Insulin-requiring diabetes and recreational diving:
Australian Diabetes Society position statement

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1 Preface:

In 2015 the Australian Diabetes Society commissioned a working group to review and revise its position statement on scuba diving in persons with diabetes. The working group consisted of endocrinologists with an interest in type 1 diabetes, diving medical specialists, a recreational diver with diabetes and an advocate for people with type 1 diabetes.

A thorough literature review was performed and all available evidence was summarised and a new position statement was drafted. The new position statement was submitted to the ADS Council for approval.

The scope of this document is restricted to recreational (not professional) diving in line with the available evidence. It is also targeted at insulin-requiring (both type 1 and type 2) diabetes, as traditionally this group has been excluded from recreational diving. This document updates the ADS position statement in line with current evidence.

2 Introduction

Recreational diving using self-contained underwater breathing apparatus (scuba) is a popular activity in Australia and around the world. Both immersion and increased ambient pressures involved with scuba diving place greater demands on the individual, in particular on the cardiovascular, respiratory and metabolic systems. The diver is required to follow set procedures and to be able to respond to sudden changes in conditions.

Insulin-treated diabetes mellitus (both type 1 and type 2) is potentially associated with problems that may limit the physical ability to dive. In particular, sudden and unexpected alteration in consciousness due to hypoglycaemia can be extremely dangerous or fatal to the diver and dive partner. As a result, many countries and authorities have historically imposed a blanket ban on scuba diving in persons with insulin-treated diabetes.

Despite the blanket ban, many persons with insulin-treated diabetes continue to dive successfully, either openly or without notification of their diabetes. Furthermore, increasing scientific literature and expert group recommendations suggest that there are approaches, which can ensure safe diving for people with insulin-treated diabetes. As a result, many countries have recently lifted the blanket ban and published recommendations designed to allow safe scuba diving in this group.

The Australian Diabetes Society (ADS) position statement published in 1994 recommended that people with insulin-treated diabetes should not dive. [1] In light of the available literature, diver experience and guidelines from professional diving medical groups, this document revises and updates the ADS position statement.

3 Worldwide experience in diving with diabetes

3.1 Literature review of scuba diving and diabetes

The academic literature in this area consists of a simulation study in a hyperbaric chamber, questionnaires for divers with diabetes, and seven prospective studies in open water. (See appendix 1).

3.1.1 Hyperbaric chamber study

In 1997 Edge et al. performed a prospective crossover study in a hyperbaric chamber simulating diving conditions at sea level (101kPa) and at 27 metres underwater (370kPa), in persons with type 1 diabetes. [2] This study demonstrated no difference in blood glucose changes during exercise at sea level and the simulated 27 metre dive.

3.1.2 Questionnaires in divers with diabetes

Persons with diabetes in the UK who wished to dive as members of diving associations (the British Sub-Aqua club, the Sub-Aqua association, and the Scottish Sub-Aqua club), were required to complete a mandatory annual questionnaire to be considered fit to dive. A case series of 323 people (totalling 8760 dives) with diabetes collected between 1991-2001 was published in 2005. [3] The cohort included 254 (75%) with insulin-requiring diabetes with a mean age of 34 years, and 25% with non-insulin requiring diabetes with a mean age of 47 years. Of these 211 (65%) people continued to dive while 55 (11%) had ceased diving and 11 (4%) were refused certification to continue diving. There were two reported deaths during this time (both with non-insulin requiring diabetes). One died of a myocardial infarct, while the cause of death for the other was not known. Forty-two (13%) people in the cohort were lost to follow up.

Of the 241 divers with insulin-requiring diabetes, 80% stated they always checked the blood glucose levels (BGL) prior to diving and 98% carried glucose paste underwater. There was only one self-reported episode of hypoglycaemia underwater, which was treated with ingestion of glucose paste while submerged. Although subject to biases intrinsic to self-reported questionnaires, this study showed that people with diabetes (both insulin-requiring and non-insulin requiring) were diving safely and successfully.

3.1.3 Prospective cohort studies in open water

There are seven prospective cohort studies of scuba diving in persons with type 1 diabetes. [4-10] Some studies also included persons without diabetes (See appendix 1). In these studies participants undertook multiple (between 6 - 12) dives over several consecutive days in tropical waters. Combined, a total of 1048 dives were completed by 109 people with type 1 diabetes and 640 dives by 62 people without diabetes.

Participants in these studies were selected using strict criteria. Persons with diabetes related complications (except background retinopathy), a history of hypoglycaemia unawareness or recent hospitalisation for diabetes were excluded. Most participants had excellent glycaemic control (mean HbA1c <7.5%), and were treated with multi-dose insulin or continuous subcutaneous insulin infusion (pump) therapy.

Participants used a pre-dive glycaemic management protocol designed to avoid hypoglycaemia. This included frequent monitoring of BGLs prior to the commencement of diving. Diving was only permitted if BGL immediately prior to diving was above a predetermined threshold with

stable or rising glucose levels. The acceptable threshold BGL was 4.4 mmol/L in two studies, [6, 10], 6.7 mmol/L in one study, [9] and 8.3-8.9 mmol/L in the remaining four studies. [4, 5, 7, 8] A carbohydrate load of 15-30 grams was ingested if the pre-dive BGL was below the set threshold or on a declining trajectory. If a satisfactory BGL increase was not achieved, the dive was aborted.

There were limitations to the scope of diving. Most dives had a maximum depth of 20-25 metres with a maximum dive time of 45-50 minutes. Diving plans were tailored to avoid diving where immediate safe access to the surface was not possible – for example diving in caves or using profiles with mandatory decompression stops. This allowed for unrestricted access to the surface in case of hypoglycaemia.

Collectively, these studies demonstrated that pre-dive carbohydrate ingestion occurred in over 50% of the dives. Symptomatic hypoglycaemia during diving was very uncommon. There were 4 episodes of mild hypoglycaemia (out of 90 dives) in one study and these were attributed to non-adherence to the pre-dive protocol. [5] Of 1048 monitored dives, there were no complications related to hypoglycaemia during dives.

The threshold BGL to permit commencement of diving is important in avoiding hypoglycaemia. Of the two studies using a pre-dive BGL threshold of 4.4 mmol/L there were 39 occurrences (out of 598 dives) of post-dive BGL <3.9 mmol/L without symptomatic hypoglycaemia. [6, 9] In contrast these events were rare in the studies using pre-dive threshold BGL of 6.7 mmol/L. Comparison of BGL before and after the dive showed that on average, participants' BGL dropped between 2.2 mmol/L and 4.3 mmol/L, although there was a wide inter-individual variability.

In one study in which participants undertook multiple dives over 6 consecutive days, there was a 15-20% reduction in total daily insulin requirements during this period. There was also an increase in the haematocrit over this time, which was corrected with adequate water intake.

Two studies used continuous glucose monitoring systems (CGMS) before, during and after scuba diving. [4, 5] Divers wore dry suits and used CGMS systems with a cable (rather than wireless) connection between the glucose sensor and receiver. These studies found a good correlation between CGMS, capillary BGL and venous glucose levels. The mean BGL drop was 1.4 to 3.3 mmol/L during the dive. In one study CGMS showed good durability under diving conditions (85% survival of sensors). [4] In contrast the second study showed poorer durability of sensors (56%). [5] These studies also suggested that CGMS can be useful in optimising diabetes management in the lead up to and in between dives as well as being useful during dives. Of note, non-cabled CGMS currently used in standard practice are not indicated for submerging more than a few metres.

In summary, there is growing evidence that in people with insulin-requiring diabetes using a predefined protocol, diving can be achieved safely without hypoglycaemia related complications.

3.2 Diabetes and recreational diving workshop 2005

A workshop jointly sponsored by the Undersea and Hyperbaric Medical Society (UHMS) and Divers Alert Network (DAN) was held on June 19th, 2005 in Las Vegas USA. [11] This workshop

brought together over 50 experts to review the existing literature and develop consensus guidelines on diving in people with diabetes. This workshop compared different protocols and reached consensus guidelines.

The three sections of the consensus guidelines pertain to 1) Selection and surveillance of persons with diabetes who are suitable for diving; 2) Scope of diving; and 3) Glucose management on the day of diving. The findings from this workshop have formed the basis for development of several subsequent guidelines from different authorities and different countries, and also underline the basis of recommendations in this document.

4 Comparison of current recommendation from other diving authorities

Appendices 2 to 5 summarise current recommendations for diving with diabetes from different countries and authorities that have been published since the 2005 workshop. [3, 5, 8, 11-16] Recommendations are necessarily conservative and based on the consensus guidelines developed at the 2005 workshop.

Appendix 2 compares the criteria used to assess a person's suitability for diving. Common criteria for exclusion include the presence of hypoglycaemia unawareness, recent major hypoglycaemia or hospitalisation for diabetes. Recent commencement of insulin, or recent significant change in diabetes medications are criteria for exclusion as these scenarios represent times at which glucose levels may be unstable or unpredictable. The presence of micro or macrovascular complications (except for background retinopathy) is also an exclusion criterion as their presence increases the risk of sudden cardiovascular related morbidity and mortality.

Appendix 3 compares the current recommendations for the scope of diving. Appendix 4 and 5 compare the blood glucose management on the day of diving and hypoglycaemia management respectively. The guidelines from the South Pacific Underwater Medical Society's (SPUMS) are of local relevance to Australia. [16]

5 New ADS recommendations:

In light of the above evidence and in consultation with Australian experts and divers with diabetes, the updated ADS recommendations are presented below. The guidelines contain three sections: 1) suitability for diving, 2) scope of diving, and 3) blood glucose management on the day of diving.

5.1 Suitability for diving

Persons with insulin treated diabetes who do not have another exclusionary reason (such as epilepsy or pulmonary disease) may undertake scuba diving, providing the following conditions are met.

- Age: 18 years and over
- Diabetes management:
    - More than 1 year since initiation of insulin
    - More than 3 months since significant change in diabetes therapy (such as change in insulin regimen or addition of new anti-diabetic medications)

    - HbA1c ≤ 9.0%. (People with HbA1c > 9.0% are not necessarily at increased risk of hypoglycaemia, but it is an indication of suboptimally managed diabetes with potential for hyperglycaemia, and unpredictable glucose levels).
    - Demonstrated accurate use of a glucose monitoring device
    - Good knowledge of carbohydrate, insulin and exercise interactions with BGL and able to self adjust insulin doses
- Hypoglycaemia history:
    - No hypoglycaemia unawareness
    - No severe hypoglycaemia in the last 1 year (defined as hypoglycaemia requiring third party assistance for recovery, emergency services attendance, emergency department attendance, or hospital admission)
- Diabetes related complications
    - There are no known microvascular complications (microalbuminuria, peripheral or autonomic neuropathy, any retinopathy greater than background retinopathy) or any macrovascular complications
- Medical examination:
    - The diver should undergo initial and annual review with the physician who assists in the management of their diabetes (GP or endocrinologist) and a doctor who has completed a post-graduate diving examiner's qualification.
    - In persons older than 40 years, formal evaluation for silent cardiac ischaemia (cardiac stress testing) as per local expertise should be completed.

5.2 Scope of diving

The following restrictions should apply to persons with diabetes undertaking recreational diving

- In between dives there should be a minimum surface interval of 1 hour. It is recommended that there be longer surface intervals between subsequent dives after the 2nd dive of the day.
- Dive with a dive partner without diabetes who must be informed of their condition and aware of appropriate response in the event of hypoglycaemia
- No diving where immediate safe access to the surface is not possible. This includes dives with mandated decompression stops, that are deeper than 30 metres or dives with overhead environment. This allows for unrestricted access to the surface in case of hypoglycaemia.
- Avoid dives longer than 1 hour duration or circumstances that may provoke hypoglycaemia (such as arduous dives in cold water or those involving very strenuous exertion)
- Carry oral glucose in a readily accessible and ingestible form at the surface and during the dive. Ensure parenteral glucagon is available at the surface and the dive partner or other persons on the surface are knowledgeable in its administration.

5.3 Diving protocol recommendations

5.3.1 BGL management:

- On the day of dive, divers should assess whether or not they are suitable to dive that day. If unwell or if blood glucose control is not in the normal stable pattern, diving should not be undertaken.
- BGL management pre-dive:
    - Test BGL 60, 30 minutes, and immediately pre-dive to ensure no downward trend
    - BGL target 8.3 – 16.7 mmol/L and stable or rising immediately pre-dive
        - If 6.6 – 8.3 mmol/L (oral CHO 15g recommended pre-dive)
        - If < 6.6 mmol/L (oral CHO 30g recommended and not submerge until rechecked. Ok to dive if BGL >8.3 mmol/L and rising)
    - If BGL > 16.7 mmol/L, recommend diving be postponed and check capillary ketones. If ketones > 1.0 mmol/L, treat as appropriate and cancel dive for the remainder of the day.
- Check BGL immediately post dive and manage appropriately.
- Each subsequent dive should follow the above BGL management

5.3.2 Other recommendations:

- In case of hypoglycaemia underwater:
    - A hand signal (an L-shape made by thumb and index finger) should be established between the diver with diabetes and dive buddy to communicate hypoglycaemia underwater.
    - If symptoms suggestive of hypoglycaemia are noticed underwater, the diver should ascend to the surface immediately, establish positive buoyancy, ingest glucose and leave the water. The informed dive partner should assist with this process. If trained, glucose paste can be consumed underwater, but the priority should be to ascend to surface.
- For divers with insulin requiring type 2 diabetes who are also treated with oral hypoglycaemic medications, it is recommended sulphonylureas be omitted on the day of diving to decrease hypoglycaemia risk.
- Avoid alcohol for 24 hours prior to dive.
- Maintain adequate hydration on days of diving
- Log all dives and BGL management and use this information to fine-tune future dives.
- Continuous glucose monitor and insulin pump: remove prior to diving, as devices are not indicated for submerging more than a few metres underwater.

6 Conclusion:

ADS recognises that motivated individuals with well-controlled diabetes (both insulin-requiring and non-insulin requiring), may be able to safely participate in recreational diving. This requires preparation, experience and protocols based on the above guidelines. Diving should not be undertaken by individuals with hypoglycaemia unawareness, recent severe hypoglycaemia, or any complications (apart from background retinopathy) as recommended by other authorities. The diver should undergo initial and annual review with the physician normally assisting with the management of their diabetes (either endocrinologist or GP) and a

doctor who has completed a post-graduate diving examiner's qualification. There are restrictions on the scope of diving to ensure safety. The diver should follow protocols for blood glucose management to avoid hypoglycaemia. These recommendations bring the ADS position statement inline with the South Pacific Underwater Medical Society and authorities from other countries.

7 References

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