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Cardiovascular risk assessment in divers: Toward safer diving

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ABSTRACT

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Similar to aviation, diving is performed in an environment in which acute incapacitation may lead to a fatal outcome. In aeromedicine, a pilot is considered "unfit to fly" when the cardiovascular event risk exceeds one percent per annum, the so-called 1% rule. In diving no formal limits to cardiovascular risk have been established. Cardiovascular risk of divers can be calculated using the modified Canadian Cardiovascular Society (CCS) Risk of Harm formula: risk of harm (RH: cardiovascular fatality rate per year during diving: number × 10^{-5} divers/year) = time diving (TD: number of dives × 10^{-4}) × sudden cardiac incapacitation (SCI: cardiovascular diver event rate per year (number × 10^{-5}/year).

The SCI and thus the RH are strongly dependent on age. Using the CCS criterion for RH, 5 × 10^{-5} divers/year, and considering an average of 25 dives per year per diver, the calculated maximum acceptable SCI is 2%/year, consistent with current practice for dive medical examinations. If the SCI were to exceed 2%/year, a diver could be considered "unfit to dive," which could particularly benefit older (≥ 50 years) divers, in whom cardiovascular risk factors are often not properly treated. For the prevention of fatal diving accidents due to atherosclerotic cardiovascular disease, a dive medical examination is of limited value for young (<50 years) divers who have no cardiovascular risk factors. Introducing a cardiovascular risk management system for divers may achieve a reduction in fatal diving accidents that result from cardiovascular disease in older divers engaged in both recreational and professional diving.

KEYWORDS: cardiovascular diseases; diving; fitness to dive; preventive cardiology; risk assessment

INTRODUCTION

Recreational scuba diving occurs worldwide. Since its popularization in the 1980s the number of scuba divers has increased enormously. The largest diving organization, the Professional Association of Diving Instructors (PADI), covers 60% to 70% of the global scuba diving market and has issued more than 28 million diver certifications globally since 1967, with one million new certifications annually [1]. The number of new certifications seems to have stabilized in recent years [2]. Since most divers are active in the sport for short periods only, the number of certifications does not reflect the number of active divers.

It has been estimated that in the United States about 3 million people annually participate in scuba diving [3]; the numbers worldwide are unknown. As many once-youthful divers continue to dive, the diving population is aging [4].

With increasing numbers of aging divers, safety issues may arise. Diving injuries and fatalities are published periodically in the DAN (Divers Alert Network) and BSAC (British Sub Aquatic Club) diving reports [5,6], among others. Diving incidents and fatalities are typically grouped into two categories: non-medical, including procedural mistakes, equipment failure, environmental problems (e.g., strong currents, reduced visibility, and low temperature); and medical emergencies, including lung problems, cardiovascular problems, neurological problems, as well as other medical conditions.

In addition to training in proper diving procedures and equipment, divers' endurance and cardiovascular health must be sufficient for emergencies [7]. However, "sufficient cardiovascular health" is not clearly defined and may be difficult for medical examiners to quantify in divers.

Aviation faces challenges similar to those in diving: Acute incapacitation in a hostile environment may lead to a fatal outcome. In aeromedicine, a pilot is considered unfit to fly when cardiovascular risk exceeds one percent per annum, the so-called 1% rule. This 1% rule was established in 1984, mainly based on the work of Joy and Tunstall-Pedoe, in order to limit the contribution of medical (especially cardiovascular) emergencies to plane crashes [8-10]. The rule states that the pilot should be considered to be part of a man-machine system, and that no part of the system (including the pilots) should contribute more than 10% to the total risk of a fatal accident. A cardiac event, especially myocardial infarction or sudden cardiac death, is an "acute incapacitation" that renders a pilot unable to fly, which can lead to a crash. This 1% rule was set up for commercial flights with two fully licensed pilots on the plane. In this paper we attempt to apply assessment strategies used in aviation medicine to diving medicine.

Risk assessment in divers

A review of the main principals of risk assessment in divers was reported by Denoble et al. [11]. The relationship between risk, hazard, and exposure is given by the following equation: $Risk = Hazard \times Exposure$, and is defined by quantification of the probability that specific hazards will result in injury or harm. Hazard, according to the Federal Aviation Administration (FAA), is a "condition, event, or circumstance that could lead to or contribute to an unplanned undesirable event" [12]. In diving, as in flying, non-medical hazards can occur outside the diver: for instance, hyperbaric circumstances, strong currents, low temperature and equipment failure. Medical hazards can occur inside the diver, including acute health emergencies such as myocardial infarction, arrhythmia, and heart failure. Exposure refers to being in the presence of or subjected to a potentially harmful condition or agent (for instance, a dive or a flight). A dive fatality is a deviation from a normal dive leading to the death of the diver. The fatality rate is the number of fatalities per population at risk (divers) or per number of exposure units (dives). The fatality rate can also be expressed as annual fatality rate per exposure, or as annual fatality rate per exposure time. In this paper, annual fatality rate refers to that within a group with the same characteristics. Fatality rates are often expressed as number per 100,000 per year (number $\times 10^{-5}$/year). A year contains $24 \times 365 = 8{,}760$ hours. In this paper, in analogy with calculations used in aeromedicine, a year is considered to be equal to 10,000 (10^4) hours.

An alternative approach to risk assessment is the "Risk of Harm" equation, derived from the Canadian Cardiac Society Consensus Conference, that estimates the yearly risk of harm (RH) to other road users posed by a driver with heart disease with an implantable cardiac defibrillator (ICD), expressed as number per 100,000 drivers per year [13-16]. This formula takes the following form: $RH\ (number \times 10^{-5}/year) = TD \times V \times SCI \times Ac$. RH is proportional to time driving (TD: the proportion of time spent on driving in a given time period [expressed as fraction of a year]), the type of vehicle (V; truck or passenger car), the yearly risk of sudden cardiac incapacitation (SCI: based on the incidence of ICD shocks [number $\times 10^{-5}$ drivers/year]), and accident severity (Ac: the probability that the accident will result in an injury or fatality [0 = never; 1 = 100%, expressed as fraction]). The yearly risk of SCI was based on the cumulative incidence of ICD shocks, mainly delivered during ventricular fibrillation (VF) or ventricular tachycardia (VT) (VF and VT are not caused by driving, but happen during driving). Left untreated, VF and VT are usually fatal, and RH can be considered an *annual fatality rate per population*.

In patients with an ICD who are driving, vehicle defects make a negligible contribution to fatalities, while in diving, non-medical hazards are important. In this respect, similar to flying, medical risk assessment in diving should be part of a total risk assessment. The use of the Risk of Harm formula in diving is consequently limited to the risk of *medical* incapacitation. To calculate the cardiovascular risk of harm for *diving*, the SCI can be redefined as the incidence of fatal cardiovascular events in the diving population per year (%/year).

The use of the Risk of Harm formula in diving implies an assumption of randomly occurring cardiac events, independent of actual diving, and that diving itself neither induces nor protects against cardiovascular events (for further discussion of these assumptions, see Limitations).

The time spent on *driving* (TD) can be rephrased as the time spent on *diving*, expressed as the time fraction of the year that the diver is actually diving. As most dives typically are about one hour, this can be simplified to the number of dives per year (number $\times 10^{-4}$). V in the RH equation designates either professional (truck) drivers or private (passenger car) drivers. The impact of an accident with a truck being usually much higher than with a passenger car, V is set to 1 for professional drivers, and 0.28 for private drivers. Evaluating only the individual risk per type of driver or, in the present case, diver (e.g., scuba, rebreather, technical), the formula applies only to *that* type of diver, in which case V can be omitted. Assuming that every cardiac event under water is fatal, which is plausible in the case of VF, VT or any other major cardiovascular event during scuba diving, Ac can be set to 1. Consequently, for scuba diving, the formula can be rewritten as:

$$RH = TD \times SCI.$$

Fit or unfit to dive?

What is the cardiovascular risk (SCI) above which an asymptomatic diver should be considered unfit to dive? Risk stratification as low (<10% mortality and morbidity/10 year), moderate (10–20% mortality and morbidity/10 year) or high (>20% mortality and morbidity/10 year) originated with the Framingham study and is now generally accepted [17]. Currently, no formal or recommended upper limit of cardiovascular risk exists above which a diver is considered unfit to dive. As recreational diving and professional diving may accept different risks, they are discussed separately here.

RECREATIONAL DIVING

It should be noted that this section applies only to regular scuba diving within the decompression limits. For diving with a rebreather or with trimix, other calculations apply.

Annual fatality rate of recreational scuba divers

A variety of values for the annual fatality rate of recreational scuba divers has been reported, of which most are hampered by being incomplete and/or the number of divers in the population concerned is not precisely known. For organizations with known populations, like the BSAC or DAN, it is possible to calculate reliable fatality rates. The fatality rates reported by BSAC and DAN are 14.4×10^{-5} in 38,717 divers and 16.4×10^{-5} in 144,400 divers, respectively. When combined, a composite fatality rate can be calculated as 15.8×10^{-5} divers/year. Since the average number of dives per year in this population is 25, the fatal accident rate per dive can be calculated as 0.6×10^{-5} dives [11].

Contribution of cardiovascular disease to having a diving fatality

The cause of a diving fatality is not always clear. The most frequently reported cause of death in diving is drowning, to which cardiovascular disease might have contributed. Generally, cardiac disease accounts for 20% to 30% of fatalities, but may play a role in up to 50% of all fatalities [5,6,18]. The cardiovascular fatality rate is strongly related to age. In a survey of 1,141,367 DAN-insured member-years, 187 diving-related deaths (16.4×10^{-5}/year) were documented. For the group as a whole, the cardiovascular contribution to the fatalities was 26%. Divided over the age groups younger than 50 years old and 50 years old or older, these percentages were 10% and 36%, respectively [19].

Establishing a degree of cardiovascular risk that fits the actual cardiovascular fatality rate in recreational diving

Using the modified RH formula, cardiovascular risk can be calculated for the DAN/BSAC population [11]. In this population, the (composite) diving fatality rate is 15.8×10^{-5} divers/year. We assume that the cardiovascular contribution to fatalities is 25% (0.25). This results in an RH of ($0.25 \times 15.8 \times 10^{-5}$ =) 3.9×10^{-5}. In this population, the average number of dives was 25 per year, which equals 25 hours/year (TD = 0.0025 year = 25×10^{-4} year). SCI for the DAN/BSAC population can be calculated as: SCI = RH/TD = $3.9 \times 10^{-5} / 25 \times 10^{-4} = 1.6 \times 10^{-2}$ = 1.6%/year. This describes the entire DAN/BSAC diving community.

When age differences are considered the situation is quite different. In the above-mentioned survey of 1,141,367 DAN-insured member-years in which 187 diving-related deaths (16.3×10^{-5}/year) were recorded, there was sufficient data to investigate a probable disabling injury resulting in death in 129 cases. Out of these, 34 (26%) were attributed to cardiovascular disease [19]. For the entire DAN-insured population, the RH was ($0.26 \times 16.3 \times 10{-}5$ =) 4.2×10^{-5}. Assuming 25 dives/year, the SCI of the DAN-insured population was RH/TD = $4.2 \times 10^{-5} / 25 \times 10^{-4}$ = 1.7/year%. In the age group younger than 50 years, the fatality rate was (73/788,489 divers) 9.2×10^{-5}, with 10% resulting from cardiovascular events. The RH in this age group was then ($0.1 \times 9.2 \times 10^{-5}$ =) 0.9×10^{-5}/year. The SCI can be calculated as follows:

$$SCI\ (< 50\ years) = RH/TD = 0.9 \times 10^{-5} / 25 \times 10^{-4} = 0.3 \times 10^{-2} = 0.3\%.$$

For the age group 50 years or older, the fatality rate was (114/352,878 divers) 32.3×10^{-5}, with a cardiovascular contribution of 36%. The RH in this age group was then ($0.36 \times 32.3 \times 10^{-5}$ =) 11.6×10^{-5}/year. The SCI can then be calculated as follows (assuming 25 dives/year):

$$SCI\ (\geq 50\ years) = 11.6 \times 10^{-5} / 25 \times 10^{-4} = 4.6 \times 10^{-2} = 4.6\%.$$

Acceptable cardiovascular risk in recreational diving

Since a definition of "acceptable risk" in diving has not been generally agreed upon, it may be appropriate to adopt the "acceptable risk" used by the CCS as a reference, 5×10^{-5}/year. The CCS has used this definition for drivers with an ICD, but it can also be applied to other populations such as divers. By adopting this value as an acceptable risk, an upper limit of "acceptable" cardiovascular risk can be calculated (assuming 25 dives a year):

$$SCI\ (acceptable) = RH/TD = 5 \times 10^{-5} / 25 \times 10^{-4} = 2\%/year.$$

It should be mentioned here that this describes only the cardiovascular risk. The (cardiovascular) RH of diving in the DAN/BSAC population is 3.9×10^{-5}/year (see above). This lies within the "acceptable" range according to the CCS and is equivalent to an SCI of 1.6% for DAN/BSAC divers as a group.

PROFESSIONAL DIVING

Professional diving involves a wide variety of activities and different forms of licensing. The largest group consists of commercial divers. Commercial divers customarily engage in three modes of diving: scuba (self-contained underwater breathing apparatus); SSD (surface-supplied diving, with an umbilical to the diving ship); and saturation and closed-bell diving (divers stay in a hyperbaric environment for several weeks during their work). The latter is typically common in the offshore oil and gas company activities. Commercial diving is strictly regulated by national authorities: for instance by the Health and Safety Executive in the United Kingdom (HSE UK) [20], and on the European level, by the European Diving and Technology Committee (EDTC) [21]. Also, the industry itself prescribes medical standards for commercial diving [22]. Special branches of professional diving are police diving and military diving. Police diving includes rescue diving for underwater casualties and search and recovery diving for evidence and bodies. Military diving includes placing and demolition of explosives under water, reconnaissance, infiltration, combat and the like. Police and military divers usually use scuba gear or rebreathers, depending on the mission. Both police and military diving are strictly regulated by their national organizations.

Fatality rate in professional divers

Fatality rates among professional divers vary considerably, from 20 to 233 × 10^{-5} dives/year [23]. This wide range in diving fatalities is caused by different factors, among which is the relatively small number of commercial divers (UK 5,000; Norway 3,000; U.S. 3,500; Belgium 100). Hence, a small number of fatalities may have a profound effect on the annual fatality rate [24]. Since the UK HSE dataset contains the largest number of divers, it is probably the most reliable. It shows a fairly stable fatal accident rate for the offshore and inland/inshore sectors of 20–40 ×10^{-5} divers/year over the recent past [23].

Contribution of cardiovascular disease to professional diving fatalities

In a review of 577 professional diving accidents from 1975 to 2013, 4% of all fatal diving accidents, both inshore and offshore, were attributed to "cardiac arrest" [24].

Establishing a degree of cardiovascular risk appropriate for the actual cardiovascular fatality rate in professional diving

To the best of our knowledge there is no publicly available data on the numbers of dives and of diving time for professional diving, and consequently a calculation using the Risk of Harm formula is not straightforward. However, some elaboration on the cardiovascular risk of the professional diving population can be made. A Norwegian study investigated mortality rate in 3,130 male occupational divers, aged 18 to 60 years, and compared it to those of a matched reference group [25]. Over the observed period of 42 years, total mortality of the reference group was equal to that of the diving group and estimated to be 0.05%. There was no significant difference in cardiovascular mortality rate between the professional divers and the reference population (0.005%/year and 0.007%/year, respectively). The mortality for dive-related accidents was 4/1,000 divers/42 year (9 × 10^{-5}/year), but the contribution of cardiovascular causes to dive-related accidents could not be not established.

Acceptable cardiovascular risk in professional diving

The European Diving Technology Committee fitness-to-dive standards guide does not provide a specific threshold for cardiovascular risk in its "cardiovascular assessment" section, but states that stress electrocardiography (ECG) (at maximal workload during an exercise test) is needed over the age of 45 years, or younger when considerable risk factors are present. However, the document does not define "considerable," leaving room for interpretation. Blood pressure should not exceed 140/90 mmHg at the initial dive medical examination, but at the follow-up dive medical examination, blood pressure of up to 160/100 mmHg is acceptable, provided there are no signs of end organ damage [21].

The UK HSE standards for professional diving do not specifically mention cardiovascular risk or a cardiovascular risk threshold, and there is no requirement to calculate a cardiovascular risk profile. The document mentions that blood pressure should not exceed 160/100 mmHg, and no end organ damage should be present [20]. According to the European Society of Cardiology (ESC) and the European Society of Hypertension (ESH) task force for the management of arterial hypertension, this is classified as grade 1 hypertension [26] and corresponds to low to moderate risk in the SCORE2 risk table. The SCORE2 (Systematic COronary Risk Evaluation) risk score predicts the 10-year risk of fatal and non-fatal cardiovascular events in European populations [27].

When determining cardiovascular risk in professional divers, it is debatable whether only cardiovascular mortality should be considered or a combination of both mortality and morbidity. As myocardial infarction or any other cardiac emergency under saturation conditions reduces the chance of survival, combining cardiovascular mortality and morbidity in risk assessment should have priority [26,27]. By accepting a blood pressure of 160/100 mmHg without an established policy to rigorously treat risk factors, both the EDTC and the HSE allow de facto a moderate cardiovascular risk according to the SCORE2 criteria.

DISCUSSION

We present here a risk assessment tool based off applying the modified RH formula to the DAN/BSAC recreational diving population and diving fatality rate. Despite thousands of professional and millions of recreational divers, there is limited data on diving fatalities and cardiovascular risk. Although a comparable lack of data in the aeromedical field exists, implementation of the "1% rule" has served as a tool to limit medical (cardiovascular) risks during flying and to improve flight safety.

The formula RH = TD × SCI implies that the number of dives and SCI are inversely related. As a result of the assumption that recreational divers make 25 dives a year, the corresponding SCI is 2%/year, and when 50 dives a year are made, the corresponding SCI should be as low as 1%/year, 100 dives yields 0.5%/year, and so on. In general, the more dives made (or the longer the diver is exposed to saturation), the lower the SCI should be to maintain a maximum cardiovascular event risk of 2%.

From a cardiovascular point of view, divers that exceed a cardiovascular event risk of 2% per year could be considered unfit to dive, because they exceed the limits currently (albeit not officially) practiced for safe diving. Treatment of cardiovascular risk factors particularly benefits the older (≥ 50 years of age) diver, both for recreational and professional diving. For instance, among the divers ≥ 50 years of age described by Denoble, a reduction of the SCI from 4.6% to 2.0% would mean a reduction in RH from 11.6×10^{-5} to 5×10^{-5}. This would be a reduction from 29 to 13 fatalities, or about 55%. A further reduction to 1% would mean a reduction in RH from 11.6×10^{-5} to 2.5×10^{-5}. This would be a reduction from 29 to six fatalities, about 78% [19]. In recreational diving, divers younger than 50 years of age without cardiovascular risk factors such as smoking, hypertension, hyperlipidemia or diabetes mellitus usually have a low cardiovascular risk (combined mortality and morbidity <10%/10 years), which limits the contribution of a dive medical examination to cardiovascular safety. As cardiovascular risk increases with age, dive medical examinations at age 50 and older and, if deemed necessary, cardiologic follow up, may reduce diving-related fatalities. The issue of a dive medical examination with or without ECG before engaging in diving is beyond the scope if this manuscript.

Limitations

It is assumed that cardiovascular disease is responsible for 25% of all diving fatalities, although this value could be higher, as discussed above. If that were the case the SCI would also be higher. For instance, if the cardiovascular contribution were 35% instead of 25% of 16.4×10^{-5} fatal dive accidents per year, the RH would be 5.7×10^{-5} per year, and the SCI 2.2%. This would make the proper treatment of cardiovascular risk factors even more important. Another assumption in these calculations is that the cardiovascular risk is equally divided over the year and that diving per se does not affect cardiovascular risk. This is indeed the case in uneventful dives, but the physical exertion associated with scuba diving might induce adverse cardiac events. This is especially true among habitually sedentary older persons with occult or known coronary artery disease (CAD) who perform unaccustomed vigorous physical activity (defined as equal or greater than 6 METs [28].

A specific diving-related problem is immersion pulmonary edema (IPE). In the older diver, this is mainly related to the presence of hypertension and pre-existing cardiovascular pathology [29]. Diving might impair endothelial function [30,31], and hyperoxia may cause coronary artery constriction [32]. Coronary circulation during diving has mainly been studied in relation to the cold pressure test and the diving reflex, which cause vasodilatation of normal coronary arteries. This response is lost in patients with hypertension, diabetes mellitus or CAD, but can be restored (partially) with proper medical treatment [33-36]. To what extent these mechanisms play a role in fatal diving incidents is unknown.

Although scuba diving per se does not induce dangerous arrhythmias in healthy volunteers, cold-water immersion may provoke these arrhythmias due to the "autonomic conflict" and may lead to fatal arrhythmias in divers with heart problems, especially CAD [37,38]. These diving-related cardiovascular risks may argue for accepting a more conservative approach in divers during medical assessments (e.g., 1% instead of 2% total cardiovascular risk), especially when the diving circumstances are expected to be less favorable (e.g., cold-water or strenuous diving). These potential diving-related contributors to cardiovascular risk are probably already included in the current data.

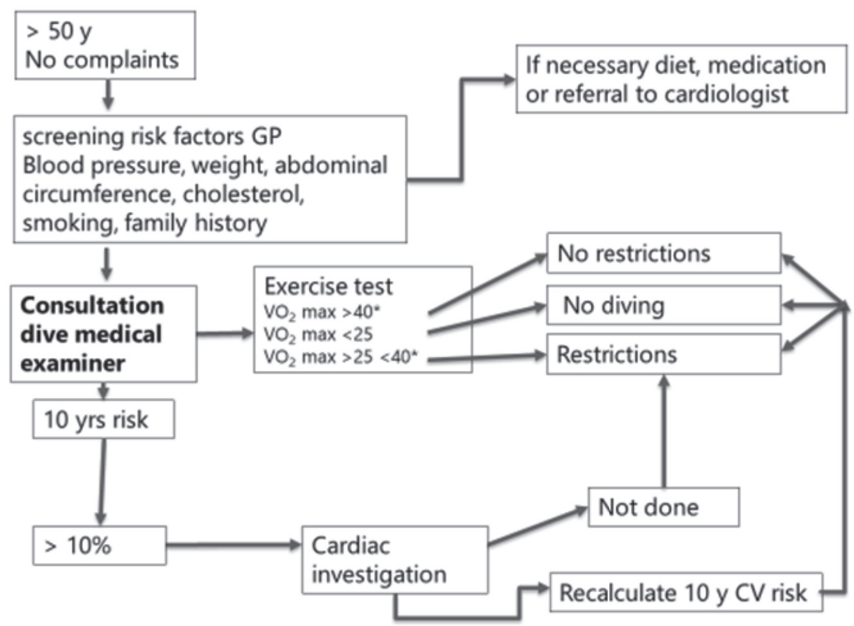
Implementation of cardiovascular risk assessment in dive medical assessments

The need for cardiovascular risk management was shown by a recent study of 113,892 American divers. One-third of active U.S. divers were 50 years old or older and/or reported prior high cholesterol, about half were overweight, more than half reported smoking cigarettes, and 32% reported hypertension or borderline hypertension [39]. Similar unfavorable cardiovascular risk factors were identified in a recent survey of 497 mostly male, older Dutch diving instructors, of which 66% of the males were overweight and one-fifth had cardiovascular disease [40].

Many cardiovascular risk assessment tools may be used, like the Framingham Risk Score, the Reynolds Risk Score, and the Euro-SCORE2, each with their own characteristics [41]. Where it is assumed that a cardiovascular event almost always leads to acute incapacitation and thus to a fatal diving accident (Ac = 1), it is preferable to use a risk calculator that uses cardiovascular mortality and morbidity, like the Framingham Risk Score or the EuroSCORE2 score. The Coronary Calcium Score (CCS) (or Agatston score) and the Coronary CT Angiogram (CCTA) are increasingly used as cardiovascular assessment tools for athletes and those with hazardous occupations [42,43]. CCS is a measure of the calcium content in the coronary artery wall, and ranges from very low (<1% risk in 10 years) to high (>20% risk in 10 years) [44]. Unfortunately, a CCS of 0 does not preclude CAD (especially not "soft plaque"). This can be visualized only by a CCTA.

Cardiovascular risk assessment, including the CCS or CCTA, as part of dive medical screening has been suggested by several dive medical societies [45,46]. A possible implementation of cardiovascular risk assessment in divers is diagrammed in the flowcharts of Figures 1 and 2 (adapted from [45]), which show that in addition to the cardiovascular risk, cardiovascular fitness must be considered before providing advice to the diver about whether to dive or to dive with restrictions. The

FIGURE 1
FLOWCHART: Risk assessment
by the General Practitioner and Dive Medical Examiner



Cardiovascular risk: Assessed risk of mortality and morbidity (%/10 year)
VO_2 max: maximum O_2 uptake (mL/kg/min).
Diving restrictions: no diving under circumstances that require good physical health, such as cold water, strong currents and high surf, among others.

flowcharts advise that when the overall cardiovascular risk, as assessed by an appropriate "risk calculation tool," is less than 1% per year, there is no objection to diving. When the total cardiovascular risk exceeds this level, it is suggested that there be further investigation using, e.g., CCS or CCTA to reclassify cardiovascular risk. When the total cardiovascular risk is considered to be too high, additional cardiologic examination may be indicated.

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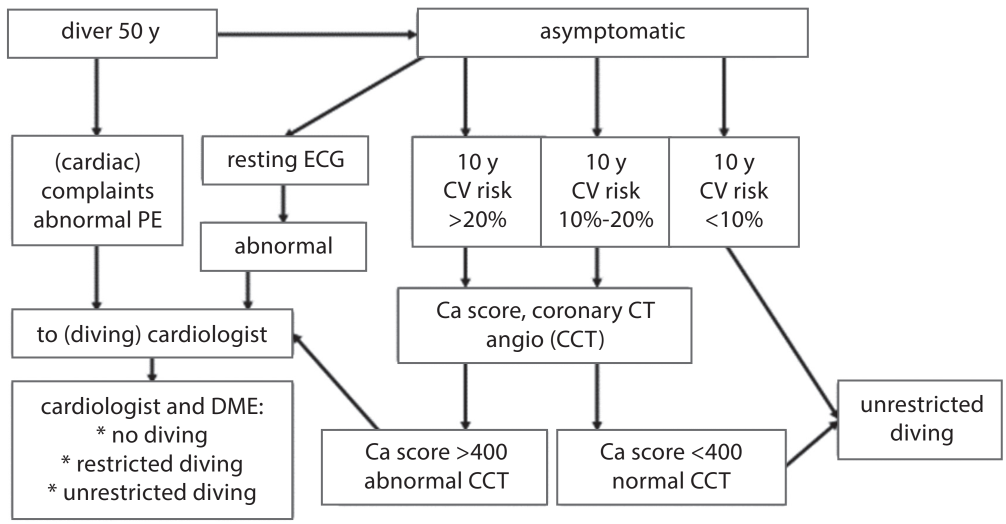
FIGURE 2
FLOWCHART: Assessment of cardiovascular risk in cardiac investigations of divers



Cardiac complaints: chest pain, palpitations, dyspnea (depending on effort), dizziness, (pre) syncope. Abnormal PE (physical examination): e.g., murmurs, signs of heart failure, cyanosis

DME: Dive Medical Examiner*
Cardiovascular risk: Assessed risk of mortality and morbidity (%/10 year).
CCS is related to cardiovascular risk as follows:
CCS = 0: very low risk of cardiovascular events (< 1% at 10 years)
CCS = 1–100: low risk of cardiovascular events (1–10% at 10 years)
CCS = 101–400: intermediate risk of cardiovascular events (10–20% at 10 years)
CCS > 400: high risk of cardiovascular events (>20% at 10 years).

Here a CCS of > 400 is considered a cutoff because when ≤ 400, the annual cardiac event rate is < 2%.

For a CCS ≤ 100, the annual cardiac event rate is < 1%. The decision to use a CCS of 100 or 400 as a cutoff value is an organizational decision.

* Dive Medical Examiner: physicians certified as such by the ECB (European College of Baromedicine), DMAC (Diving Medical Advisory Committee), the UHMS (Undersea and Hyperbaric Medical Society), or otherwise at an equivalent level.

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