Recurrent decompression sickness in experienced divers treated with percutaneous patent foramen ovale closure

Sylwia Sławek-Szmyt, Joanna Grygier, Marek Grygier, Michał Łączak, Maciej Lesiak, Aleksander Araszkiewicz

1st Department of Cardiology, Poznan University of Medical Sciences, Poznań, Poland

Correspondence to:
Sylwia Sławek-Szmyt, MD, PhD, 1st Department of Cardiology, Poznan University of Medical Sciences, Długa 1/2, 61–848 Poznań, Poland, phone: +48 61 854 91 46, e-mail: sylwia.slawek@skpp.edu.pl

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INTRODUCTION

Decompression sickness (DCS) is a rare diving-related disease triggered by trapping nitrogen gas emboli in vessels and tissues as the ambient pressure surrounding the body pressure rapidly decreases during ascent and surfacing [1]. DCS may present with a wide range of acute clinical manifestations, from mild to severe, including persistent paralysis or even death [2]. The reported estimated prevalence of DCS is approximately up to 1.5%, depending on the diving environment and type of diving [1, 2].

The presence of patent foramen ovale (PFO) increases the risk of venous bubble transfer to the systemic circulation and of subsequent DCS by facilitating arterial air embolization (AAE). Therefore, PFO closure may play a role in reducing these complications. However, a treatment strategy for patients with DCS and PFO has not yet been established due to limited data. The guidelines indicate that PFO investigation and its closure should be conducted only in specific cases with high-risk and frequent activities [1, 3, 4]. Moreover, there are limited studies on diving habits and DCS incidence following PFO closure. The objective of this study was to summarize our experience in the field of device PFO closure in divers with a history of recurrent DCS.

METHODS

Among all 562 transcatheter PFO closures in our department, three procedures were performed for the secondary prevention of DCS between 2007 and 2022. Detailed data on the individual diving experience and DCS symptoms were collected. Indications for PFO closure and procedural characteristics were carefully analyzed in each case. The PFO with the right-to-left shunt was diagnosed with contrast transesophageal echocardiography (TEE) and the Valsalva maneuver and confirmed during the procedure. Each procedure was performed under sedation anesthesia via femoral venous access. In 2 patients, the PFO was closed with a 25-mm Amplatzer PFO Occluder (St. Jude Medical, St. Paul, MN, US), and in one patient with a 26-mm PFO Nit-Occlud device (PFM, Cologne, Germany). A telephone questionnaire was used to collect information about the current diving activities. The divers were asked if they were still diving and if they had changed their diving profile concentrating on the reduction of venous bubble load (restrictions on the depth of the dive, precise adherence to decompression guidelines, no repetitive dives during a single-day, reduced rate of ascent, use of nitrox), and if they had suffered any diving-related problems such as DCS. The study was approved by the local bioethics committee (approval no. 187/2016).

RESULTS AND DISCUSSION

We included one female and two male professional divers with at a median age of 45 (range 43–52) years on the procedure day. None of the patients had any concomitant chronic disease. Each patient experienced at least three episodes of DCS, with the symptom onset from half an hour to several hours after surfacing. All patients had cutaneous and musculoskeletal manifestations of DCS (Supplementary material, *Figure S1*), and the two male patients had also simultaneous neurological symptoms. Both patients had complete resolution of neurological symptoms without ischemic foci in neuroimaging.

There were no complications associated with the PFO closure. A follow-up assessment showed no residual shunts, device dislocation,

Table 1. Patients, PFO procedure, and follow-up characteristics

Characteristics	Patient 1	Patient 2	Patient 3
Sex	Female	Male	Male
Age, years	45	52	43
BMI, kg/m^2	23.6	28.3	22.5
Co-morbidities	Migraine headache	None	None
Drugs taken chronically	None	None	None
Usage of stimulants	No	No	No
Nicotinism	No	No	No
Type of diving (recreational or professional)	Professional	Professional/ currently recreational	Professional
Number of DCS events before the intervention	3	3	4
Number of dives before the intervention	800	2000	1600
Max depth of diving before the intervention (meters of seawater)	103	130	139
Mixture of breathing gas used during dives	Nitrox 28, 32, 36, 50 Trimix 18/35, 15/55, 12/60, 10/70 Pure oxygen during decompression	Nitrox 28, 32, 36 Trimix 18/35, 15/55, 12/60, 10/70 Heliox Pure oxygen during decompression	Nitrox 32, Pure oxygen during decompression
Symptoms of DCS (musculoskeletal, skin bends, cutis marmorata, neurological, vestibular, hemisensory loss, paresis, vomiting, visual disturbances)	musculoskeletal, skin bends, cutis marmorata	musculoskeletal, skin bends, cutis marmorata, visual disturbances and hemisensory loss, vestibular	musculoskeletal, skin bends, cutis marmorata, neurological, vomiting, visual disturbances, hemisensory loss
Time from diving to symptoms onset (hours)	1–2	1–2	up to half an hour
Hyperbaric Oxygen Treatment of DCS (session number and duration)	After 2nd DCS 1 session, 1.5 h	No	After 2nd DCS 5 sessions, 1.5 h
Ischemia confirmed by neuroimaging	None	None	None
Time from DCS event/events to PFO diagnosis (months)	1st DCS – 11 3rd DCS – 1	1st DCS – 24 2nd and 3rd DCS 3 – several weeks	1st DCS – 2 3rd DCS – 1 week
Time from DCS event/events to procedure (months)	1st DCS – 28 2nd DCS – 18 3rd DCS – 5	1st DCS – 24 2nd and 3rd DCS – 2	1st DCS – 2 2nd and 3rd DCS – 1
Type of implanted Occluder	Amplatzer PFO Occluder	Amplatzer PFO Occluder	PFO PFM Nit-Occlud
Size of implanted Occluder (mm)	25	25	26
Postprocedural thromboprophylaxis time (months)	6	6	6
Drugs used for thromboprophylaxis	Aspirin+clopidogrel	Aspirin+clopidogrel	Asprin +clopidogrel
Complications after PFO closure (bleeding, tamponade, occluder dislocation, occluder thrombosis, stroke)	None	None	None
24-hour follow-up echocardiography after closure (residual shunt/no residual shunt)	No residual shunt	No residual shunt	No residual shunt
6-12 month follow-up echocardiography after closure (residual shunt/no residual shunt)	No residual shunt	No residual shunt	No residual shunt
Time from the intervention to the next diving, (months)	4	6	6
Number of dives after the intervention	20	500	1600
Number of dives per year	50	250	200
Max depth of diving after the intervention (meters of seawater)	65	90	130
Number of DCS events after the intervention	0	0	0
Time of follow-up from PFO closure to phone call (months)	12	58	96

Abbreviations: BMI, body mass index; DCS, decompression sickness; PFO, patent foramen ovale

or embolization. The median follow-up was 58 (range 12–96) months. All three patients continued diving. However, two patients performed shallower dives than before the procedure. None of the divers experienced a DCS recurrence after PFO closure. Details are presented in Table 1.

This study included only professional divers who followed safe decompression rules and were willing to continue diving. It was demonstrated previously that right-to-left shunt and a lack of changes in the way of diving after prior DCS were the only predictors of DCS recurrence, especially with regard to neurological manifestation [5]. In our group, each patient experienced at least three DCS episodes, but not after PFO closure. However, in qualification for PFO closure after DCS, potential complications of PFO closure must be considered, even though their occurrence is generally low (<2%) [6, 7]. In our study, there were no complications related to device implantation.

Our results demonstrated that PFO closure seems to be a feasible approach for the secondary prevention of DCS. Similar findings were shown by the DIVE-PFO registry,

indicating catheter-based PFO closure as more effective in DCS prevention than conservative dive profile in divers with a high-grade PFO [8].

Moreover, PFO closure apart from decreasing the likelihood of DCS, may also alleviate such conditions as migraine with aura or cryptogenic stroke. Shunt closure will not prevent DCS caused by other mechanisms, including AAE resulting from pulmonary barotrauma or a provocative diving profile (rapid ascent or missed decompression stops) [2].

Our patient cohort was small, and the number of dives made calculations of DCS risk recurrence unreliable. Nonetheless, there is a paucity of data on these findings and our results could be important in future recommendations regarding diving for patients with a closed PFO.

Supplementary material

Supplementary material is available at https://journals.viamedica.pl/kardiologia_polska.

Article information

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