A review of 149 Divers Alert Network emergency call records involving diving minors

Elizabeth T Helfrich[1], Camilo M Saraiva[1], James M Chimiak[1], Matias Nochetto[1]

[1] *Divers Alert Network, Durham (NC), USA*

Corresponding author: *Dr Matias Nochetto, Vice President, Medical Services, Divers Alert Network, Durham NC, USA*
mnochetto@dan.org

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Abstract
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Introduction: Minors have been scuba diving for decades, and while the initial concerns about potential long-term complications related to bone development appear to be unfounded, the incidence of scuba diving injuries among them has been poorly studied.
Methods: We reviewed 10,159 cases recorded in the DAN Medical Services call center database from 2014 through 2016 and identified 149 cases of injured divers younger than 18 years. Records were analysed for case categorisation on the most common dive injuries. Information about demographics, level of training, risk factors, and relevant behavioural aspects were collected when available.
Results: While the most common reason for the call was to rule out decompression sickness, the majority of cases pertained to ear and sinus issues. However, 15% of the dive-related injuries involving minors had a final diagnosis of pulmonary barotrauma (PBt). While no reliable data is available on the incidence of PBt in adult divers, the authors' impression based on personal experience suggests that the number of cases of PBt in minors trends higher than in the general diving population. The narratives on some relevant records describe unmanageable levels of anxiety leading to panic.
Conclusions: Based on the results and narratives on these cases, it is reasonable to infer that psychological immaturity, suboptimal management of adverse situations, and inadequate supervision might have led to severe injuries among these minor divers.

Introduction

Minors between 8 and 18 years old have been scuba diving for decades, but data on participation numbers and incidence of injuries are unavailable. When recreational scuba diving began in the 1950s, it was primarily reserved for relatively young, physically fit men. Over the following decades, recreational scuba expanded to include more women with both sexes of varying ages and fitness and, more recently, children. Training agencies have developed programs issuing special certifications for children as young as ten. Once the junior diver turns 15 years old, upgrading to a full certification is an administrative process. Some agencies have gone beyond, developing programs that allow participants as young as eight years old to breathe from a compressed gas source, although these usually involve only surface water activities and close supervision.

Most outdoor recreational activities involve managing inherent risks. Scuba diving requires special equipment and training to survive a hostile environment and physical and mental capacity to manage its risks. Diving can be psychologically stressful for those new to the sport or practicing it in challenging conditions. The most common cause of death in child divers is drowning, whilst the major contributor is panic.[1]

During childhood, dramatic changes happen in the brain. The prefrontal cortex and amygdala mature, giving us tools to perfect decision-making processes, regulate emotions, detect threats, and activate appropriate fear-related behaviours in response to threatening or dangerous stimuli.[2] Psychological immaturity can prevent minors from reacting to emergencies underwater with the same capacity as adults.[3] Panic can lead to uncontrolled rapid ascents, increasing the risk of pulmonary barotrauma.[4] Alternatively, children can lose focus within routine dives and make mistakes such as holding their breath or losing buoyancy control, similarly leading to an increased probability of injury.[5] Scuba diving requires a specific set of skills and physical coordination that may be poorly developed in minors. Demonstration of these skills in a highly controlled environment such as a swimming pool may not readily transfer to the open water environment.[6]

There have been concerns about the potentially harmful effects of compressed gas diving on growth rates. Epiphyseal growth plates have an increased blood supply, and there

was concern that under these unique conditions, scuba diving could impose a higher inert gas load and higher decompression stress than on most other body compartments, potentially impairing long-bone development. However, after decades of extensive diving by minors, including long-term follow-ups on cases of the bends, there does not seem to be any evidence to support this theory.[7,8]

Patent foramen ovale (PFO) is more common in children and can be found in up to 36% of individuals.[9] However, the incidence of decompression sickness does not seem to be higher than adults, possibly due to the depth restrictions commonly imposed on young divers.

Asthma with associated bronchoconstriction, air trapping phenomena, and reduced exercise tolerance is frequent in children. Its prevalence diminishes with age, demonstrating that the respiratory system is often still developing until teenagers become young adults. A child breathing from a compressed gas source in a swimming pool only two metres deep may not be at risk of decompression sickness (DCS), but is certainly at risk of pulmonary barotrauma (PBt) and arterial gas embolism (AGE).[10]

The Eustachian tube is not fully developed until approximately 12–13 years of age. The shorter and horizontalised Eustachian tubes, and often hypertrophic adenoids, tend to hinder normal middle ear ventilation, possibly making them prone to middle ear infections. These characteristics expose children to a higher risk of otic barotrauma.[11–13] Adults often experience difficulty with the concept of ear equalisation techniques, and instructors and parents must be convinced the minor comprehends the importance of this skill and is physically capable of performing these techniques effectively and efficiently without hurting themselves.

Temperature loss is higher in children due to the higher body surface area to mass ratio. Poor fit of neoprene wetsuits can increase conductive and convective heat loss, increasing the risk of hypothermia and forcing a high metabolic compensation to mitigate the energy consumption.

The World Recreational Scuba Training Council (WRSTC), a self-governing body with the primary goal of developing minimum standards for training recreational diving worldwide, has determined that a minor may not be deemed fully certified as an autonomous entry-level diver until age 15.[14] The council, however, does not define the minimum criteria to enrol a candidate in training. The council's standards also state that "*students under the minimum age may qualify for a special certification that allows them to dive under the supervision of an adult who has, as a minimum, an entry-level scuba certification*."[14]

While the incidence of diving injuries among recreational divers has been the focus of many studies, very few investigations focus on diving injuries of minors.[15,16] One retrospective study described 22 dive accidents in minors who were treated for AGE (six cases) and DCS (16 cases).[17]

Our study represents a retrospective analysis of diving injuries involving minors assisted through the emergency line of DAN's Medical Services Call Centre (MSCC) and recorded in a database between January 2014 and December 2016. The MSCC is open to all divers in need and professionals managing diving injuries. In general, more than half of users are non-DAN members and thus MSCC data provides a snapshot of injuries in the entire population of active recreational scuba divers.

Methods

The study was approved by the Institutional Review Board at the Divers Alert Network (Approval 020-15020).

This was a retrospective analysis of records stored in MSCC database, in the period from 2014 to 2016 inclusive.

SOURCE OF DATA

MSCC digital records contain case notes of incidents reported to DAN. Some records contain audio files and documents shared by the calling party, like medical notes, diagnostic studies, images, and dive profile logs.

A record usually starts as a transcribed narrative of the first interaction between a caller to the DAN Hotline and the DAN hotline agent (a diver medic, a nurse, or a physician) on call who interviewed the caller. The agent leads the call, gathering the minimally necessary information before recommending the best course of action.

The caller is interrogated about the reason for the call (usually documented as a chief complaint), the events leading to the injury or incident, and the subjective description of symptoms. Recommendations are offered once the hotline agent has enough information to have a reasonably good idea of what might be going on. After the initial contact, DAN Medics remain engaged with the case as it progresses through all phases: during case management while the diver is in the field, offering expert consultation once the injured diver is admitted to a medical facility, and monitoring the patient's progress with frequent follow-up calls after the diver is discharged. The result is usually a reasonably good recollection of events and outcomes.

IDENTIFIYNG CASES INVOLVING MINORS

In the observed period, there were 10,159 emergency case records involving divers of all ages. The injured diver's age or date of birth was not being explicitly recorded or provided by callers. Thus, we used a query written in Transact Structured Query Language (T-SQL) SQL Server Management Studio (SSMS) to search through four text

fields (chief complaint, history of present illness, initial assessment, recommendations) for the keywords suggesting the victim was a minor (e.g., identifiers for ages < 18 years old, child, daughter, son, boy, girl, etc.).

After identifying 2,269 cases, further review rejected 2,020 false-positive cases not involving minors. Out of the remaining 249 cases, 35 were not diving-related. Of the remaining 214 cases, only 106 cases had explicitly stated the diver's age; these cases were confirmed to fit the study criteria. One hundred and eight cases were ambiguous and required further investigation.

For an ambiguous case to be included, there had to be an abundance of indicators that the case referred to involved a minor. Some of the indicators of a minor were a parent calling on behalf of their child, the injured diver being a member of Boy Scouts, or enrolment in high school. Exclusion information for potential adults included enrolment in college or university, completing a divemaster course, or being in military service. With further review, 65 records were excluded as the divers were positively identified as older than 18 years of age at the time of the incident. From the remaining 43 records, 34 divers were positively identified as minors with a confirmed age, and nine divers were confirmed minors at the time of the incident but did not have confirmed ages. All 43 cases, in addition to the previous 106 cases, were included in the 149 cases in this study.

CASE CATEGORISATION

The included cases were classified using a protocol with inclusion criteria for each category. The categories, based on the most common dive injuries, were as follows: arterial gas embolism (AGE); anxiety; decompression sickness (DCS); ear, nose and throat injuries (ENT); hazardous marine life injury (HMLI); immersion pulmonary oedema (IPO); musculoskeletal; other; pulmonary barotrauma (PBt); caller 'uncertain'; unrelated; and unrelated infectious gastroenteritis. Each case was categorised twice, once for 'reason for call' and once for 'final diagnosis category'. The reason for call was determined from the caller's concerns or chief complaint (see Table 1). The final diagnosis category used for this study was determined by a senior physician at DAN after reviewing all case notes (see Table 2). When available, a treating physician diagnosis (TMD) was cross-matched with DAN's final diagnosis category.

SUBSAMPLE VALIDATION

The final sample of cases was validated with subsample validation. Three hundred and fifty cases were randomly selected from the original 2,269 cases and independently verified by a second reviewer with 100% match for both confirmed and suspected minors.

The categorisation of 'reason for call' and 'final diagnosis category' was also confirmed via subsample validation

Table 1

Reason for call classification descriptions; AGE – arterial gas embolism; DCS – decompression sickness; HMLI – hazardous marine life injury

Reason for call	Description
Arterial gas embolism	Caller suspected AGE. Chief complaint was acute onset of focal neurological deficit, severe headaches associated with vomiting and seeking hyperbaric treatment options.
Anxiety	Caller's chief complaint was minor's anxiety
Decompression sickness	Caller suspected DCS. Chief complaint related to joint pains, fatigue, decompression injuries.
Ear nose and throat	Complaints related to ears and sinuses including problems equalising and headaches.
HMLI	Injury from hazardous marine life.
Other dive related	Non-emergent dive-related injury including 'fin foot', trauma, and eye irritation.
Respiratory	Complaints related to respiratory system including shortness of breath, difficulty breathing, non-cardiac chest pain, dyspnoea, coughing, suspected pulmonary barotrauma including pneumothorax, immersion pulmonary oedema.
Uncertain	Caller suspected something was wrong with child but was 'uncertain' regarding cause. Caller was seeking any connection between child's complaints and diving.

Table 2
Final diagnosis classification descriptions; DCS – decompression sickness; HMLI – hazardous marine life injury

Final diagnosis category	Description
Arterial gas embolism	Confirmed focal neurological deficit in direct association with a dive exposure. Unlikely if onset greater than 15 minutes after surfacing.
Anxiety	Treating physician diagnosed minor with anxiety or anxiety-related issue; no other injuries.
Decompression sickness	Signs and symptoms highly compatible with DCS in association with a moderate to significant dive exposure. No other compelling explanation for symptoms. Recompression therapy, normobaric oxygen, or simply time (mild/marginal cases) resolved the case. Unlikely if symptom onset more than 6 hours after surfacing. Very unlikely if symptom onset more than 24 hours after surfacing.
Ear nose and throat	Signs and symptoms compatible with ear or sinus barotrauma, and/or ear infection (troubles equalising, dizziness, nausea, vomiting, headaches, pain in sinus regions, or as diagnosed by a physician).
HMLI	Injury reported as being caused by direct or indirect contact with hazardous marine life species.
Musculoskeletal	Musculoskeletal ailments not compatible with DCS. Symptoms can often be explained by recent, normal movements associated with diving such as carrying a tank.
Other, dive related	Non-emergent dive-related injuries. Included fin foot, dehydration, trauma, exhaustion, suit squeeze, contact dermatitis, unknown rash (non-HMLI and non-DCS), eye irritation, and swallowed water.
Pulmonary barotrauma	Signs and symptoms compatible with a form of extra-alveolar air (pneumothorax, pneumomediastinum, subcutaneous emphysema).
Non-diving related	Signs and symptoms, or symptom latency is incompatible with a diving injury; or examining physician ruled out a diving injury. Patient had unrelated illness or infectious gastroenteritis that is not a result of diving.

with a second independent reviewer, with 100% match of categorisation following criteria in Tables 1 and 2.

Results

Among 10,152 cases in the database for the observed period, we positively identified 149 records (1.5%) involving minors with a suspected diving injury, 100 of which were finally diagnosed with dive-related injuries.

A concern about DCS was the primary reason for calls involving minors, accounting for 38% of all calls, followed by ENT-related complaints (26%). Pulmonary barotrauma was suspected in 12 cases (8%), and AGE was suspected in six cases (4%). However, the final diagnosis was more often ENT-related with 32% of all injuries, 15% musculoskeletal issues, 12% gastrointestinal issues, 9% PBt without AGE, 1% PBt with AGE, and 6% DCS, with other diving and non-dive related cases accounting for 25% of all calls (see Table 3).

DECOMPRESSION SICKNESS

Decompression sickness was indicated as a reason for a call in 56 cases. However, the diagnosis was confirmed in only nine, representing 16% of suspected DCS cases, 6% of all calls, and 9% of all diving injuries. Based on manifestations, four cases were neurological DCS, four were mild DCS (three with musculoskeletal pain and one with rash), and one case was inner ear decompression sickness (IEDCS). Only one minor diagnosed with DCS reported having decompression obligations during the dive.

Of the remaining 47 cases initially suspected to be DCS, the final diagnosis was musculoskeletal issues in 22 cases; gastrointestinal issues in 12 cases; four cases of ENT barotrauma; one case of PBt, one anxiety, and one HMLI. Five cases were classified as 'other, dive related', two being dehydration, one physical exhaustion, one case of contact dermatitis, one fin-foot, and one suit squeeze.

EAR AND SINUS BAROTRAUMA

Similarly to adults, ENT issues were minors' most common diving-related injuries (n = 47, 32%). Ear nose and throat injuries were suspected early on 39 calls, and in all those cases, ENT injuries were confirmed, validating the general assumption that ENT barotraumas can usually be self-diagnosed by laypeople. Of the remaining eight cases, ENT issues were not initially suspected. Four called for concerns

Table 3

Reason for call vs final diagnosis category; AGE – arterial gas embolism; DCS – decompression sickness; ENT – ear, nose and throat; GI – gastrointestinal issues; HMLI – hazardous marine life injury; IPO – immersion pulmonary oedema; PBt – pulmonary barotrauma

Condition	Reason for call		Final diagnosis		
	Cases (*n*)	% of all calls	Cases (*n*)	% of all calls	% of diving diagnoses
DCS	56	38%	9	6%	9%
Respiratory (unspecified)	12	8%	–	–	–
PBt (without AGE)	–	–	13	9%	13%
PBt and AGE	6	4%	2	1%	2%
Anxiety	1	1%	3	2%	3%
ENT	39	26%	47	32%	47%
HMLI	12	8%	12	8%	12%
IPO	1	1%	0	0%	0%
Other dive related	5	3%	14	9%	14%
Caller uncertain	17	11%	–	–	–
Sub-total diving	149	100%	100	68%	100%
GI issues	–		18	12%	–
Musculoskeletal	–		23	15%	–
Other non-diving	–		8	5%	–
Sub-total non-diving	**–**		**49**	**32%**	**–**
Total:	**–**		**149**	**100%**	**–**

about DCS, two called suspecting AGE, one called for PBt, and one caller was 'uncertain' about what was going on with the minor but knew there was something wrong. Eleven minors with ENT injuries were relatively inexperienced divers, 10 being entry-level students.

PULMONARY BAROTRAUMA AND ARTERIAL GAS EMBOLISM

Fifteen minors were diagnosed with PBt, 13 without neurological findings, and two exhibited signs compatible with AGE. Concerns about PBt was a reason for the call on 12 occasions, and among those the diagnosis was confirmed in eight instances. Of the remaining four, two were diagnosed with non-dive-related issues, one with an ENT barotrauma and one with a musculoskeletal ailment. Of those finally diagnosed with PBt, only one caller was initially concerned about AGE with PBt being the culprit. Three callers did not seem to have any red flags about the type of injury possibly sustained, and one called for concerns about DCS.

Possibly contributing factors associated with PBT were identified in 11 cases (73%); there was insufficient evidence to determine a cause of PBt in the remaining four cases (27%). In seven cases (64%), there were confirmed reports of rapid ascents; of these seven cases, six (86%) had rapid ascents due to confirmed or highly suspected anxiety. One child became anxious after practicing a controlled emergency swimming ascent (CESA) during training; another reported an anxiety attack underwater that led to breath-hold and a rapid ascent. A child freediver planned a dive to 15 feet (4.6 m), then extended to 35 feet (10.7 m) for unknown reasons. This child then had 'seizure-like' activity underwater, right leg weakness upon surfacing, and a final diagnosis of AGE from the treating physician. It is unreported if the child breathed from compressed air at depth, although likely given the symptomology and treating physician diagnosis. Three more minors likely became anxious at depth, leading to rapid, unplanned ascents and consequent PBt. The final case with rapid ascent did not confirm or deny any anxiety from the child, although both the child and their dive buddy were diagnosed with PBt by their physician.

Of the remaining four instances of PBt (36%), an event happened at depth that likely led to accidental breath-hold and PBt. Two of these cases (50%) were caused by issues with equipment; one child reported a free-flowing regulator, while another reported being overweighted. It is likely this diver attempted to assist ascent by increasing lung volumes with deep inspiration and breath-holding. Of the other two cases, one diver had an 'enormous belch' during ascent, which suggested considerable aerophagia. In the final case, the minor stated they simply laughed 'uncontrollably' underwater. Also of interest is two young divers in this cohort (13%) who noticed chest pain after the first dive but continued to dive for the day. It is unclear whether that might have contributed to the severity of the initial injury.

Concerns have been raised about weight belts slipping off and causing uncontrolled ascents,[2] but incidents of this nature were not seen in this group. Regarding their level of training, five of the injured children were students completing a junior open water diver or open water diver program. Level of training was not available in the remaining cases.

ANXIETY

Anxiety seems to have played a significant role as the trigger in at least one third of the cases of PBt, but anxiety was also the final diagnosis in three minors (2%) with post-dive symptoms. Only one caller considered anxiety as the potential culprit for the child's manifestations. In this case, the treating physician considered anxiety the most likely cause of symptoms. Still, there was a discrepancy between treating physicians and DAN regarding whether recompression and hyperbaric oxygen treatment (HBOT) would be recommended as a precautionary approach. In another case, the Coast Guard evacuated a minor for suspected DCS, but the final diagnosis was 'hyperventilation syndrome'. In the third case, the initial working diagnosis was 'possible IPO' due to an unprovoked sudden onset of coughing while at depth. However, a timely medical evaluation did not reveal any objective findings or abnormalities to substantiate this suspicion and diagnosed the case as being due to a panic attack. Later, the novice diver admitted to feeling too anxious underwater due to limited visibility and wanting to end the dive.

Discussion

The number of injured minors recorded in the MSCC represents only 1.5% of all reports. The most remarkable finding of this study is that despite having significantly more calls for suspicion of DCS, pulmonary barotrauma was more common. The low number of DCS cases is possibly the result of less provocative dives being done by minors.

Although anxiety was rarely the reason for a call or a final diagnosis, different levels of anxiety are woven throughout various case narratives. Panic is a known trigger leading to dangerous scenarios in diving.[18] A recent study suggests a major difference between minor and adult divers is developmental difference in executive function, leading to issues with response inhibition, sustained attention and cognitive flexibility.[19] This conclusion is in line with our observations; in one third of the cases of PBt, narratives describe high levels of anxiety and even panic. These minors were accompanied by an adult diver, which might have prevented an even more severe outcome.

Physiological, psychological, and behavioural differences between minors and adults support the notion that their challenges also differ. A difference in diving injuries, especially between instances of DCS and PBt, is also consistent with DAN's observations with adult callers on the DAN Hotline – a future extension on this study would compare injury incidence between adults and minors.

ASSESSMENT OF MEDICAL, PHYSICAL, AND PSYCHOLOGICAL FITNESS TO DIVE

Minor diver candidates are often referred to physicians for assessments for fitness to dive. Medical fitness to dive is well-covered on dedicated forms available online on the World Recreational Scuba Training Council's (WRSTC) website, on the Undersea and Hyperbaric Medical Society's (UHMS) Recreational Diving Medical Screening System, and by the South Pacific Underwater Medicine Society's (SPUMS) Diving Medical.[14,20,21] Physical and psychological fitness can be challenging to assess and are often left to the discretion of a clinician who may not have training in diving medicine or any diving experience. However, such assessments have limitations even when conducted by appropriately trained physicians. Provided there are no medical or physical contraindications, psychological fitness might be better gauged as a candid discussion between the physician, the candidate's legal guardians, and the scuba instructor,[22] with the candidate present if deemed appropriate.

Assuming the minor has the body mass and strength to cope with and overcome potentially adverse situations (currents, drifting, or rescue of an adult-sized diver) and has no medical contraindications, perhaps the most critical aspect of diving fitness is reviewing the candidate's psychological maturity, as this is the most important factor in accepting and managing unseen risks, and predicting behaviour in adverse circumstances. Children often have a well-developed sense of adventure and a poorly developed sense of mortality.[5] Chronological age is a poor predictor of maturity in minors. Albeit more cryptic and admittedly rather impractical, perhaps reflection on the intersection between biological, psychological, and social age could more accurately predict the physiological and psychological response of a person making use of life-support equipment to survive a hostile environment.

Remarks for clinicians

A physician assessing fitness to dive should only do so if being fully cognisant of the nature of the activity, the type of equipment to be used, the environment in which it is to take place, and the physiological and psychological effects of the underwater environment on the diver.

When assessing a minor's fitness to dive, clinicians must remember that the candidate's guardians and dive instructor might offer a valuable perspective on the candidate's psychological maturity.

Diving can impose a wide variety of challenges on those practicing it. As an aquatic recreational activity, diving can lead to musculoskeletal strain, which can be, and often is, misdiagnosed as DCS. While some risks are inherent to diving physiology, others might be related to psychological stress, practicing physical activity, or traveling (for example, fatigue, gastrointestinal issues, dehydration, among others). Divers often experience non-diving injuries during or around the diving activity and are misdiagnosed due to a recent history of diving. Conversely, dive-related injuries can often be missed by a clinician without knowledge of diving medicine. If a physician is unsure of the proper course of action, the DAN hotline is available 24/7 for consultations in diving medicine.

Remarks for the industry

Minor divers are a special population. These individuals face different challenges than adult divers and pose different challenges for dive professionals.

When training individuals in vulnerable populations, no other group generates more polarisation than young divers. Those with a favourable view are often seduced by the child's joy, lack of fear, and the rewarding feeling of witnessing the development of aquaticity in a short time. Those sceptical often base their position on mental maturity, rudimentary understanding of physics, anatomy, and physiology necessary to understand mechanisms of injury and accept risks, or simply question the physical strength of a young diver to rescue an adult in an adverse situation. Solid arguments can be made both against and in favour.

Perhaps dive professionals should have specialised training to teach young divers and lead them during open water dives. Such training should focus on their individual needs and unique behavioural aspects that seem to make them more prone to incidents and injuries. Minor divers should always be at an arms-length distance from an adult diver who needs to monitor them closely, especially with regards to comfort and air consumption. As the diver matures emotionally and their response to stress becomes more predictable, this distance could be gradually relaxed.

Safety enhancements can also be made regarding the standard operating procedures in open water dives. Recreational scuba divers are encouraged to adopt the 'buddy system' for mutual support and monitoring stress reactions in adverse circumstances. Under this arrangement, two individuals are paired and operate together as a single unit throughout the dive. They are encouraged to stay close and communicate regularly. The more they dive together, the more they know each other, and the more efficient they become. The concept has proven to work well in many disciplines, including diving. However, minor divers may not be reliable dive buddies due to their smaller body size, reduced strength, lesser maturity, and often unpredictable response to threats. WRSTC standards state that "*students under the minimum age may qualify for a special certification that allows them to dive under the supervision of an adult who has, as a minimum, an entry-level scuba certification*".[14] An argument could be made that when the team involves pairing an adult and minor where there is a significant body size or strength dissymmetry, the safety of both could be unacceptably compromised if the adult is depending on the minor for assistance in an emergency. In these cases, a team of three seems to be a more prudent minimum.

Modifying the dive plan and standard safety protocols is logical when leading dive groups containing young divers with inherent limitations. In the same way that a dive professional must hold certifications in wreck diving to teach wreck diving or to lead a group on a wreck, specific dive training should be available for dive professionals to teach and guide minor divers before working with them. This training should include an extensive explanation of minors' different challenges and how to manage them.

Instructors should be knowledgeable about the signs of anxiety and be confident in recommending to the candidate and their parents that the candidate might not be yet mentally mature enough to be a safe diver without fear of being accused of discrimination. Each minor is physically and psychologically different, and pre-existing physical, behavioural, and emotional limitations can compound the anxiety minors are more likely to experience.[23]

LIMITATIONS

This study has limitations worth emphasising. As with most epidemiological studies in diving medicine, the primary limitation to the generalisation of results is the lack of a denominator. This limitation, and a relatively small sample size, prevents us from inferring the possible prevalence of diving injuries among minors and making sensible comparisons with adult diving populations. A future study design would be to look at adult diver injury incidence from the DAN Hotline and compare to minor divers.

Another limitation concerns the methodology used. As this retrospective study was waived from consent, we did not contact any party to gather more information about these incidents. Instead, we worked with the documentation available: written narratives, call recordings, medical records shared by calling parties, and any public domain records when available. Re-interviewing the parties involved in these cases could provide much more data than we could gather by retrospectively reviewing existing records.

The role of anxiety as a trigger and root cause of an injury is likely underrepresented. This could be partly due to the subjective nature of anxiety, a possible behavioural bias from

minors not always accepting and verbalising their fears, and inherent defects in the quality of the data captured and its completeness.

Due to inherent limitations in telecommunications, the final diagnosis category of 'anxiety' as the explanation of all manifestations was at the discretion of the evaluating physician and could be underestimated as well. We have since updated our standard operating procedures and tools to better capture anxiety as a differential diagnosis and risk factor.

Conclusions

Dive-related emergencies involving minor divers are rare. Our data suggest that lung over-expansion injuries seem more common than DCS. During the three years we analysed, 10% of the calls involving a minor with a suspected diving injury had a final diagnosis of PBt, making up to 15 percent of the diving injuries in minors during that period.

Factors contributing to PBt in minors might be associated with fitness and immaturity. Qualified fitness to dive evaluation, improved training, and closer adult supervision might help mitigate the risks of injuries in minor divers.

Dealing with diving accidents is extremely stressful at the best of times, but it is far more so if the victim is a minor, due to the additional emotional pressures, which should not be underestimated.

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