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Temporary and permanent unfitness of occupational divers. Brest Cohort 2002–2019 from the French National Network for Occupational Disease Vigilance and Prevention (RNV3P)

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ABSTRACT

Background: *In France, the monitoring of professional divers is regulated. Several learned societies (French Occupational Medicine Society, French Hyperbaric Medicine Society and French Maritime Medicine Society) have issued follow-up recommendations for professional divers, including medical follow-up. Medical decisions could be temporary unfitness for diving, temporary fitness with monitoring, a restriction of fitness, or permanent unfitness. The aim of study was to point out the causes of unfitness in our centre.*

Materials and methods: *The divers' files were selected from the French National Network for Occupational Disease Vigilance and Prevention (RNV3P). Only files with a special medical decision were selected, between 2002 and 2019.*

Results: *Three hundred and ninety-six professional divers are followed-up in our centre and 1371 medical decisions were delivered. There were 29 (7.3%) divers with a special medical decision, during 42 (3.1%) medical visit. Twelve (3.0%) had a permanent unfitness. The leading cause of unfitness was pulmonary diseases: emphysema (3), chronic obstructive pulmonary disorder (2), asthma (2). Sixteen (4.0%) divers had temporary unfitness. The leading causes were cardiovascular (4 times) and neurological (6 times). Twelve (3.0%) divers had had at least one decompression sickness.*

Conclusions: *Judgments of permanent unfitness for diving were rare (3.0% of divers), but were because of life-threatening disease. Medical follow-up of occupational divers was justified to decrease the risk of fatal event during occupational dives.*

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Key words: diving, occupational medicine, decompression sickness, France, contraindications

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INTRODUCTION

Many professions include underwater activities, exposing employees to hyperbaric constraints. In France, for example, professional divers may be scuba divers, carrying out construction, repair or building supervision work; aquarium officers, working on the technical side of facilities, or as veterinarians and caretakers; or scientists carrying out fauna or flora surveys, or geological or oceanographic studies. Many other professions also include underwater activities, such as coast guard work or fishing [1].

Professional divers are thus exposed to several types of risks. Depending on their specific profession, they may be exposed to risks related to biological, chemical or psychological hazards, etc. [2, 3]. All professional divers are also subject to the risks associated with diving in water, as are recreational divers. The literature reports many risks for divers, whether professional or recreational. On the one hand, we have the risk of developing a pathology related to hyperbaric stress, such as dysbaric osteonecrosis, decompression sickness, thoracic barotrauma or barotraumatic otitis, and many other pathologies [4–7]. On the other hand, there is also the risk of an accident occurring underwater, even if the origin is not hyperbaric stress in itself. For example, a fainting episode could lead to drowning.

Some of these accidents are therefore life-threatening medical emergencies. This is particularly the case for decompression sickness or drowning [8–10]. Other pathologies involve long-term functional capacities, such as spinal cord injury or dysbaric osteonecrosis [11]. For this reason, many countries have regulations and recommendations for the medical follow-up of professional divers [12, 13]. In France, the text regulating the monitoring of professional divers was adopted in 1991 and repealed in 2011 [14]. Since 2016, several learned societies (French Occupational Medicine Society, French Hyperbaric Medicine Society and French Maritime Medicine Society) have issued follow-up recommendations for professional divers, including medical follow-up and paraclinical examinations to be adapted according to the diver's health status and diving profile [14].

As in other countries, this type of approach is sometimes questioned [15, 16]. The objective of this study was to determine the conditions that led to a contraindication to a profession with hyperbaric stress, or to a restriction of diving techniques (type of gas, depths, etc.), and to determine which unfitness notices were issued in a centre carrying out professional diver fitness visits.

MATERIALS AND METHODS

This was a retrospective study of the Centre for Maritime Health at the University Hospital (Centre Hospitalier Régional Universitaire [CHRU]) in Brest, between 1st January 2002 and 31th July 2019.

The files of the 396 professional divers are recorded in our centre. The divers' files were selected from the French National Network for Occupational Disease Vigilance and Prevention (RNV3P). The data were collected anonymously on a CHRU computer, requiring no authorisation from the National Commission on Informatics and Freedom. Patients had given their prior consent for any anonymous retrospective studies of their medical data.

To be included in the study, divers had to have been seen at least once in our centre, between 2002 and 2019, for a professional diving aptitude visit (initial visit before beginning a professional diving career or follow-up visit during the diving career, according to the regulations in force in France); divers also had to have had a particular restriction (depth, type of gas, temperature etc.) or been found temporarily or permanently unfit for professional diving [14].

Divers who had not come to the centre for a professional diving follow-up consultation were excluded (i.e., those who had come for advice on recreational diving), as were those who came for a professional diving visit and were given an assessment of complete fitness for professional diving.

Files meeting the selection criteria were then manually analysed by a Centre for Professional and Environmental Pathologies (CRPPE) marine physician. Socio-professional parameters were collected: age, sex, body mass index, smoking, regular alcohol consumption, and regular sports practice. Medical histories and treatments were also collected. Professional and recreational diving profiles were compiled: length of professional and recreational diving practice, as well as the annual and lifetime number of dives, average duration and depth. The focus was on the analysis of pathologies that motivated a restriction or incapacity (type of pathology, link with diving), as well as the impact on professional practice (i.e. permanent or temporary interruption). From these data, it was possible to determine the number of cases of decompression sickness (DCS) in our cohort, since all divers who had had DCS, with the exception of barotraumatic otitis, were seen again in our centre before resuming their professional activity.

Data entry was done using Excel software, Microsoft Office 2017®. Averages and extremes were worked out on this software. The correlation analysis of pathologies was done using Biostatgv®, by χ^2 test or Fisher test, depending on the validity parameters.

RESULTS

DESCRIPTION OF THE POPULATION

Our sample included 29 divers, 22 (76%) male and 7 (24%) female. There were more women in our sample than in the source population (i.e. all divers followed in the centre), but this was not significant: 7 (24%) vs. 69 (17%) ($p = 0.32$). The average age at the time of the problemat-

Table 1. Dive profiles according to type of dive (recreational or professional)

Type of dive	Occupational dives	Recreational dives
Number of divers	22	13
Seniority [years]	9.5 (1–32)	7 (3–15)
Number of dives per year	70 (10–250)	35 (2–100)
Number of dives over lifetime	724 (10–4750)	264 (10–1000)
Depth [m]	17 (5–50)	31 (7–50)
Time [min]	64 (30–180)	70 (30–150)

Data are shown as number or mean (extreme)

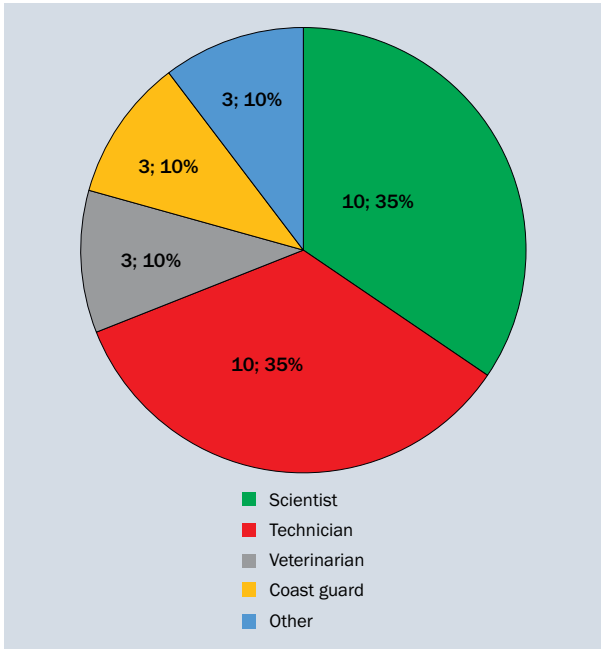

Figure 1. Distribution od divers by trade

ic diagnosis was 37 years (extremes: 23–59 years). The average length of time in professional diving was 7 years (extremes: 0–19 years). For 7 divers, the health problem was discovered during the initial examination, a regulatory prerequisite at the beginning of the professional diving career in France. It should be noted that among these 7 divers with contraindications to professional diving, 5 practiced recreational diving, with significant diving profiles: between 50 and 600 lifetime recreational dives (annual average of 30 dives per year), at depths of 30 to 50 m and durations of 60 to 120 min.

DESCRIPTION OF PROFESSIONAL ACTIVITY AND DIVE PROFILES

The majority of divers either were scientists (e.g. biology, oceanography, etc.) (10; 34%) or did different types of underwater work (10; 34%) (Fig. 1).

There were therefore 22 divers in professional activities, who made an average of 70 dives per year (extremes: 10–250 dives/year), and 7 divers were seen before the beginning of occupational diving (initial visit). Thirteen people were also engaged in recreational diving, two of whom also practiced snorkelling (Table 1).

MEDICAL DECISIONS

Medical decisions could be temporary unfitness for diving (19 times), temporary fitness with monitoring (7 times), a restriction of fitness (4 times), or permanent unfitness (12 times). The same diver may have had decisions of provisional fitness or provisional unfitness several times. This was the case for 7 divers. In total, the centre issued 42 such advisories, for 29 divers. There was a total of 1371 medical visits for 396 divers. So 3.1% of medical visits found out a contraindication or a restriction to dive, and there was 7.3% divers who had a contraindication or a restriction to dive.

Permanent unfitness for professional diving

Twelve divers had a definitive contraindication to professional diving, representing 3.0% of the divers monitored at the centre (12/396). There were 4 scientists, 1 veterinarian, 6 technicians (1 for scientific aquarium maintenance, 1 for laboratories and 4 for underwater worksites), as well as a truck driver who had an initial visit.

Three out of these 12 (25%) divers had already had a temporary restriction: 1 for a barotraumatic otitis; 1 for a work accident with a whiplash injury; and 1 following the discovery of chronic obstructive pulmonary disorder (COPD) while the assessment was being made, leading to the final contraindication.

Four out of these 12 divers (33.3%) were declared permanently unfit for professional diving during their initial visit, even if 3/4 had been practicing recreational diving for 3 to 10 years. Lung pathologies were the main cause of permanent incapacity: 8/12 (66.7%) of the cases of permanent unfitness (Fig. 2). Three of the divers had had decompression sickness at least once, including one diver who had suffered alveolar haemorrhages several times during scuba dives.

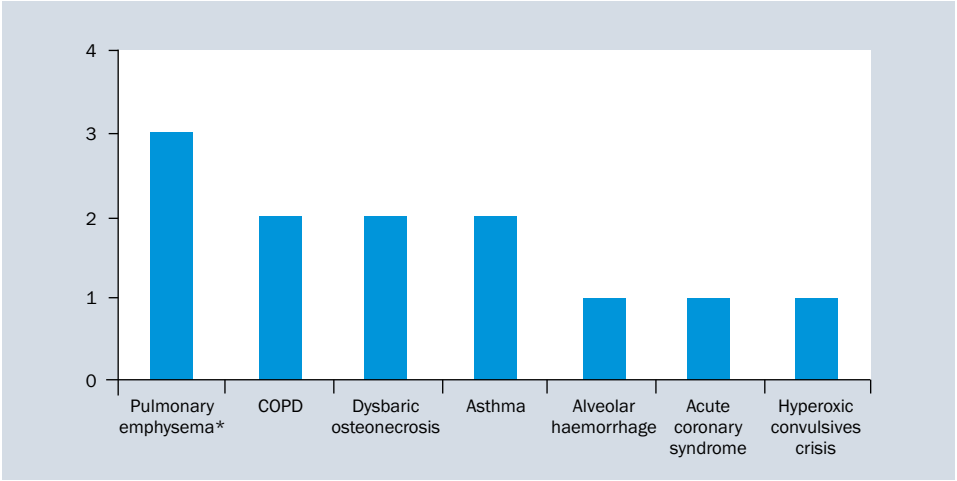

Figure 2. Causes of definitive contraindication to professional diving; *one emphysema with pneumothorax; COPD — chronic obstructive pulmonary disease

Description of temporary unfitness and restrictions

There were 19 provisional unfitness assessments, involving 16 different divers (4.0% of all divers), often to have time to explore an anomaly found during the medical examination (Table 2). There were 10 restricted fitness notices for 6 divers (Table 3).

DESCRIPTION OF DECOMPRESSION SICKNESS CASES

Twelve divers out of 396 divers followed in our centre (3.0%) had had at least one DCS incident, including 2 divers who had had 2, resulting in a total of 14 DCS incidents. Vestibular DCS was the most common (Fig. 3).

DISCUSSION

This united, focused, retrospective study provided information on the prevalence of decompression sickness among the 396 divers at this centre, and mainly, the different types of medical opinions issued in the event of a proven or suspected pathology that might increase the risk in professional diving. Only 12 (3.0%) divers reported having had a DCS incident. Similarly 12 (3.0%) divers had a permanent contraindication to the practice of a professional activity in hyperbaric environments, mainly due to pathologies of the respiratory system. And 16 (4.0%) divers had a temporary inability to heal or to complete clinical and paraclinical explorations of an abnormality discovered by chance during the medical examination.

This study had several limitations. By being carried out at a single centre, it represented the medical activity of this centre and also concerned a very particular population of divers. The divers monitored in Brest consisted mainly of scientists, veterinarians, port infrastructure security personnel and members of the coast guard. There are relatively few scuba divers working in deep water, or off shore. Similarly, this centre followed few fishermen, unlike other geographical areas [17]. This study therefore did not allow us to know the exact prevalence of DCS among divers in the regions of the west coast of France. These divers are often followed in other centres, such as those in Paris, depending on their company's headquarters. This was not the focus of our study. The purpose of this study was rather to know the fitness limitations issued by our centre and determine the pathologies that motivated them. These pathologies included DCS, but such incidents did not represent the majority. It would also be unwise to estimate the prevalence of barotraumatic otitis based on this study alone. Many divers are only seen once a year. In case of barotraumatic otitis, the care circuit in France provides for a consultation in the emergency room of a hospital (knowing that there are 2 university hospitals and a dozen hospitals in Brittany), where they are treated by an ear-nose-throat (ENT) physician. Temporary cessation of diving is generally defined as a work stoppage prescribed by the ENT physician, until the eardrum heals. In other words, not all divers with a barotraumatic otitis necessarily return to our centre for further consultation before resuming diving. Finally, it may seem surprising not to have any temporary unfitness for diving due to pregnancy, when 69 women were followed in this centre. This was also due to the care circuit in France: in the event of pregnancy, work in a hyperbaric environment is prohibited by the Labour Code. There is therefore no medical advice for diving in the case of pregnancy.

In our centre, respiratory pathologies as a whole were the leading cause of unfitness, due to the risk of decom-

Table 2. Description of provisional unfitness decisions

Organ	Pathology Number of occurrences	Further explorations	Links with diving and objectives of the medical opinion
Cardiovascular	Arterial hypertension: 3 times	Cardiological exam, cardiac ultrasound, blood work	No link Objective: avoid workplace injury
	Heart murmur Patent foramen ovale was suspected: 1 time	Cardiological exam, cardiac ultrasound	No link Objective: possible permeable oval foramen, the aim being to avoid DCS
Neurological	Vertigo: 2 times	ENT and neurological opinions, MRI	Type 2 cochleovestibular DCS related to diving Unfit for 6 months
	Paraesthesia of the lower limbs: 3 times	Neurological opinion, CT, MRI and electromyography	Type 2 spinal cord DCS Unfit for 6 months
	Epileptic seizure 1 time	Neurological opinion, MRI, EEG	Epileptic seizure in an ethyl intoxication context Unfit for 12 months
ENT	Barotraumatic otitis: 3 times	ENT opinion	Barotrauma related to diving
Musculoskeletal	Enchondroma: 1 time	Abnormality of the humeral diaphysis. CT and MRI, rheumatoid and orthopaedic opinions	No link with diving Objective: eliminate osteonecrosis Unfit for 6 weeks
	Workplace dive accident: whiplash injury: 1 time	Operation	Non-specific link Unfit during 6-month recovery period
Respiratory	Suspicion of emphysema upon X-ray: 2 times	Thoracic CT scan	No link Objective: avoid pulmonary barotrauma Unfit 1 month
	TLCO disorders: 1 time	Thoracic CT scan	No link Objective: avoid DCS
Haematologic	Lymphoproliferative disorder: 1 time	Haematological opinion	No link Objective: understand the relative risk of DCS Unfit for 1 month

CT — computed tomography; DCS — decompression sickness; EEG — electroencephalogram; ENT — ear-nose-throat; MRI — magnetic resonance imaging; TLCO — transfer factor of the lung for carbon monoxide

Table 3. Particular medical opinions

Medical opinion	Clinical situation	Number of medical advices Number of divers
Provisional fitness with the objective of reducing modifiable factors: tobacco use, sedentary lifestyle, cholesterol	Cardiovascular risk factors and risk calculation too high	6 advices; 2 divers
Restriction: diving only with air, limited depth	History of decompression sickness	2 advices; 2 divers
	Commencement of HIV treatment	1 advice; 1 diver
	History of asthma in childhood, persistence of non-specific bronchial hyper-responsiveness	1 advice; 1 diver

HIV — human immunodeficiency virus

pression sickness. Two divers (2/29) were declared unfit for professional diving due to asthma, and 1 other received diving restrictions (diving with air, max. 7 m). Several factors were taken into account in these medical decisions. For a long time, asthma contraindicated diving, both professional and recreational. Indeed, many studies have shown the risk of bronchospasm. Recent analyses have shown that this risk increases mainly in cold water or with depth [18]. Logic therefore seemed to indicate that asthma could increase the risk of bronchospasm, which, on ascent, could result in chest barotrauma. Some studies have shown this increased risk for asthmatic divers compared to non-asthmatic divers [19]. However, the available literature does not support this hypothesis [18, 20]. For this reason, several countries have updated their recommendations for recreational diving. In France, asthma contraindicated professional diving until 2011. Since the 2016 recommendations, cases can be considered individually, similar to the case-by-case approach

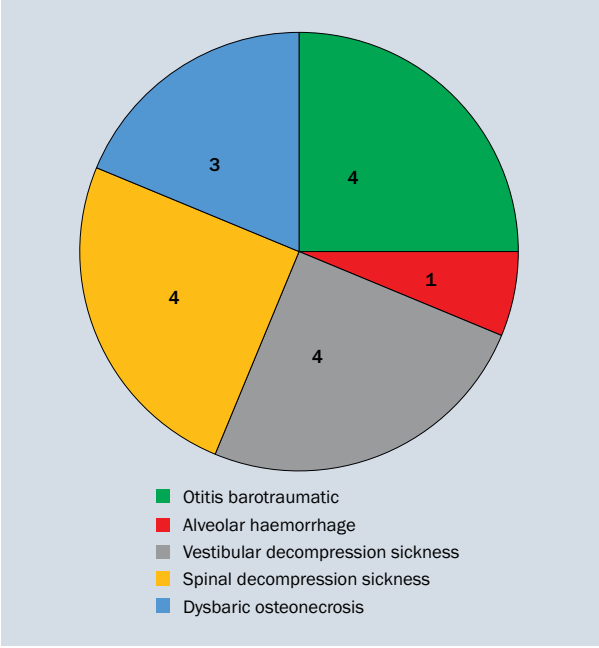

Figure 3. Distribution of decompression incidents

used with recreational diving. Medical judgments must then take into account the balance of asthma, the impact on respiratory functional explorations and the type of diving. Three divers had emphysema and one of these three had emphysema with a subpleural bubble; he had spontaneous pneumothorax at home. Two divers had COPD. Studies have not shown the development of obstructive ventilatory disorders due to diving, defined as FEV1/CV < 80% [21]. The data available in the literature only showed decreases in peripheral bronchial flow rates and transfer factor of the lung for carbon monoxide [22, 23].

It may seem surprising that temporary unfitness and/or specific fitness judgments were rendered 9 times with respect to cardiovascular risks. The question arose here, given the professional nature of the dives. Divers did not have the flexibility to schedule their dives according to their perceived "state of fitness". The aim was to limit the risk of cardiovascular incidents during a dive in people who do not have any particular physical training and a high cardiovascular risk. The aim was therefore to limit the risk of accidents and drowning [1, 14]. Recent literature also reports the hypothesis of cardiovascular effects even if dives are of short duration [24]. Åsmul et al. [24] showed that divers who did more than 150 dives per year had a higher risk of myocardial infarction than those who did fewer than 50 dives per year: risk ratio 2.91 (confidence interval 1.23–6.87). They also found a risk of high blood pressure in former divers compared to the general population.

The case of unfitness for suspected patent foramen ovale (PFO) was part of an approach to preventing decompression sickness. Studies have shown that gas bubbles can pass through the PFO and cause stroke. People with a PFO are more likely to have strokes and migraines than others, including at atmospheric pressure. In our centre, we gave a judgment of fitness for diving to divers with a PFO after transcatheter closure [25]. However, treating the PFO does not guarantee that no bubbles will pass through [26]. Before allowing diving to continue, especially for people who have had a DCS, it seems reasonable to discuss the benefit/risks balance of an intervention on a case-by-case basis [27]. It might be better for some divers to stop diving.

The decompression sickness among divers in our centre was mainly vestibular and spinal cord DCS. Most of these divers were able to return to professional diving after temporary unfitness judgments lasting 6 to 12 months. It may seem surprising that dysbaric osteonecrosis is more likely to lead to permanent disability. The decision took into account functional impact and recurrences. For example, the same diver had 2 dysbaric osteonecrosis. For central DCS, the decision to allow diving to resume was made based on the origin of the accident. If there was no pathology exposing a diver to a risk of recurrence greater than the normal risk associated with diving, and if physical and psychological recovery allowed it, the resumption of diving was possible. This was in line with the practices of other French maritime medicine centres [28]. The deliberation weighed the importance of diving for the person and his socio-professional integration, as well as the diver's psychological state. The literature reports several studies on the psychological profile of divers. Van Wijk [29, 30] showed that the psychological profiles of military divers have been stable in recent decades in the literature. However, the author pointed out that these results were not applicable to all populations. A study by Lafère et al. [31] analysed the behaviour of divers who had previously had a DCS. They found that some divers were unable to exercise caution when diving [31]. Further studies would be useful to determine how to predict whether divers will exercise caution. However, in our centre, we only followed civilian divers. They practiced diving in a professional setting, without always enjoying this exercise. Decisions could therefore not always be based on literature data. As it is often the case in medicine, this was a case-by-case analysis, often carried out in consultation with the doctors at the centre [32].

CONCLUSIONS

This study analysed the medical opinions during the monitoring of 396 professional divers in a marine medicine centre. Judgments of permanent unfitness for diving were rare (3.0% of divers). These opinions were motivated by the desire to avoid a diving accident. On 19 occasions, temporary unfitness rulings were issued, mainly in the months

following decompression illness to determine the origin of abnormalities detected during medical examinations. Finally, 3% of divers had had an incident of decompression sickness between 2002 and 2019.

The results of these years of medical monitoring showed that the French model made it possible to detect pathologies leading to a risk for divers, or pathologies caused by diving. However, our collection should be more comprehensive. For example, people who have stopped professional diving could be interviewed in order to determine the reasons why they stopped.

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