Editorial

Risk mitigation in divers with persistent (patent) foramen ovale

In this issue, Anderson and colleagues report follow-up of divers who were found to have a persistent (patent) foramen ovale (PFO) or, in eleven cases, an atrial septal defect (ASD).[1] In most divers diagnosis followed an episode of decompression illness (DCI). The efficacy of closure of the PFO/ASD in preventing future DCI was compared with conservative diving. They reported that in the closure group the occurrence of confirmed DCI decreased significantly compared with pre-closure, but in the conservative group this reduction was not significant.

It is believed there are three requirements for a diver to suffer shunt-mediated DCI:

- A significant right-to-left shunt (usually a large PFO but sometimes an ASD or pulmonary arteriovenous malformation).
- Venous bubbles nucleated during decompression circumvent the lung filter by passing through the shunt.
- Target tissues are supersaturated with dissolved inert gas, so that they are able to amplify embolic bubbles.[2,3]

All three are required because DCI does not occur after contrast echocardiography when bubbles cross a right-to-left shunt.

Therefore, there are two ways that a diver who has suffered shunt-mediated DCI may continue to dive – either their shunt is sealed or future dives should be so conservative that venous bubbles are not liberated and/or critical tissues are not able to amplify embolic bubbles.[4]

PFO/ASD closure will give divers a risk of DCI comparable to the risk in others without a right-to-left shunt, if the procedure adequately seals the shunt. Closure of the shunt will not prevent a diver suffering DCI by other mechanisms, such as when there is arterial gas embolism (AGE) as a result of pulmonary barotrauma or when the dive profile is provocative (e.g., if there is rapid ascent or missed decompression stops). Conservative diving will be effective only if all the dives performed are truly conservative and prevent bubble nucleation and/or amplification.

The study by Anderson et al. has a number of serious limitations.[1] The study was small with only 62 self-selected divers, who self-reported outcomes. Eleven divers had not had DCI when their PFO or ASD was detected. Initially 36 divers were classified as closure and 26 as conservative treatment, but six subjects crossed from the conservative group to the closure group. Three of the six dived in the conservative group before having closure and are classified in both groups depending on whether the dives performed were before or after closure. As a result, there were 42 in the closure group and 23 in the conservative group.

Randomisation to the treatment groups was not possible and its absence results in imbalance. Because the closure group is approximately twice as large as the conservative group, similar changes in incidence would have a greater probability of achieving statistical significance in the former. Large shunts were present in more than three-quarters of the closure group but fewer than half of the conservative group. The authors have three definitions of a 'large' PFO, so the definition of large was inconsistent. All ASDs were considered to be large.

When dealing with small numbers, one needs patient-level data, but that is lacking and may mask inconsistency in management. The divers were investigated and treated in at least 38 hospitals (some divers did not state where they were treated). We do not know what devices were used for PFO/ASD closure, and closure effectiveness varies, or what tests were performed to assess the effectiveness of closure.[5]

The primary end-point was not different between the two groups because only two episodes of confirmed DCI occurred in each group. The authors also considered a softer and subjective end-point, possible DCI.

Crucially we are not told what the divers in the conservative group were told constitutes a conservative dive and whether it was consistent. Nor are we told whether they followed the advice given. That is important because it appears that incidence of possible DCI increased considerably in only the conservative group, which means either that the advice they were given on what constitutes a conservative dive was flawed, that the divers failed to follow good advice or that they frequently reported innocent symptoms as possible DCI, because knowledge that they had a PFO may have increased their reporting – introducing further bias.

There should be assessment of whether DCI after the intervention was shunt-mediated or had another cause. For that assessment, one needs to know details of the dives resulting in symptoms, clinical manifestations and latency of onset.[6]

I have investigated 20 divers who had DCI after PFO closure. In five divers, a contrast echocardiogram showed a significant residual shunt. Typically, the diver had their closure procedure by a cardiologist lacking knowledge of diving medicine and no post-closure contrast echocardiogram was performed. In one case, the diver's PFO was closed but they had a residual pulmonary shunt that was not detected. In those cases where there is a significant residual shunt, the dive profiles, clinical manifestations and latencies of onset were typical of shunt-mediated DCI.[6]

Three divers, who had PFO closure with no residual shunt, subsequently had neurological symptoms with manifestations consistent with AGE secondary to pulmonary barotrauma. High resolution CT scans of their chests showed pulmonary bullae and emphysema.

The remaining divers seen had no residual shunt but had performed highly provocative dives, usually much deeper than 50 metres' sea water (msw). The most recent case that I saw had dived to 102 metres' fresh water (mfw) in a lake at high altitude breathing trimix.

In contrast, several hundred divers in whom I diagnosed a PFO and who elected to dive conservatively had not reported further DCI. I advised them that I have never seen shunt-mediated DCI after dives breathing air to depths of 15 msw or less provided no rules were broken. So I set that as the depth limit or allow them to dive to greater depths breathing nitrox so that there are equivalent partial pressures of nitrogen (e.g., 19 msw with nitrox 32 or 23 msw with nitrox 40) provided they use an air decompression table/algorithm. Alternatively, one can dive using the DCIEM recreational air diving table.

Recurrence of DCI after PFO closure may be the result of a residual shunt or may have other causes. It is difficult to draw conclusions about the safety of 'conservative' diving unless one knows what the divers were advised constitutes conservative dives and whether they adhered to the advice.

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