 'fitness to dive' and scope of diving are critical pieces of the UHMS/DAN guidelines, but are beyond the scope of this paper. Here, my personal experience of diving with type 1 diabetes and details of how I put the UHMS/DAN recommendations into practice on dive days are related. Key elements of the self-assessment process, long- and rapid-acting insulin adjustments, meal timing, responses to blood glucose trends, handling hypoglycaemia, and approaching multi-dive days are considered. Also briefly discussed are some considerations for people using insulin pumps. Readers are encouraged to refer to the complete guidelines for additional information.[2,3]

Managing type 1 diabetes

Diagnosed with type 1 diabetes in 2001, when I was 17 years old, I currently follow a regimen of multiple daily injections (MDI) using analogue long- and rapid-acting insulins (detemir and lispro). I generally inject long-acting insulin (morning and night) and up to four, small rapid-acting insulin doses for meals and corrections during the day. I eat a low-carbohydrate diet which keeps my blood glucose very stable; eliminating carbohydrate-based foods reduces both post-prandial glucose excursions and the amount of insulin I need, which minimises error margins in dose calculations. I am very active, which keeps me insulin-sensitive, and I use both a continuous glucose monitoring system (CGMS; Dexcom Inc, San Diego, USA) and now 'flash' monitoring (Freestyle Libre, Abbot Diabetes Care, UK) to fine-tune my overall management. I choose not to use an insulin pump because I am comfortable and confident with MDI and consistently achieve HbA1c values around mid-5 mmol·L^{-1} with my approach.

Diving with type 1 diabetes

I learned to dive in 2007, certifying as a PADI Divemaster in 2008. Armed with a history of excellent HbA1c values and good hypoglycaemia awareness, I passed the dive medical and became certified in Thailand and Honduras rather than in Australia, where people with type 1 have difficulty accessing dive training. The access issue in Australia is due primarily to a position statement issued in 1994 by the Australian Diabetes Society (ADS) declaring diabetes to be contraindicated for diving, which is at odds with positions

on diving with diabetes in the United Kingdom, the USA and a number of European countries. The ADS statement was withdrawn for review in April 2015, and at the time of writing (20 August 2016), people with diabetes in Australia await an updated statement.

When I learned to dive, I was not aware of the UHMS/DAN protocols and I established my own safe blood glucose management strategies based on logic and years of learning about blood glucose management for sports. My approach was in essence similar to the UHMS/DAN protocols: I tested frequently in the lead up to a dive, dived with slightly elevated blood glucose levels in order to manage hypoglycaemia risk, briefed my dive buddy about diabetes and always carried hypoglycaemia treatment. Now, a clear set of strategies for blood glucose management on dive days is available and accessible for people with diabetes to follow, with support from both health care professionals and peers.[2,3]

Goals on dive days

Diving with type 1 diabetes requires careful planning and management, with the main aim of avoiding underwater hypoglycaemia. A secondary aim is to minimise anxiety about blood glucose – I would rather be captivated by a beautiful reef than worrying about my levels – so my approach is to control all the variables in play to make the outcomes as predictable as possible.

CONTROLLING THE VARIABLES

The four major variables that influence blood glucose are activity, timing, food and insulin. This is what I have learned about the four variables in relation to diving:

Activity

The type, intensity, and duration of physical activity impacts blood glucose. When making predictions about this variable, I need to consider factors like water temperature, likelihood of current and purpose of the dive (e.g., relaxing and drifting, or active and intense). I can generally predict that a combination of the fall in temperature from immersion in water and constant slow kicking will drop my blood glucose level by 2–3 $mmol \cdot L^{-1}$ over a 50-minute dive. If I am kicking into a current and working hard, it may drop more.

However, on rare occasions this does not hold true: if I have a particularly intense or exciting dive, I can emerge from the water with elevated blood glucose because adrenalin causes my liver to release glycogen. This is important to keep in mind for anxious or novice divers with diabetes as it can explain unexpected high blood glucose levels after diving.

Timing

Like many people with diabetes, I experience the "*dawn phenomenon*" which is a sharp increase in blood glucose early in the morning and subsequent insulin resistance that lasts until about 11:00 am. I become more sensitive to insulin as the day progresses. This means mornings are the ideal time to dive for me, as it is the time when I am naturally well protected from hypoglycaemia.

If I am scheduled to dive in the afternoon or evening, I plan around my increased insulin sensitivity. Because I know diving generally causes my blood glucose to drop, I can manage my hypoglycaemia risk by either reducing the rapid-acting insulin I take with my lunch and running my glucose level slightly high until dive time, or (my preferred method) raise my blood glucose slightly by eating two to four glucose tablets (8–16 grams of carbohydrate) about 45 minutes prior to diving.

Insulin

Understanding insulin is essential for the diabetic diver, and healthcare professionals are key to educating people with diabetes about insulin pharmacodynamics and pharmacokinetics. If people with diabetes understand insulin time/action profiles, absorption rates and mechanisms of action, they can work with their diabetes care teams to select the most appropriate insulins for their lifestyles, eating habits and physical activity pursuits.

Changing my long-acting insulin, for example, has helped me dive and exercise safely. When I moved from human to analogue insulins, I was started on glargine insulin. Glargine precipitates into an insoluble depot of insulin in the tissues at the injection site, which gradually becomes soluble and moves into the bloodstream. I found I sometimes experienced hypoglycaemia when I was physically active as activity increased blood flow around the insulin depot and, therefore, increased the speed at which the insulin was released into my bloodstream. I switched to insulin detemir, which binds to albumin in the blood and slowly dissociates, giving it a more stable absorption profile which I have found protects me from hypoglycaemia during exercise.[3]

Information about long-acting insulins is important for people on MDI only; knowing rapid-acting insulin time/action profiles is essential for people on both MDI and insulin pumps. Rapid-acting insulins have intense rises and peaks, generally becoming effective within 15–20 minutes of injection, peak after 60–90 minutes, and are active for around three hours. I find having rapid-acting insulin in my system when I exercise can make me prone to hypoglycaemia, so I never dive with active rapid-acting insulin on board. This strategy impacts meal timing when diving.

Food

As I prefer to dive with a system clear of rapid-acting insulin, I do not eat meals in the three hours prior to diving. I generally do morning dives in a fasted state, eat a late breakfast/early lunch for afternoon diving, and

leave my evening meal until after a night dive. Controlling my variables like this means I can minimise my risk of hypoglycaemia and dive with confidence. More generally, as dietary carbohydrate has a profound impact upon blood glucose, I minimise it. My diet generally consists of non-starchy vegetables, quality protein and healthy fats which keeps my blood glucose stable and predictable.

A note on insulin pumps

Insulin pumps only use rapid-acting insulin, so people on pumps must strike a fine balance between having some rapid-acting insulin on board to prevent hyperglycaemia, but not so much as to cause hypoglycaemia. Pumpers could manage hypoglycaemia risk by reducing their basal insulin delivery rate 2 to 5 hours prior to diving, and/or ingesting some fast-acting carbohydrate such as glucose tablets in the 45 minutes before diving. As with MDI regimens, controlling the four variables on pumps helps manage blood glucose. Not diving within three hours of a meal and insulin bolus, i.e., diving with only basal insulin on board and fine tuning with glucose tablets only, is a strategy some people employ to make levels more predictable.

Insulin pumps cannot be taken more than 1 metre below the surface, so pumps need to be disconnected prior to diving. Insulin will remain in a person's system for approximately three hours after a pump is disconnected. The amount of active insulin on board (bolus insulin only) can be obtained from most new pumps. Combined with a good understanding of rapid-acting insulin time/action profiles, insulin-on-board information will help a diver decide the best time to disconnect his/her pump prior to diving. Pumps should be reconnected upon surfacing, immediately after testing blood glucose levels to ensure the diver is not hypoglycaemic.

Blood glucose management on diving days

The UHMS/DAN guidelines give a series of recommendations about how to approach dive days with diabetes. This section outlines how I put these recommendations into practice.

SELF-ASSESSMENT

UHMS/DAN recommends that divers with diabetes assess themselves in a general sense prior to diving, and cancel a dive "*if* [the diver] *is uncomfortable, unduly anxious, unwell in any way (including seasickness), or blood glucose control is not in its normal stable pattern.*"[2]

I need three hours' notice at a minimum to do a dive; generally I prefer my self-assessment to begin about eight hours before a dive. My overnight blood glucose is generally stable, but if I am diving in the morning, ideally I use my flash monitor or CGMS overnight, which involves a sensor inserted under my skin that transmits and records my glucose levels every five minutes. CGMS transmitters cannot be taken more than 1 metre below the surface so I need to disconnect the transmitter and tape the sensor site before diving. Alternatively, I test my blood glucose before bed and rise to test at least three hours before the dive. If I am diving in the afternoon or evening, I test six to eight times during the day. If my blood glucose has been elevated (above 10 $mmol \cdot L^{-1}$) for more than three hours or if I have a significant hypoglycaemic event (below 3 $mmol \cdot L^{-1}$) in the lead-up to a dive, then I call it off.

Seasickness is a particular issue if the diver has chosen to manage hypoglycaemia risk by ingesting carbohydrate rather than reducing insulin; if the diver vomits s/he will have active insulin on board but no carbohydrate for it to act upon, which may lead to hypoglycaemia. A diabetic diver who becomes seasick should not dive, and glucose replacement to counteract active insulin is crucial. In my experience, a way to counteract hypoglycaemia when vomiting with active rapid-acting insulin on board is to frequently sip small amounts of fluids containing sugar, as at least some sugar will be absorbed before the fluid is rejected. The 'sick day' procedures from the diver's diabetes team should be followed in relation to issues like ketone management.

MINIMUM BLOOD GLUCOSE AND TREND

The UHMS/DAN protocol recommends establishing a blood glucose level of at least 8.3 $mmol \cdot L^{-1}$ (SPUMS recommends 9 $mmol \cdot L^{-1}$) and both recommend ensuring blood glucose is either stable or rising before entering the water.[1,2] Assuming long-acting/basal insulin doses are correct and remain unchanged, achieving the target minimum blood glucose level requires either reducing rapid-acting insulin for any meal eaten prior to diving, or ingesting carbohydrate. As I prefer to avoid dosing and eating meals before diving, I may need to increase my blood glucose level with a small, controlled amount of carbohydrate such as two to four glucose tablets (totalling 8–16 grams of carbohydrate which normally raises my blood glucose by 2–3 $mmol \cdot L^{-1}$) in order to reach a level where I am safe to dive. I generally do this about 45 minutes before diving. I test my blood glucose 90, 60 and 30 minutes and immediately prior to the dive to establish that I am entering the water with a stable or slightly rising blood glucose trend. The 90-minute test is additional to the UHMS/DAN guidelines.

MAXIMUM BLOOD GLUCOSE

The reason I eat very few carbohydrates and use only small amounts of glucose for corrections is because it is very easy to raise blood glucose levels too much. The protocol states that corrections with carbohydrate to raise blood glucose should not result in a level higher than 14 $mmol \cdot L^{-1}$, and diving should be cancelled if levels reach 16 $mmol \cdot L^{-1}$ or higher. High blood glucose increases the risks of dehydration, cramps and ketone accumulation.

If blood glucose levels are within the target range recommended for diving (8.3 [or 9]–14 mmol·L^{-1}) then they are higher than the ideal range of 4–8 mmol·L^{-1}. I aim to maintain levels of 8.5–10 mmol·L^{-1} when diving. I am comfortable running my blood glucose levels slightly higher than usual in order to dive safely; however, I need to drink extra water in order to counteract the dehydration I feel when I do this.

CARRYING EMERGENCY GLUCOSE AND HYPOGLYCAEMIA PROCEDURES

I try to ensure my risk of hypoglycaemia is remote by the choices in the lead-up to a dive; however, as recommended by UHMS/DAN, I always carry glucose in my buoyancy compensator (BCD) just in case. The most durable and easily ingestible form of glucose I have found for diving is gel shots, sold in cycling and running shops. I usually give one gel shot to my dive buddy, and inform him or her that I also have gel shots in the pocket of my BCD. The UHMS/DAN guidelines also recommend having glucagon available at the surface.

I brief my dive buddy thoroughly about diabetes and what to do if I have a hypoglycaemia event. I have never experienced low blood glucose underwater during a dive, but I have experimented in swimming pools in order to better understand my hypoglycaemia symptoms in water; I know that a sudden, acute awareness of cold and a feeling of weakness are my main symptoms. If I were to feel hypoglycaemic underwater, I would signal "*L*" with index finger and thumb for "*Low*" to my buddy, surface with him or her, establish positive buoyancy, ingest glucose on the surface and leave the water.

The worst case scenario is loss of consciousness underwater, in which case the only additions needed to a standard rescue procedure are administration of parenteral glucagon if available, and notifying emergency services that the rescued diver has diabetes.

AFTER DIVING

I always check my blood glucose immediately after diving, and have noticed that my pattern of a 2–3 mmol·L^{-1} drop is very predictable and I generally emerge between 5.5 and 8 mmol·L^{-1}. If we are due to do another dive, I avoid eating and taking rapid-acting insulin during the surface interval so I can remain in tight control of my variables. If I need to correct my blood glucose level to bring it up to a level that is safe for a second dive, I do so with glucose tablets only. As with all sustained exercise, if I have a particularly active day diving I need to be cautious about delayed hypoglycaemia, which I manage for eight to ten hours after diving, with regular blood tests or my CGMS. Finally, UHMS/DAN recommends logging blood glucose levels, diabetes interventions and dives. Ensuring blood glucose meter date and time settings are correct is important (and often overlooked when replacing batteries or changing meters) in case records need to be corroborated at a later date.

Table 1
The major principles of management for safe scuba diving for a person with type 1 diabetes

- People with well-managed insulin-dependent diabetes can dive safely.
- Divers with diabetes should tightly control the variables that impact blood glucose levels, including activity, timing, food and insulin.
- Honest self-assessment is critical. A diver with diabetes should cancel a dive if seasick, unusually anxious, or if s/he has had significant high or low blood glucose levels in the preceding 24 hour period.
- Enter the water above 8.3 mmol·L^{-1} and below 14 mmol·L^{-1} with a stable or rising trend in blood glucose established with glucose tests at 90, 60, and 30 minutes prior to a dive.
- Carry emergency glucose at all times and brief dive buddies about hypoglycaemia procedures.
- Use the online diabetes community for support and practical advice about reaching physical activity goals with insulin dependent diabetes.

The future: new technology

'Flash monitoring' is a new system that monitors interstitial glucose through a subcutaneous sensor that transmits a tethered radio signal to a receiver came to market recently in Australia. The sensor is scanned by the receiver to provide an instantaneous glucose reading and the glucose level trend for the previous eight hours. No finger pricks are needed to calibrate the device and it is considerably cheaper than existing continuous glucose monitors on the market. I now use a flash monitor regularly. The sensor is not supposed to be submerged deeper than 3 m but I took it on a 18 m dive and it survived and remained accurate post dive (compared to finger prick glucose measurements). I then went on several 15 m dives with the receiver in a jury-rigged pressure-proof camera housing. The system gave me what appeared to be accurate in-dive readings, corroborated on the surface immediately post dive. Research on the sensor's pressure tolerances and its accuracy at depth would seem well worthwhile pursuing. With a custom housing, such new technology potentially promises much for divers with diabetes to obtain glucose information while diving.

Conclusions

Diving with insulin-dependent diabetes presents some challenges, but it is certainly achievable for those medically cleared, capable, and motivated to participate. It is crucial for diabetic divers to identify, understand and control

the variables that impact blood glucose in order to dive safely (Table 1). My approach is simple: I minimise risk by avoiding rapid-acting insulin and meals prior to diving and adhere to the UHMS/DAN recommendations on dive days. The UHMS/DAN recommendations can be tailored to suit different diabetes regimens and preferences for hypoglycaemia management, and divers should create individual management plans in conjunction with their healthcare providers.

When developing management plans, divers and doctors alike can tap into the vast collective knowledge of thousands of active people living with diabetes by joining the thriving, knowledgeable online diabetes community. Online discussion boards such as those hosted by the American Diabetes Association (http://community.diabetes.org/), Diabetes.co.uk (http://www.diabetes.co.uk/forum/), and communities on Facebook such as the Type 1 Diabetic Athletes Group (https://www.facebook.com/groups/Type1DiabeticAthletes/) and Sporty Diabetic Type 1s (https://www.facebook.com/groups/SportyT1/) are rich sources of information acquired from years of lived experience. Divers and healthcare professionals can crowdsource problems and seek support from these powerful resources in order to attempt and achieve diving goals.

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