

# Patent Foramen Ovale

## *Is It Important to Divers?*

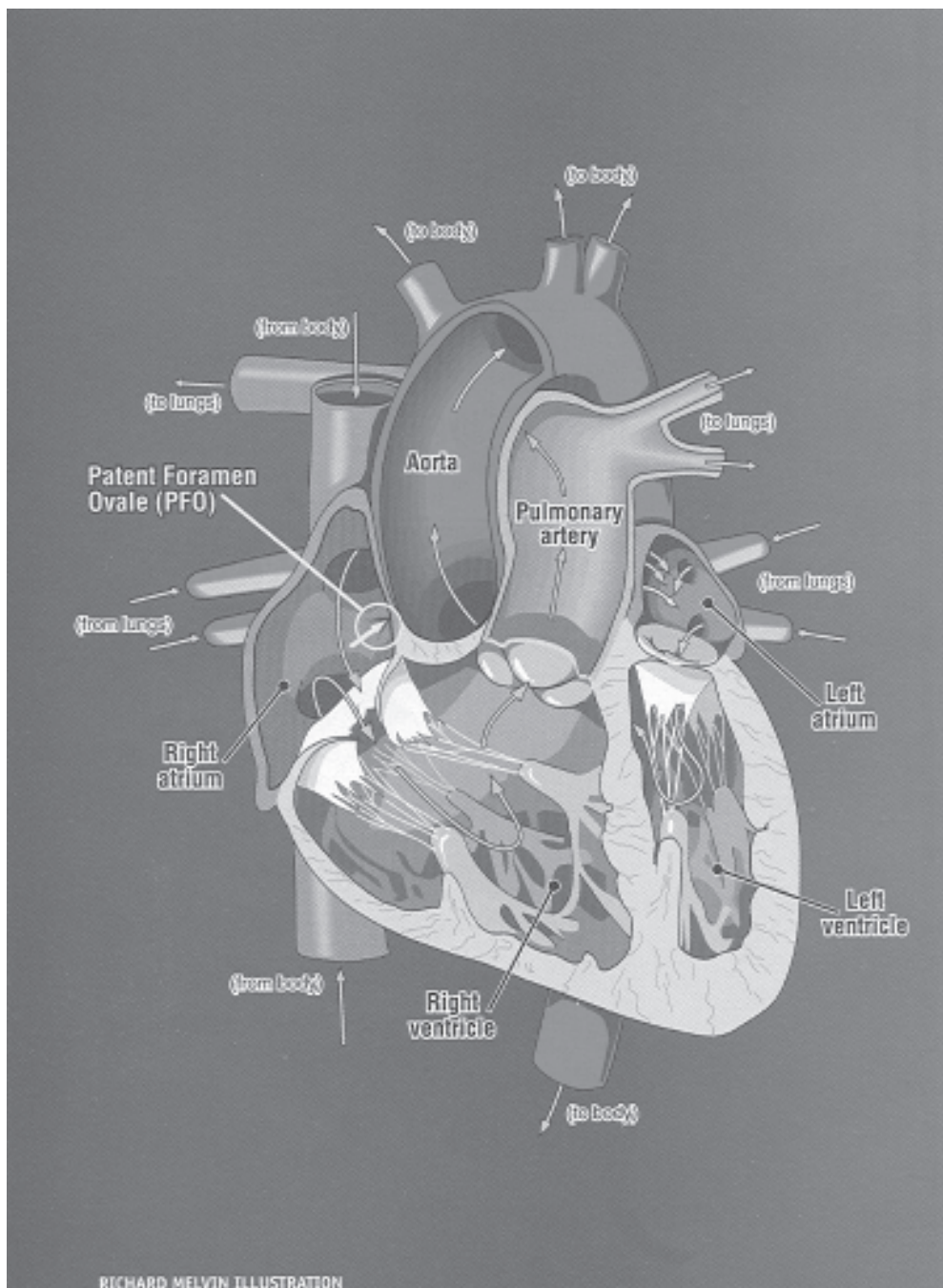
MEDICAL LINE

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### **What is a PFO?**

The upper chambers of the heart (the atria) are separated into a right chamber that conveys blood from the veins to the right ventricle, then to the lungs, and a left atrium that conveys blood from the lungs to the left ventricle and then to the whole body.

In the unborn fetus, the lungs are not functioning, and to provide oxygen to the fetal circulation, an opening is present (the foramen ovale) in the wall between the two atria (the atrial septum). The foramen ovale allows blood coming from the placenta to flow through the right atrium directly into the left atrium and then into the body, providing the oxygen needed for growth and development.



At birth, when the baby begins to breathe, a flap valve closes over the opening in the atrial septum and eventually becomes part of the atrial septum from growth of tissue sealing the opening. However, in about 30 percent of all people, the closure of the foramen ovale is incomplete, and the persistent foramen ovale (patent foramen ovale, or PFO; see figure) becomes a potential route for blood from the veins to flow directly into the arterial circulation, thus allowing bubbles to enter the arteries and bypass the lung filter.

In a small number of people, the flap valve is missing completely, and a persistent opening occurs in the atrial septum (atrial septal defect, or ASD). Concern for bubbles reaching the brain by this pathway seem to be validated by several reports in the medical literature of unexpected or unexplained decompression illness (DCI), particularly involving the brain in divers who were subsequently found to have a PFO. A medical report in 1986 suggested that neurological DCI after a 15-minute dive to 38 metres in

a recreational scuba diver with an ASD was caused by venous gas emboli (VGE) passing through an undiagnosed ASD.

### **Beliefs About PFO and Occluders**

Embolisation through a PFO has been described for more than 50 years. The concept of venous-to-

arterial embolisation led to the notion that venous gas bubbles, common after recreational dives but usually silent due to filtration by the pulmonary vasculature or system of blood vessels, could cross through the PFO and cause injury to the brain and spinal cord. Since these initial observations, several other medical reports have suggested an association between PFO and



cerebral, spinal cord, certain types of skin decompression illness and possibly, inner ear decompression illness.

Divers have enthusiastically latched onto this concept. During fitness-to-dive evaluations, questions about PFO are always near the top of divers' lists. Also, DAN is bombarded with PFO queries.

With the development of devices that can be implanted without surgery to close the PFO called occluders, this interest has gained momentum. In Europe, these devices are commercially available and approved for closure of ASD and PFO. In the United States, these occluders are still undergoing experimental study. They are soon to be approved by the U.S. Food and Drug Administration (FDA) for treatment of certain forms of stroke caused by blood clots, which are thought to come from the veins, then flow to the right atrium and cross a PFO.

To reduce the risk of DCI, some professional divers have received the occluder devices. During a follow-up period of three to 12 months, these divers experienced no further neurological decompression episodes. However, it is difficult to be sure that this represents a true reduction in risk. More information is needed about their diving patterns before and after the procedure.

### **Should You Dive With a PFO?**

While there is thought to be an association between PFO and severe neurological DCI, causation is unproven. Indeed, important logical links between the purported mechanism and many of the facts are missing. Venous bubbles are very common in recreational divers. In a DAN study of repetitive multilevel dives, published in 2002, venous bubbles were observed by Doppler in 91 percent of recreational divers

(Dunford RG, Vann RD, Gerth WA, Pieper CF, Huggins K, Wachholz C, Bennett PB. The incidence of venous gas emboli in recreational diving. *Undersea & Hyperbaric Medicine* 29: 247-59, 2002).

While 20-30 percent of divers might be expected to have a PFO, decompression illness (DCI) in recreational divers occurs after only 0.005-0.08 percent of dives, clearly much lower than the one in five or six that might be expected if every diver with a PFO and venous bubbles developed DCI. Based on current experience, the estimated risk of a DCI incident characteristic of those correlated with PFO is between 0.002-0.03 percent of dives.

For DCI to occur, there must therefore be other factors, such as bubble load or some other susceptibility factor as yet unknown, possibly involving body tissues. It is also conceivable that a PFO represents a marker for susceptibility (such as red hair and sunburn) but is not involved directly in DCI.

Clinical observations to date have focused on the correlation of PFO with neurological injuries, particularly serious ones, but these represent only a third of DCI incidents. Most DCI cases in recreational diving consist of pain or sensory abnormalities, and no one has yet shown that PFO is related to these cases. The exception is skin DCI, but this is uncommon. Only around one third of cases of DCI in recreational divers are considered severe. If 60 percent of these have a PFO, and 25 percent of the

remainder have one, then it can be estimated that most DCI cases must occur in divers without a PFO.

Associating a common finding (PFO) with an uncommon disease (DCI) is a common mistake, and this often mistaken relationship is likely to be involved in the data regarding DCI and PFO.

### **Should You Have a PFO Closed?**

Those who undertake or sign up for such a procedure should be aware of several issues: Insertion of an occluder has some risk. According to data submitted to the FDA by the manufacturer of the AMPLATZER PFO Occluder, in 442 insertions, seven major adverse events occurred, including cardiac arrhythmia requiring major treatment; device embolisation (the device breaking free from its position in the atria of the heart and being carried away by the bloodstream), requiring either percutaneous or surgical removal; and failure of the system by which the device is inserted ([www.fda.gov](http://www.fda.gov)).

More recent articles in medical journals have continued to report complications such as device malposition, device embolisation, changes in heart rhythm, perforation of the heart, vein damage, bleeding and both right and

left atrial blood clot formation. Late complications have included sudden death.

One of the purposes for which these occluder devices will be marketed is to prevent blood clots from passing through a PFO and into the left side of the heart, from which they could travel to the brain and cause a stroke. However, even for prevention of recurrent blood clots, the effectiveness of transcatheter devices has not been proven. Regarding closure of a PFO to prevent DCI, scientific evidence does not exist at present.

### **In Conclusion**

In short, having a PFO is not necessarily a contraindication for diving. If it is proven with certainty that a PFO in a diver with VGE predisposes to 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, limiting bottom time or by the appropriate use of oxygen-enriched breathing mixes. □

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