

Guidelines

South Pacific Underwater Medicine Society guidelines for cardiovascular risk assessment of divers

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Abstract

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The South Pacific Underwater Medicine Society (SPUMS) diving medical for recreational scuba divers was last reviewed in 2011. From 2011 to 2019, considerable advancements have occurred in cardiovascular risk assessment relevant to divers. The SPUMS 48th (2019) Annual Scientific Meeting theme was cardiovascular risk assessment in diving. The meeting had multiple presentations updating scientific information about assessing cardiovascular risk. These were distilled into a new set of guidelines at the final conference workshop. SPUMS guidelines for medical risk assessment in recreational diving have subsequently been updated and modified including a new Appendix C: *Suggested evaluation of the cardiovascular system for divers*. The revised evaluation of the cardiovascular system for divers covers the following topics:

1. Background information on the relevance of cardiovascular risk and diving;
2. Defining which divers with cardiovascular problems should not dive, or whom require treatment interventions before further review;
3. Recommended screening procedures (flowchart) for divers aged 45 and over;
4. Assessment of divers with known or symptomatic cardiovascular disease, including guidance on assessing divers with specific diagnoses such as hypertension, atrial fibrillation, cardiac pacemaker, immersion pulmonary oedema, takotsubo cardiomyopathy, hypertrophic cardiomyopathy and persistent (patent) foramen ovale;
5. Additional cardiovascular health questions included in the SPUMS guidelines for medical risk assessment in recreational diving;
6. Updated general cardiovascular medical risk assessment advice;
7. Referencing of relevant literature.

The essential elements of this guideline are presented in this paper.

Introduction

Diving in all forms places increased demands on the cardiovascular system. Immersion itself causes an increase in cardiac preload (increased venous return) and at the same time, peripheral vasoconstriction, causing an increase in blood pressure and afterload. These changes are typically

accompanied by sustained mild to moderate exercise and occasional requirements for peak exercise in challenging circumstances. Given all this and the increasing age of the ‘average’ diver, it is not surprising that 39% of recreational diving fatalities in divers aged 45 or over in our region have a cardiac event as the disabling injury.¹

The primary goals of evaluating the cardiovascular system in a diving candidate are to:

- Identify those who appear to be at increased risk of myocardial ischaemic events, heart failure, dysrhythmias and other cardiac pathology that might disable a diver underwater; and
- Establish that the candidate has an adequate exercise capacity for diving.

Methods

The South Pacific Underwater Medicine Society (SPUMS) 48th (2019) Annual Scientific Meeting theme was cardiovascular risk assessment in diving. The meeting had multiple presentations updating scientific information about assessing cardiovascular risk. These were distilled (with audience participation) into a new set of guidelines applicable to prospective or established divers at the final conference workshop. Conference presentations and workshop discussions were led by a committee (represented by the authorship of this paper) that included three cardiologists (NJ, RR, MT) and three diving physicians (DS, MHB, SJM). This committee subsequently refined and finalised the following guideline.

Guideline

All diving candidates and established divers aged 45 years and over should undergo a medical assessment with a focus on cardiovascular evaluation, preferably by a doctor with training in diving medicine. This recommendation is based on commonly used age criteria accepted as risk thresholds in cardiovascular risk calculators.^{2,3}

WHICH DIVERS WITH CARDIOVASCULAR PROBLEMS SHOULD NOT DIVE?

Diagnoses usually considered to render an individual unsuitable for diving include:

- Untreated and/or symptomatic coronary artery disease;
- Left ventricular dysfunction of any cause. Divers with well treated or recovered left ventricular dysfunction with good ejection fraction (especially with ejection fraction (EF) > 50%) would usually be acceptable if there was good exercise capacity and the underlying causes treated. All such divers require cardiology review;
- Hypertrophic cardiomyopathy would usually preclude diving. Cardiology review is required in all cases;
- Congestive heart failure;
- Pulmonary hypertension;
- Long QT syndrome or other arrhythmia-inducing ion channelopathies;
- Paroxysmal arrhythmias causing unconsciousness or impairment of exercise capacity;
- Poor exercise capacity of apparent cardiac origin;
- Moderate to severe valvular lesions;
- Complex congenital cardiac disease. (Note that an atrial

septal defect (ASD) is not included here – ASD patients are at increased risk of neurological decompression sickness (DCS) and should be assessed by a diving doctor and a cardiologist before being cleared for diving);

- The presence of an implanted cardiac defibrillator;
- Recurrent syncope;
- Anticoagulation – including warfarin, direct thrombin inhibitors (e.g., dabigatran), and factor Xa inhibitors (e.g., rivaroxaban, apixaban) or similar – for whatever reason; this does not include single antiplatelet therapy (e.g., aspirin).] Some experts allow single anticoagulant therapy under selected circumstances. This remains a controversial area and the committee acknowledges the lack of reliable evidence to support either position.

The successful treatment of some of these disorders may result in a candidate becoming suitable for diving. In particular, a candidate with coronary artery disease who has been successfully revascularized may be suitable for diving if inducible ischaemia can be excluded and adequate exercise capacity demonstrated (see below). Another example is a candidate with a history of paroxysmal arrhythmia who has undergone successful pathway ablation.

Following successful cardiac intervention, candidates may require some recovery time before commencing or resuming diving. Many cardiologists and diving physicians would not allow diving while on dual antiplatelet therapy. The precise period of diving abstinence should be determined by the cardiologist and diving physician.

Candidates with any of the above diagnoses who wish to consider diving after appropriate treatment should be referred to a physician with training in diving medicine for evaluation.

RECOMMENDED SCREENING PROCEDURES FOR DIVERS AGED 45 AND OVER

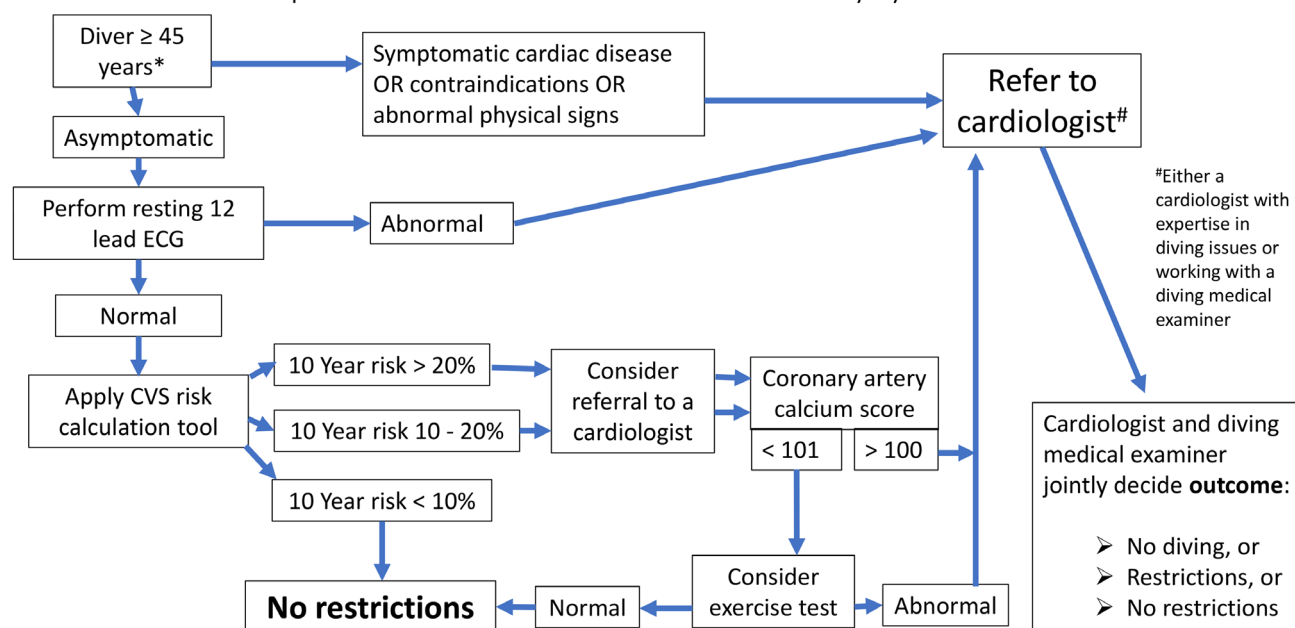
Figure 1 proposes a screening algorithm for diving candidates or divers aged 45 years and over.

- All symptomatic candidates should be referred to a cardiologist for investigation.
- Candidates with a positive cardiovascular history (including younger diving candidates or established divers < 45 years) should undergo a focused medical assessment; initially by a doctor with training in diving medicine. Cardiology referral should be considered.
- All asymptomatic divers or candidates ≥ 45 years should have a resting electrocardiogram (ECG) performed and any significant abnormalities should prompt referral to a cardiologist.
- Asymptomatic candidates or divers ≥ 45 years should be assessed with a standard, validated, cardiovascular risk assessment tool (e.g., the National Vascular Disease Prevention Alliance in Australia).² The specific tool used may vary.

Figure 1

Screening algorithm for cardiovascular disease in diving candidates or divers aged 45 years and over

*Subsequent reassessment should be carried out at least every 5 years



- Candidates with an estimated 10 year risk < 10% may proceed to diving with no further assessment. Some diving doctors would also perform a standard exercise test (with ECG monitoring). The diving medical may also prompt a discussion of life-style modification.
- Candidates with a higher risk should have a coronary calcium score and those at > 20% (and possibly those > 10%) 10-year risk should have a computed tomography (CT) angiogram and/or functional stress test. Such testing may be best organised by a cardiologist.
- A normal CT angiogram or a functional stress test negative for ischaemia suggests that the candidate should be able to dive without important excess risk.
- A plan (including review frequency) for follow-up cardiac health surveillance tailored to the diver's risk profile should be established at the time of the initial evaluation.

ASSESSMENT OF DIVERS WITH KNOWN OR SYMPTOMATIC CARDIOVASCULAR DISEASE

All candidates for diving, or seeking ongoing monitoring of their suitability to continue diving should complete the full questionnaire that forms part of the SPUMS guidelines for medical risk assessment in recreational diving.

Candidates who have responded indicating they may have known or symptomatic cardiovascular disease need further specialist investigation by an appropriate physician. This may include myocardial perfusion scan, stress echocardiography or stress exercise ECG ("stress test"). Although an exercise ECG is relatively insensitive to early coronary disease, it has

the advantage of demonstrating exercise capacity and can be modified to test sustained exercise at 6 MET. Sustained exercise at a minimum of 6 MET is a pragmatic expectation for a recreational diver but there may be an occasional need to exercise transiently at higher levels during diving.

NOTES ON SPECIFIC DIAGNOSES

Treated hypertension with adequate control and in the absence of other risk factors that would indicate screening for coronary artery disease is acceptable for diving. Although local practices may vary in some details, hypertension should always be investigated and treated according to contemporary evidence-based guidelines.^{4,5} Hypertension above 160/100 mmHg is a contraindication until investigated and treated.

For divers taking antihypertensive drugs, certain antihypertensive drugs may be preferred to others in the context of scuba diving, and participation in scuba diving may be of consequence for antihypertensive treatment choices. Expert opinion should be sought. It is recommended that subjects with hypertension be assessed for signs of cardiac ischaemia and/or dysfunction and be referred to a vascular specialist or cardiologist for cardiovascular screening when deemed appropriate. Divers with hypertension should be informed about the symptoms of immersion pulmonary oedema and receive specific instructions to immediately abort a dive in case of these symptoms.⁵

Atrial fibrillation where the rate is adequately controlled in a candidate without inducible myocardial ischaemia and

who exhibits adequate exercise capacity is acceptable in diving. However, many such patients are anticoagulated and anticoagulation is itself a contraindication for diving (see above). All patients with atrial fibrillation should have an echocardiogram to exclude structural heart disease and to assess for diastolic dysfunction.

Successful aberrant pathway ablation in case of Wolff Parkinson White (WPW) syndrome and atrio-ventricular nodal re-entry tachycardia (AVNRT), or pulmonary vein isolation in case of atrial fibrillation may also render the candidate acceptable for diving, however these individuals should have a bubble-contrast echo to ensure no persistent hole remains through the inter-atrial septum.

A *cardiac pacemaker* is not an absolute contraindication to continued diving, but the underlying pathology is important to consider, as is the proven ability of the device to function at depth. Pressure capability of a device can usually be obtained from the manufacturer.

A previous episode of *immersion pulmonary oedema*, *Takotsubo cardiomyopathy* or a diagnosis of *obstructive cardiomyopathy* should contra-indicate further diving until appropriately assessed. A diver or new diving candidate with such a history should be referred to a physician with training in diving medicine for discussion of the relevant issues.

Persistent (patent) foramen ovale (PFO). SPUMS does not advise routine testing for the presence of a PFO.⁶

A PFO that exhibits right-to-left shunting with no or minimal provocation is a risk factor for serious neurological DCS. In established divers, such lesions are usually discovered by bubble contrast echocardiography conducted after a relevant episode of DCS or the development of a suspicious rash after diving.

These divers are usually advised to cease diving, modify their diving to reduce venous bubble formation or to have the PFO repaired. There are some data to suggest the incidence of DCS remains higher in those who elect to modify their diving, and this option is less often recommended than previously.^{7,8} When this option is taken for whatever reason, it would be reasonable to advise diving more conservatively in order to minimise venous bubbles. There are various strategies that might be employed to reduce the risk of significant venous bubble formation after diving, or the subsequent right-to-left shunting of such bubbles across a PFO. The appropriateness of this approach, and the strategies chosen, need to be considered on an individual basis and in discussion with a diving medicine expert. Examples include: reducing dive times to well inside accepted no-decompression limits; restricting dive depths to less than 15 m; performing only one dive per day; use of nitrox with air dive planning tools; intentional lengthening of a safety stop or decompression time at shallow stops and avoidance

of heavy exercise and unnecessary lifting or straining for at least three hours after diving.⁶⁻⁹

Occasionally new diver candidates have a previously discovered PFO; in such cases an objective assessment of the shunting behaviour of the lesion is required in order to adequately counsel the candidate about the implied risks in diving. If not already done, this is best achieved using a bubble contrast echocardiogram and provocative manoeuvres. It is strongly recommended the results of such tests are discussed with a physician who has training in diving medicine.

ADDITIONS TO THE SPUMS DIVER HEALTH RISK ASSESSMENT QUESTIONNAIRE

As a result of the workshop, it was identified that a number of additional questions needed to be added to the SPUMS guidelines for medical risk assessment in recreational diving questionnaire, covering lifestyle and specific cardiovascular risk.

The general advice preceding the questions was also revised to state:

- If you have never heard of the condition or had the diagnosis applied to you – then reply no; and
- If you are not confident that you understand the question, then leave this blank and discuss with the doctor.

The new questions are documented next.

Lifestyle questions:

- How often do you exercise and at what estimated level of intensity of that exercise (minutes per week, high/ moderate/low intensity)?
- Are you currently smoking?
- Did you smoke in the past?
- How many cigarettes per day do/did you smoke and for how many years?
- If other forms of tobacco, please detail.

Specific cardiovascular risk questions:

- Do you have any known heart disease, or have you ever consulted a cardiologist (specialist heart doctor)?
- Is there any family history of heart disease or diabetes?
- Is there any family history of sudden death at a young age?
- Are you ever aware of a racing or irregularly beating heart, or any other known problem with your heart beat?
- Have you ever had giddiness, light-headedness or periods of unconsciousness, whether or not associated with exercise?
- Do you ever get discomfort in your chest on exertion (angina)?
- Do you get very short of breath on exertion (out of proportion to the exercise, or before your legs get tired)?
- Have you ever been short of breath lying down or woken from sleep with breathlessness?

- Do you have a pacemaker or implanted defibrillator?
- Have you ever had an operation on the heart including any placement of stents?

Have you ever had a diagnosis of the following:

- a) High blood pressure?
- b) Rheumatic fever or problems with your heart valves?
- c) High cholesterol?
- d) Immersion pulmonary oedema?
- e) Heart failure, or a problem with your heart muscle including cardiomyopathy or obstructive coronary heart disease?
- f) A 'hole in the heart' (patent foramen ovale, atrial septal defect, ventricular septal defect) or other congenital heart disease?
- g) Blood clots in the legs or lungs?
- h) A stroke?

Have you ever failed or had a significant medical issue with a diving medical in the past?

Modifications to section A 4.10 – Cardiovascular system

Twenty-eight percent (28%) of recreational diving fatalities have a cardiac event as the disabling injury. It follows that the primary goals of evaluating the cardiovascular system in a diving candidate are to identify those at risk of myocardial ischaemic events, myocardial insufficiency, or other cardiac events (such as arrhythmias) that might be disabling underwater.

All divers or diving candidates aged 45 and over are at higher risk of cardiac disease even when asymptomatic. Therefore, all should be assessed according to the guidelines documented according to the algorithm above.

The SPUMS guidelines for medical risk assessment in recreational diving (Appendix C) also provide guidance for assessment of younger candidates or other high-risk groups who have a history indicating increased cardiac risk or in whom physical examination reveals cardiovascular abnormalities.

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Conflicts of interest and funding

Professor Mitchell, an author on this paper, is the Editor of *Diving and Hyperbaric Medicine* journal. However, there were no review management process conflicts in respect of this article. As an adopted societal guideline arising from an iterative process of consensus generation by international experts, it was not subject to peer review.

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