Diving after SARS-CoV-2 (COVID-19) infection: Fitness to dive assessment and medical guidance

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Scuba diving is a critical activity for commercial industry, military activities, research, and public safety, as well as a passion for many recreational divers. Physicians are expected to provide return-to-diving recommendations after SARS-CoV-2 (COVID-19) infection based upon the best available evidence, often drawn from experience with other, similar diseases. Scuba diving presents unique physiologic challenges to the body secondary to immersion, increased pressure and increased work of breathing. The long-term sequelae of COVID-19 are still unknown, but if they are proven to be similar to other coronaviruses (such as Middle East respiratory syndrome or SARS-CoV-1) they may result in long-term pulmonary and cardiac sequelae that impact divers' ability to safely return to scuba diving. This review considers available literature and the pathophysiology of COVID-19 as it relates to diving tness, including current recommendations for similar illnesses, and proposes guidelines for evaluation of divers after COVID-19. The guidelines are based upon best available evidence about COVID-19, as well as past experience with determination of diving tness. It is likely that all divers who have contracted COVID-19 will require a medical evaluation prior to return to diving with emphasis upon pulmonary and cardiac function as well as exercise capacity.

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Scuba diving is a passion for many recreational divers, but also represents a critical component of the commercial diving industry, scienti c research, military operations and public safety diving. Severe acute respiratory syndrome coronavirus two (SARS-CoV-2 hereafter referred to as 'COVID-19') affects the lungs with potential sequelae in the lung parenchyma.[1] During descent to depth gas-containing anatomic spaces will be compressed, and during ascent, any compressed gas introduced to these spaces will expand. These potential gas volume changes create a risk of barotrauma, hence the general consensus that healthy lungs are a requirement for diving.[2,3] Diving also poses signi cant stressors on the cardiovascular system resulting from increases in systemic blood pressure, centralisation of blood volume, thermal stress from water immersion and increases in systemic oxygen consumption.[4] Physical challenges similar to those of other sports would require similar evaluation while keeping in mind the added physiologic changes from immersion.[5] There are currently widespread concerns in the diving and medical communities on tness to return to dive post COVID-19. Research examining the origins and structure of the virus, its pathogenesis, and the clinical features of its acute presentation is growing, creating a foundation of evidence from which to draw while evaluating divers. However, the long-term sequelae are still unknown.

University of California San Diego diving medicine practitioners released guidelines for return to diving based upon decades of diving medical experience and the currently available literature about COVID-19.[6] Our objective here is to review the available literature considered when generating these guidelines, as well as to discuss the potential implications of COVID-19 sequelae in divers and draw relevance from tness to dive implications of similar diseases.

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In a pre-COVID-19 underwater world, decompression sickness (DCS) and pulmonary barotrauma with resultant arterial gas embolism (AGE) were the dominant diving-related injuries originating from breathing compressed air under pressure and requiring treatment with hyperbaric oxygen treatment in a pressurised chamber. The overall per capita DCS rate among recreational divers has been reported as 20.5 per 10,000 person years.[7] Although DCS is a rare and usually self-limiting injury, permanent disability can occur.

The risk of dying from recreational diving activit 55.f6 hsIn a pre-COVID-19 underw93 61.3 612.8407 24.9 (v)15 (eund255.1er

term implications, particularly for divers, because DCS appears to cause endothelial dysfunction.[37] Troponin elevation is reported to occur in 8–28% of patients with COVID-19 and is associated with a higher mortality risk.[38] Isolated elevations in brain natriuretic peptide (BNP) have also been reported in patients with increased mortality.[38] The mechanisms underlying cardiac injury in these patients are complex and the following have been proposed:

- COVID-19 uses the angiotensin converting enzyme II (ACE-2) receptor as a port of entry to human cells and in turn leads to its down-regulation. This results in an increase of circulating angiotensin-II levels leading to vasoconstriction, in ammation and a prothrombotic state.[39]
- Systemic hyperin ammation resulting from uncontrolled ampli cation of cytokine production following the initial immunologic response against viral replication may lead to direct myocardial injury, microvascular dysfunction or atherosclerotic plaque rupture.[35]
- Cardiac damage may result from direct invasion of the virus into the myocardium or the endothelium.[36]
- Myocardial damage may simply result from increased metabolic demands coupled with systemic hypoxia due to respiratory failure.

Our knowledge of these manifestations derives mostly from reports of hospitalised patients with higher disease severity.[40,41] The incidence of cardiac involvement in patients with mild or moderate illness managed in ambulatory settings is largely unknown. Attention should be paid to the potential lack of work-up patients may have received during the acute phase of their illness. In this pandemic, resources are strained and patients convalesce at home in circumstances where they may otherwise be hospitalised. If there is a history of potential cardiac involvement, the physician should attempt to clarify what type of cardiac manifestations were present and 2 (en-GB)/MCod2T40 >>BDC B9hi00.5 (la)0.>.>.>.0

been raised whether or not this would predispose a diver who had COVID-19 to DCS, which is also thought to be an in ammatory, prothrombotic state. The chronic effects are unknown, but it seems unlikely the hypercoagulable state would remain after the acute phase of the illness is over. The more likely consequence to divers would be the complication of ACS (see above in cardiac section) or pulmonary embolism.

FITNESS TO DIVE IN OTHER THROMBOEMBOLIC CONDITIONS

Pulmonary embolism. Pulmonary embolism is not an absolute contraindication to diving. An echocardiogram and exercise tolerance test could be performed to evaluate for any residual right heart strain or development of chronic thromboembolic pulmonary hypertension. Caution should be taken when diving on anticoagulant medication due to the increased risk of bleeding from even minor trauma.

C rr t r r a at r a at r f a at t r COVID-19

We have developed working guidelines based on the limited evidence of sequelae of COVID-19 available and experience with other diseases which share similar features (see above). We have categorised divers based on the history and severity of their illness and determined their return to dive evaluation accordingly. As with any illness, ultimately the work-up is left to the discretion of the evaluating physician. The guidelines which follow explicitly pertain to divers who are asymptomatic after their illness, including normal exercise tolerance (see exercise tolerance section). We currently recommend following CDC guidelines for screening of an employee for any diver prior to diving.

indicated if a patient has a normal radiograph, PFTs, and exercise tolerance. CT may be overly sensitive for clinically insigni cant lesions, as well as cause unnecessary radiation exposure and cost.

The guidelines detailed above require a more rigorous and conservative workup than would traditionally be required after a viral respiratory illness. However, this disease has proven itself to be atypical in a number of ways, including multi-organ system involvement and potential long-term effects on the pulmonary and cardiovascular systems. It

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Recommendations for evaluations of divers or diving candidates. Recommendations for evaluation are based upon the divers' severity of COVID-19 suspected illness (see Table 1). If results are unknown or unavailable, recommendations are for more extensive cardiac and pulmonary evaluations. BNP = brain natriuretic peptide; CK-MB = creatine kinase MB fraction; CT = computed tomography; ECG = electrocardiogram; PA = posterior-anterior; RSTC = Recreational Scuba Training Council. * If there is doubt that the diry e799 >.5 (*)0.6 (84

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