

Patent Foramen Ovale (PFO)

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The Cardiovascular System

- The cardiovascular systems consists of:
 - A pump (the heart) and
 - A network of blood vessels
- Interesting facts about the heart:
 - The heart is about the size of a closed fist.
 - The heart beats (pumps), on average, 70 times per minute; approximately 2.5 billion times in a person's lifetime!
 - The heart can pump the body's entire blood volume (approximately 10 pints) around the body once every minute.
- Interesting facts about the network of blood vessels:
 - The blood vessels continuously deliver oxygen (O₂) and nutrients to the cells of a person's body and remove cellular waste.
 - The blood vessels range in size from the thickness of a person's thumb to a fraction of the width of a person's hair – only visible under a microscope.
 - If laid end-to-end, a person's blood vessels would stretch 62,500 miles ~ 2.5 times around the world!

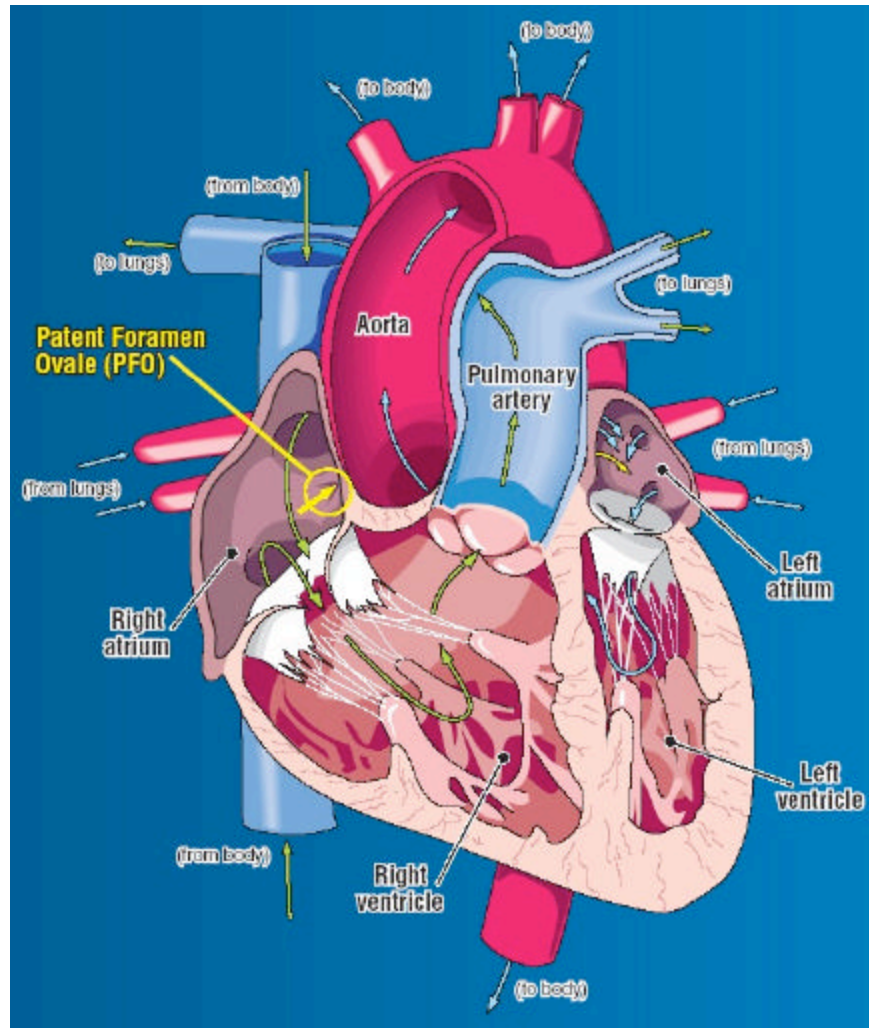
The 3 Stages of the Heartbeat Cycle

	Stage 1 Diastole (relaxation)	Stage 2 Atrial systole (Atria squeeze)	Stage 3 Ventricular Stroke (Ventricles squeeze)
O ₂ poor blood from the body	Enters right atrium	Blood is pumped into the right ventricle	Blood is pumped to lungs to get oxygenated
O ₂ rich blood from the lungs	Enters left atrium	Blood is pumped into the left ventricle	O ₂ rich blood is pumped to the blood

Patent Foramen Ovale (PFO)

- “Patent” ? Still open
“Foramen” ? a window or opening
“Ovale” ? oval-shaped
- Before you were born, a hole (the foramen ovale) existed between your atria which allowed the majority of the oxygenated blood from your mother to bypass your non-functioning lungs and flow throughout your body.

- At birth, when you began to breathe, a flap valve was supposed to permanently close this hole. [It does NOT close in about 25-30% of people; a small number of people (around 5%) are missing this flap valve entirely.]
- IF you have a PFO, the flap valve is held shut by ventricular pressure. When a diver with a PFO exerts him/herself*, (s)he can temporarily increase the pressure in the right atrium and allow venous blood to 'shunt' from right to left bypassing your lungs. If this happens, venous gas bubbles** can cause cerebral, spinal cord, certain types of skin bends and possibly, inner ear DCS.



[Picture taken from DAN's website.]

- * Shunting is aided by any action that pressurizes the right atrium relative to the left. Shunting is aided by coughing, the Valsalva maneuver (popping one's ears) or other exertion.
- ** A DAN study of repetitive multilevel dives published in 2002 found that venous bubbles were observed (using Doppler tests) in 91% of recreational divers.

The Statistical Risk

- According to DAN estimates, decompression sickness (DCS) in recreational divers only occurs in .005% to .08% of recreational dives.
- Based on retrospective studies, DAN estimates the risk of developing DCS when diving with a PFO is between 2 and 5 times higher than if no PFO is present.
- If 30% of divers have PFO's, why aren't 30% of all divers getting bent???
 - DCS is caused by nitrogen (N₂) bubbles, not the PFO by itself. If divers do not produce N₂ bubbles, they will not suffer from PFO related DCS. [Again, most recreational divers do have Doppler detectable bubbles after a dive.]
 - The bubbles that pass through the PFO may somehow disappear in the arterial circulation.

DAN's Stance on PFO's?

- Having a PFO is not necessarily a contraindication for diving.
- IF it is proven with certainty that a PFO in a diver with venous gas emboli (VGE) predisposes him/her to decompression illness (DCI) by providing a route through which bubbles can pass into the arterial circulation, then the safest strategy would be to reduce the venous bubble load by developing different decompression procedures* which include limiting bottom time or by the appropriate use of oxygen-enriched breathing mixtures.

Testing for PFO

- The 2 most common methods to test for a PFO are:
 - Contrast echocardiography
 - Transesophageal echocardiography (TEE)
- The TEE is unpleasant and more costly, but it is a more sensitive test.

Should You Get Tested???

- If you follow safe diving practices, the risks of DCS due to a PFO is relatively small so most experts do not recommend getting tested as a precautionary measure.
- As with anything else in diving (& life), the diver should weigh the costs and benefits for him/herself.