An anatomical illustration of a human torso, rendered in a semi-transparent blue color. The heart is highlighted in a vibrant red, with its major arteries and veins branching out across the chest and neck. The overall aesthetic is clean and medical, with a dark blue background.

smart guide

Patent Foramen Ovale
and Fitness

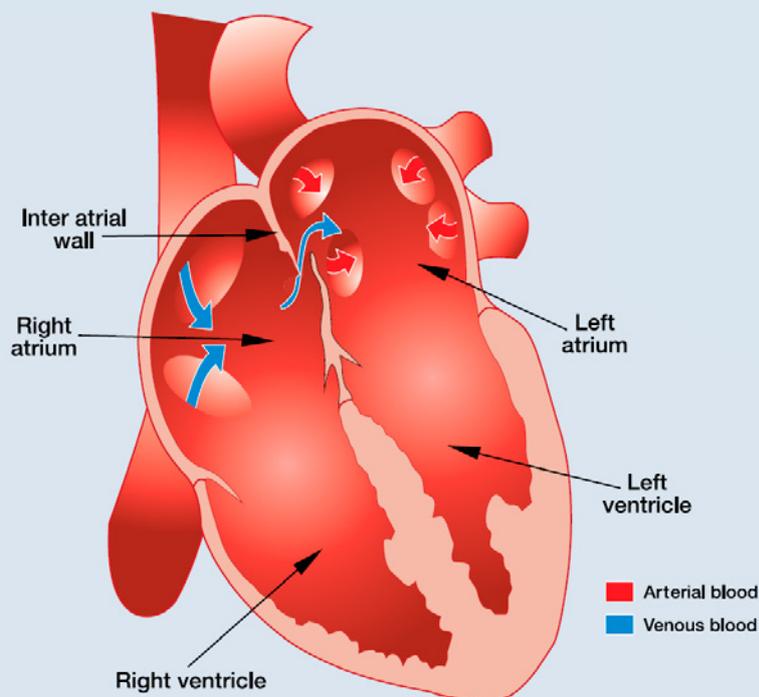


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INTRODUCTION

Prior to birth, oxygenated blood flows from the mother, through the placenta, to the heart of the foetus via the opening in the wall separating the left and right atrium (foramen ovale), into the foetal circulation. The foramen ovale has a “trap-door” feature which opens due to the pressure of blood flow from the mother’s placenta entering the

right atrium and lets the blood pass to the left atrium. At birth, the lungs expand and the pressure in the left atrium increases and “slams shut” the foramen ovale. Shortly after birth the “door” fuses together, but it fails to fuse completely in roughly 27% of people and results in a patent foramen ovale, also called persistent foramen ovale (PFO).



27%
Approximate percentage of people affected by Patent Foramen Ovale (PFO)

In people with PFO, if the pressure in the right atrium rises above the pressure in the left atrium, blood can flow from the right to the left atrium. The direct flow of blood from the right to the left atrium, which bypasses the lungs, is called right-to-left shunt (RLS). The RLS is known to let blood clots pass to the arterial side which can cause a stroke (brain thromboembolism). Similarly, the PFO in divers may let gas bubbles from the venous blood (venous gas emboli – VGE) pass the arterial side and cause decompression sickness (DCS).

Epidemiological studies have shown an association between PFO and certain types of neurological and cutaneous DCS. The DCS risk in recreational divers has been reported at 3.6 cases per 10 000 dives, with 0.84 cases of neurological DCS per 10 000 dives and

a four-fold increase in risk with a PFO. The overall risk of neurological DCS is low, even in the presence of a PFO. However, for some individuals, PFO seems to be a greater risk than predicted. Guidelines for PFO testing are aimed at identifying such individuals and managing their DCS risk.

The following guidelines were developed from the joint position statement on PFO and diving published by the South Pacific Underwater Medicine Society (SPUMS), the United Kingdom Sports Diving Medical Committee (UKSDMC), and the DAN-sponsored workshop held in conjunction with the Undersea and Hyperbaric Medical Society (UHMS) Annual Scientific Meeting in Montreal, Canada in June 2018.

WHO SHOULD BE TESTED FOR PFO?

Routine screening for PFO at the time of dive medical-fitness assessment (either initial or periodic) is not indicated. Consideration should be given to testing for PFO when there is a history of more than one episode of DCS with cerebral, spinal, vestibulocochlear or cutaneous manifestations.

Non-cutaneous manifestations of "mild DCI" as defined in the Remote DCI Workshop Proceedings [DIVERS ALERT NETWORK (2005). Consensus Statements. In: Doolette,

D.J. et al (Eds.). *Management of Mild or Marginal Decompression Illness in Remote Locations, Workshop Proceedings*. Durham, NC. p.6-9.] are not indications for PFO investigation. Headache as an isolated symptom after diving is not an indication for PFO investigation.

PFO TESTING AND EVALUATION RECOMMENDATIONS

PFO testing

- Testing is undertaken by centres well practised in the technique
- The testing must include bubble contrast, ideally combined with transthoracic echocardiogram (TTE). Use of two-dimensional and colour-flow echo cardiography without bubble contrast is not adequate
- The testing must include the use of provocation manoeuvres to promote right-to-left shunt including Valsalva release or sniffing, as described in the supporting references (both undertaken when the right atrium is densely opacified by bubble contrast)

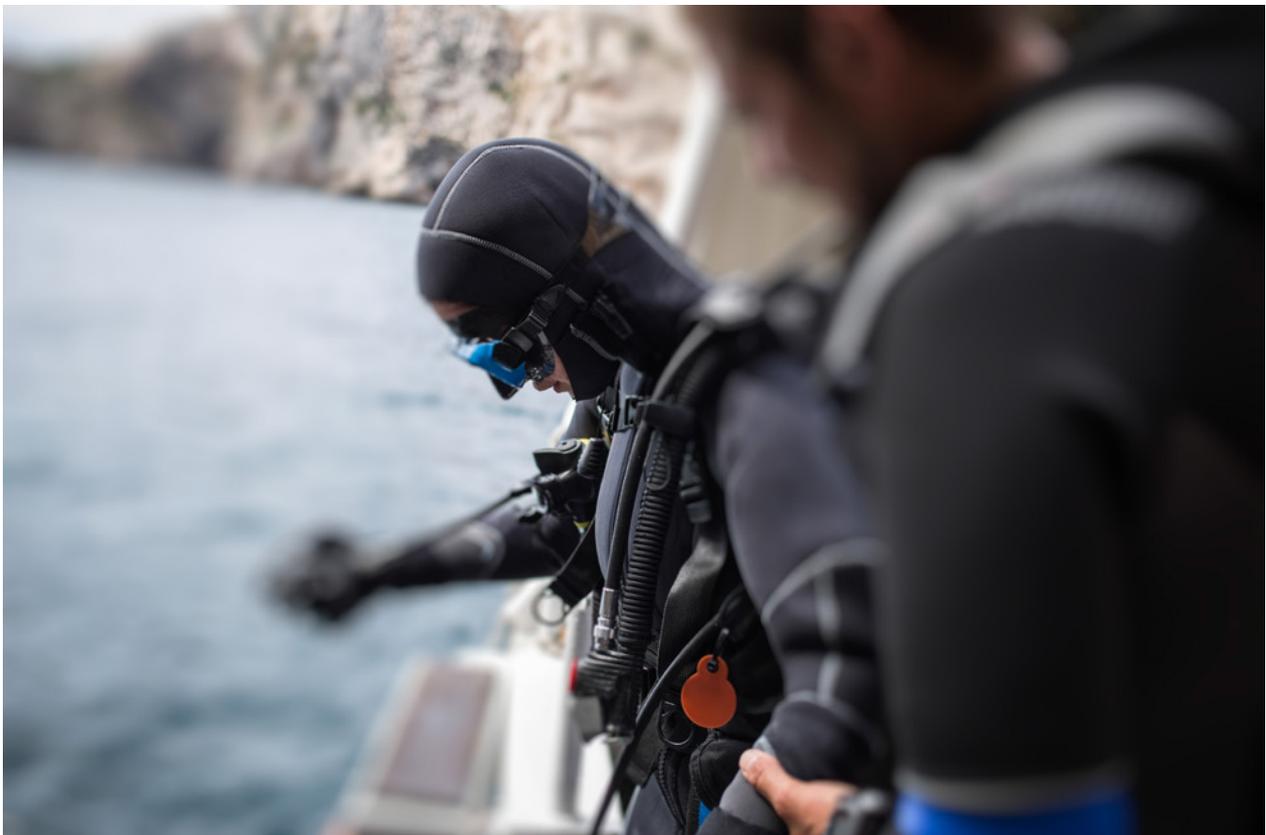
What does a positive test mean?

- A spontaneous shunt without provocation or a large, provoked shunt following diving with venous gas emboli present is recognised as a risk factor for those forms of DCS with cerebral, spinal, vestibulocochlear or cutaneous manifestations
- Smaller shunts are associated with a lower but poorly defined risk of DCS. The significance of minor degrees of shunting needs to be interpreted in the clinical setting that led to testing
- Detection of a PFO after an episode of DCS does not guarantee that the PFO contributed to causation

WHAT ARE THE OPTIONS FOR DIVERS WHO TEST POSITIVE?

Following the diagnosis of PFO that is likely to be associated with an increased DCS risk, the diver may consider the following options in consultation with a diving physician:

- Stop diving
- Dive more conservatively. 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-stop limits; 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; avoidance of heavy exercise and unnecessary lifting or straining for at least three hours after diving
- Close the PFO. However, it is emphasised that closing a PFO after an episode of DCS cannot provide complete assurance that DCS will not occur again. The options outlined above require careful consideration of the risks, benefits and the clinical setting that led to screening





WHEN CAN DIVERS WHO UNDERGO CLOSURE RETURN TO DIVING?

Following closure of a PFO and before returning to diving, the diver requires a repeat bubble contrast echocardiogram demonstrating shunt closure. This should be performed a minimum of three months after the closure. Diving should not be resumed until satisfactory closure of the PFO is confirmed and the diver has ceased potent antiplatelet medication (aspirin is acceptable).

Caution

Venous bubbles can also enter the systemic circulation through intrapulmonary shunts, although the role of this pathway in the pathogenesis of DCS is not as well established as PFO. These shunts are normally closed at rest. They tend to open with exercise, hypoxia and beta-adrenergic stimulation, and close with hyperoxia. It is therefore plausible that exercise, hypoxia and adrenergic stimulation after a dive could precipitate DSC when it might not otherwise have occurred, while supplemental oxygen is likely to minimise this effect.

FACTS ABOUT DIVERS WITH PFO

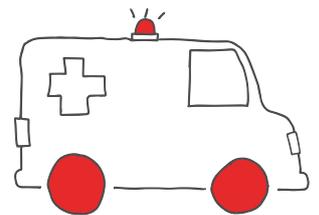
- Divers with PFO have a two-and-a-half-times greater risk of DCS than divers without a PFO and a four-times greater risk of neurological DCS. However, the absolute incidence of neurological DCS in divers with PFO is estimated at 4.7 DCS cases per 10 000 dives
- A major study at the Mayo Clinic by Dr Hagen and colleagues determined there is a large prevalence of PFO in young people, but it declines and levels off at approximately 25%. They also found that in each of the decade intervals, there is no difference in prevalence of PFOs between men and women
- Four studies were compared, determining the prevalence of RLS or large PFO in divers with spinal DCS and those without. The prevalence of those with spinal DCS and RLS or a large PFO is 44% compared to the 14.2% without
- Half of the divers in the studies with RLS-related DCI have a PFO that is a centimetre in diameter or larger. Therefore the greatest risk of DCI is in those with the largest PFOs, not the entire 25% of the population of divers with a PFO
- Cerebral, spinal, cutaneous and inner-ear DCS have been associated with PFO, however the link between PFO and cutaneous and inner-ear DCS is the strongest. In approximately 74% of the cases presenting with isolated inner-ear symptoms (no other symptoms of hyperbaric-related issues), 80% of the cases had a large, spontaneously shunting PFO
- There are factors necessary for PFO to contribute to DCS: You need to have a large PFO; venous gas emboli must form; bubbles must cross the PFO (meaning that there must be a provocative factor to open the PFO) to arterial circulation; and the bubbles must reach a target tissue while it is still supersaturated and vulnerable

Source: *DIVERS ALERT NETWORK (2015). In: Denoble, P.J. & Holm, J.R. (Eds.). Patent Foramen Ovale and Fitness to Dive Consensus, Workshop Proceedings. Durham, NC. p.146.*





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