

U.S. Navy diver/aviator/skydiver with AGE from a previously unknown PFO.

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Wyland J, Krulak D. U.S. Navy diver/aviator/skydiver with AGE from a previously unknown PFO. *Undersea Hyperb Med* 2005; 32(2): 129-133. A 32 year old US Naval aerospace physiologist with dive, jump and flight qualifications presented to a US Navy hyperbaric medicine department complaining of nausea, unsteadiness and left hand and forearm paresthesia that began almost immediately after completing a 28ft/ 40min recreational dive. Following an abbreviated history and physical examination the patient was diagnosed to be suffering from an arterial gas embolism. He was treated with hyperbaric therapy during which his symptoms resolved. Follow-on transesophageal echocardiography revealed an atrial septal aneurysm with a patent foramen ovale resulting in a right-to-left shunt after Valsalva maneuver, but no evidence of ventricular dysfunction, wall motion abnormalities, or abnormal ejection. His episode was attributed to paradoxical air embolism and he was disqualified from further special duty. In order to regain his dive, jump and flight qualifications, the patient elected to undergo repair of the cardiac defect with a device that is relatively new in the operational military setting. The procedure was a success, he was granted waivers for his prior qualifications, and remains in that status to this day. This is the first known case where an atrial septal occluder has been used to preserve these special duty qualifications.

INTRODUCTION

Recreational scuba diving, when performed by properly trained individuals, is recognized as a safe sporting activity where serious injury or death is uncommon. Yet data from 2002 revealed that 1,063 divers in the US were treated with recompression therapy for serious diving related complications (1). One of the most serious of these complications is arterial gas embolism (AGE). The following case report involves a highly qualified and experienced military diver, parachutist, and aviator who experienced an AGE during a recreational dive. After acute hyperbaric oxygen (HBO₂) therapy, a thorough work-up determined the etiology of the AGE to be related to a previously undiscovered patent foramen ovale (PFO), and thus the diagnosis of paradoxical AGE was made. The US Navy was concerned that this defect might result in an AGE recurrence; therefore, the patient was removed from dive, jump, and flight status.

While not required in this case, the patient chose to undergo a surgical repair of the PFO in order to pursue a waiver for his dive, jump, and flight status. The case is presented as both a brief review of AGE, and to serve as notification of a newly approved treatment for PFO available to operational military personnel. This treatment consists of surgical repair of the PFO using the CardioSEAL device. This device is the first allowed for use outside clinical trials by the Food and Drug Administration, which has approved it under Humanitarian Use Guidelines.

CASE REPORT

A 32 year old Caucasian male US Naval aerospace physiologist arrived at a US Naval station hyperbaric medicine department complaining of nausea, unsteadiness, and left thumb paresthesia that was spreading to the left hand and forearm. The patient's symptoms began within two minutes following a normal

ascent from a 28ft/40min recreational dive. Transit by dive boat and automobile to the facility had taken 20 minutes. Upon arrival he was alert and oriented, and stated the nausea and unsteadiness had improved but that the “tingling” had continued to progress up his left arm. His vital signs were normal. The patient was immediately started on 100% oxygen, and during the focused examination the patient noted the beginning of paresthesia in his left lower leg, foot and toes. He denied headache, visual or hearing changes, chest pain, shortness of breath, pain, or skin changes. He had a 12-year history of military and civilian diving, flying, and skydiving, and he held multiple qualifications in each of those areas. Past medical history was significant for one episode of Type I DCS at the beginning of his US Navy dive training 12 years ago. Hyperbaric treatment (US Navy Treatment Table 6) at that time resulted in complete resolution. He denied any other medical history such as head injury, migraine headache, previous neurological events/disorders, substance abuse, or diabetes mellitus. He rarely used alcohol and avoided all tobacco products. He was not taking any medications and had no known drug allergies. His physical examination was completely normal with the exception of the neurological examination that revealed sensation deficits to pain and light touch in the dorsal foot, anterior lower leg, and a glove distribution of the left hand and arm.

The patient was diagnosed to be suffering from a paradoxical arterial gas embolism and he underwent recompression treatment in accordance with the US Navy Diving Manual within 40 minutes of surfacing. Shortly after reaching 60 fsw and being placed on 100% oxygen, he had a 50% improvement in his symptoms. By the end of the third O₂ period he had only a small area of paresthesia in his left foot. Treatment was

extended by one period and subsequently all symptoms resolved. On reaching 30 fsw, symptoms returned in his left thumb and he was taken back to 60 fsw where two additional extensions were completed. He was brought to 30 fsw, and then to the surface. Upon arrival he noted only mild irritation of his distal left thumb. Physical examination at that time demonstrated a full restoration of sensory function to all previously affected areas. The patient was transported to the local hospital for overnight observation where he was discharged the next morning with complete symptom resolution.

Within 2 weeks, a cardiologist familiar with operational medicine requirements arranged for the patient to undergo an echocardiogram that revealed an atrial septal aneurysm. A follow-on bubble study echocardiogram, verified by subsequent transesophageal echocardiogram, revealed a patent foramen ovale with activation of a right to left shunt during valsalva. The patient was later cleared of any neurologically related cause or sequelae related to the AGE. His case was deemed non-emergent and he was given two options. First, he could forgo treatment and be followed with yearly echocardiogram studies that would allow him to remain in the Navy but result in loss of his dive, jump, and flight qualifications. Alternatively he could seek to undergo surgical repair, which, if successful, might allow him to retain his qualifications. He elected the latter course, and after an extensive work-up the patient underwent a percutaneous closure of the defect using a 28 mm CardioSEAL device without complication. A follow-up echocardiogram study performed ten weeks later demonstrated no residual shunt by two-dimensional imaging, color flow mapping or agitated saline injection. The interventional cardiologist recommended the patient be allowed to go back to all previous activities

including dive and flight duties. The US Navy later granted waivers for the patient to return to dive, jump, and flight status.

DISCUSSION

Arterial Gas Embolism is a highly feared complication of diving resulting from gas bubbles being introduced directly into the arterial system. More than 80% of the time it presents within 5 minutes of surfacing (2), and this condition accounts for nearly one-third of the yearly fatalities in recreational divers (3). The most common cause of AGE is pulmonary barotrauma, often caused by improper breath holding during ascent. The lung trauma allows bubbles to pass directly into the pulmonary vasculature and thence to the arterial circulation. Another important cause is right-to-left cardiac shunting, which may allow venous nitrogen bubbles to bypass the filtering capability of a normal, non-damaged lung. This situation is known as paradoxical air embolism. The individual in this case report suffered an AGE caused by a previously unknown cardiac atrial septal defect while following proper dive procedures.

Whether caused by barotrauma or shunting, two specific conditions must be met for a potential AGE to occur. First, bubbles must be present, and second, they must have a pathway to enter the arterial circulation. The prevalence of these two conditions in the general population is well documented in the literature. Probability predictions (4), and observational studies (5), establish the incidence of venous bubbles following sport/ chamber dives as being approximately 20%. The persistence of the normal right-to-left embryologic shunt (PFO) exists in approximately 30% of the general population (6), and can serve as the

pathway into the arterial circulation. These relatively high prevalence rates, coupled with numerous observations and studies that have documented cardiac shunt related arterialization of venous bubbles (7), (8), (9), support the notion that right-to-left shunts are important contributors to AGE. In fact, it is likely that cases of PFO related AGE are significantly underreported. Mild cases may go completely unrecognized or may not be reported when simple oxygen therapy at the local level results in rapid resolution of symptoms. Attempts at risk stratification must also consider that the mere presence of a wall defect does not automatically foreordain an active right to left shunt, or result in symptomatic AGE. Size of the defect, dive profile and activity, atrial pressure gradients (commonly associated with the valsalva maneuver), terminal location of emboli, and many other variables may further affect the actual and/or documented occurrence rates (7), (9), (10), (11).

It is essential to address a few unknowns in this particular case. The team managing the treatment of this patient made an empirical diagnosis of a paradoxical AGE based on clinical experience and compelling circumstantial evidence. One item in the differential diagnosis that must be considered is a cryptogenic stroke. Unfortunately a coagulopathic workup was not performed so a thrombotic embolism can not be formally excluded. However, the rapid response of the patient to timely recompression therapy conflicts with a thrombotic etiology for the symptoms. Another inconsistency in this case is that it could be argued that a 40 minute dive at 28 FSW is a profile that has a low likelihood of generating an AGE of any sort. Indeed, a non-paradoxical mechanism for the patient's embolism can not be totally excluded. However, the patient is an experienced military diver who strongly denied any actions

that might provoke pulmonary barotrauma and a subsequent non-paradoxical AGE. In the final analysis, the patient was effectively treated as the worst case scenario, had his cardiac defect repaired, and was successfully returned to full duty.

Current Navy policy precludes the induction of any member into the service with known congenital anomalies of the heart, with the exception of a previously corrected patent ductus arteriosus. Both the dive and flight communities also disqualify any person with a known congenital cardiac anomaly (12). That being said, there is no requirement to screen for PFO when a service member is accessioned into the Navy or selected for special duty. Discovery of such a condition generally occurs only with symptoms that would generate a cardiac workup. Aviators with asymptomatic PFOs are considered physically qualified by the US Navy, however, the paradoxical AGE in this case report changes the category of the patient's previously undiagnosed PFO to symptomatic (13). This change in status made the patient no longer physically qualified for flying duties.

New advancements in the treatment of PFO are encouraging. Percutaneous closure for the condition has been available for years and is a vast improvement over open repair. The complication rate of this procedure continues to fall as technology and procedures improve. In the present case, the placement of the CardioSEAL device allowed the patient to retain his dive, jump, and flight qualifications with the US Navy. Since returning to special duty status the patient has been event free, and has continued to dive and fly without any recurrence of symptoms.

To our knowledge, this is the first case of percutaneous PFO repair that has allowed a patient to return to full military dive, jump, and flight status. Providers and

patients involved in similar situations where a current or future military dive or flight career is jeopardized may find this information beneficial in support of that career.

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