Decompression Sickness in Miskito Indian Lobster Divers: Review of 229 Cases

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Background: The Miskito Indian lobster divers of Central America employ very provocative diving profiles and experience severe neurological decompression sickness (DCS) and/or arterial gas embolism (AGE). Scientific data are scarce regarding the clinical patterns of injury, response to treatment, and functional outcomes for such cases. ***Methods:*** A retrospective review of 229 cases of DCS and/or AGE was conducted at 2 hyperbaric units in Central America. ***Results:*** The following deficits were recorded on presentation: any neurological deficit: 94%; motor: 79%; sensory: 60%; urinary: 48%; reflex: 45%; and loss of consciousness: 20%. The patterns of weakness (n = 182) were as follows: paraparesis: 27%; paraplegia: 26%; lower extremity monoparesis: 14%; lower extremity monoplegia: 6%; quadriparesis: 4%; hemiparesis: 4%; hemiplegia: 3%; and quadriplegia: 2%. Treatment was delayed by a mean and median of 5 and 2 d, respectively. The majority received hyperbaric oxygen and systemic steroids. Motor function on discharge (n = 182) was as follows: normal: 30%; paraparesis: 15%; lower extremity monoparesis: 15%; paraplegia: 3%; quadriparesis: 2%; hemiparesis: 2%; and missing data/other: 33%. Gait on discharge (n = 182) was as follows: normal: 19%; abnormal: 19%; required one crutch: 10%; required two crutches: 16%; not ambulatory: 5%; and missing data: 31%. ***Discussion:*** The majority of severe injuries could be localized to the thoracolumbar spinal cord. One-fifth had bilateral cerebral dysfunction manifested by loss of consciousness. Despite long delays to treatment, divers responded to hyperbaric oxygen. At the time of discharge, almost a third had complete recovery of strength and the majority were ambulatory.

Keywords: decompression sickness, hyperbaric oxygenation, barotrauma, air embolism, diving.

THE MISKITO ARE A Central American indigenous population. By some estimates, they number 250,000 and occupy a territory approximately the size of Costa Rica, stretching from remote portions of the Atlantic Coast of Honduras to Nicaragua (**Fig. 1**) (6). The Miskito people participate in subsistence farming, fishing, and hunting. Since the 1970s, the lobster industry has been the primary source of cash flow into the coastal Miskito communities of Honduras. Working as a wage-earner, a diver might earn as much income in one 12-d dive trip as he could working an entire year in the fields (2).

Industrial diving boats (**Fig. 2**), based in the Bay Islands of Honduras (2) and in Puerto Cabezas, Nicaragua, transport divers to the lobster fields near the Miskito keys* From there, scuba tanks are loaded into canoes, which are launched from the diving boat. While a canoe handler remains above the surface, his diver descends multiple times per day to collect lobsters with a hook and bag. Similarly, a group of self-employed divers launch their canoes directly from Corn Island, Nicaragua.

Previous studies have reported that Miskito divers were poorly trained and equipped (7) and used alcohol and drugs prior to diving (3,4). They were found to perform extremely provocative dives to depths greater than 100 fsw (1,5,7) using 12–16 tanks per day (7), and made rapid ascents without decompression stops (3) for the duration of the 12-d dive trips (2). Severe neurological injuries (5,7) have occurred. A fatality rate of 2 per thousand divers per year was reported from a large, well-documented community survey (7).

Such provocative diving practices have not been well studied. A search of PUBMED revealed only one article on the Miskito divers, a collaborative study from St. Luke Episcopal Medical Mission in Honduras, Virginia Mason Medical Center, and the U.S. Navy Experimental Diving Unit, that described diving methods and the incidence of limb pain among Miskito divers (4). Other reports describing decompression sickness (DCS) and arterial gas embolism (AGE) in this population are written in Spanish and published in sources that are difficult to obtain (1,5,7).

We studied a large series of cases to address the following questions: 1) What were the most common patterns of severe neurological injury that resulted from multiple deep dives with missed decompression and rapid ascents? 2) What functional outcomes resulted from severe neurological DCS following long delays to treatment? 3) What was the impact of hyperbaric oxy-

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*USAID. Unpublished report. Cayos Miskitos. Environmental initiatives of the Americas Fisheries Project; 1996.

Fig. 1. The Miskito people inhabit a territory stretching from remote portions of the Atlantic Coast of Honduras to Nicaragua (6).

gen on severe neurological DCS? 4) What can be done to help prevent injuries in this population?

METHODS

The review of medical records took place at two hyperbaric oxygen (HBO) units. 1.) Clinica Evangelica Morava (CEM) in Ahuas, Honduras, was a remote inland clinic/hospital. Because there were no roads that connected it to the capital city, it was accessible only by plane or by boat from the river. The HBO unit consisted of a monoplace chamber that delivered oxygen with a demand regulator. Due to the expense, the generator that supplied electricity was only used for several hours per day. 2.) Hospital Nuevo Amanecer (HNA) was a regional hospital in the port city of Puerto Cabezas. Although it was also remote, it was accessible by ship from the sea. In addition, daily flights from the capital city were available, as well as ground transportation. The HBO unit consisted of a multiplace chamber. Electricity was usually available 24 hours per day. Oxygen was always in short supply to both facilities.

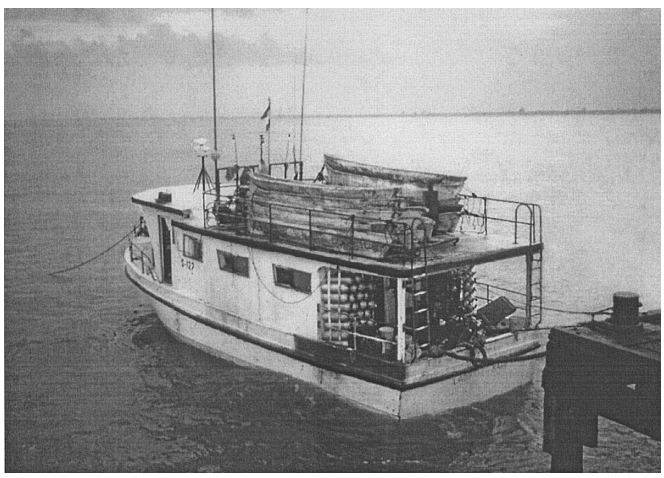

Fig. 2. Industrial boats transport divers and canoe handlers to the lobster fields for 12-d trips.

TABLE I. DIVING PRACTICES OF MISKITO DIVERS WITH DECOMPRESSION SICKNESS.

	Mean	Range
Years diving (n = 169)	11	<1–35 yr
Depth on day of injury (n = 141)	102	14–192 ft
# Tanks on day of injury (n = 140)	7	1–18 tanks
Days diving prior to injury (n = 45)	5	1–12 d

Although some charts were missing or difficult to access, we reviewed all available medical records pertaining to divers with DCS or AGE. The total was 229 cases: 162 from CEM between 1985 and mid-1996 and 67 from HNA between 1996 and 1998. Data on demographics, diving practices, presenting signs and symptoms, treatment, and outcomes were collected.

When calculating means, missing data were disregarded. When calculating percentages in terms of presence or absence of a condition, in most cases, the denominator was 229, the total number of cases in the database. However, when outcome data were calculated, the denominator used for ambulation and motor deficits was 182, the number of divers presenting with motor deficits.

RESULTS

Some of the medical records contained very detailed dive histories, accompanying signs and symptoms, and neurological exams with localization of the lesions. However, other charts had very abbreviated notes that focused on the patterns of weakness. In a considerable number of cases, outcome data were absent. There was often no follow-up information after discharge unless the diver suffered a subsequent injury.

Demographics and Diving Practices

CEM in Ahuas treated 71% of the divers in this study and HNA in Puerto Cabezas treated 29%. Due to its remote location, most divers treated at CEM were admitted regardless of the severity of the injury. At HNA, about half of the divers were admitted. Since many lived locally, the milder cases were treated as outpatients; records on outpatients were not available.

All divers were male. The average diver in this series was 29 yr old, but ages ranged from 16–67 yr. Data on diving practices is detailed in **Table I**. After injury, a few divers attempted (unsuccessfully) to use in-water recompression on air.

Clinical Presentation

Some divers were flown in for treatment, especially to CEM. However, that information was frequently not documented, nor was the altitude of the flight. Most of the divers treated at HNA (Puerto Cabezas) arrived by boat. For all cases, the mean delay to presentation (n = 197) was 116 h, and the median was 48 h with a range of 4 h to 44 d. When analyzed separately, mean time to presentation for patients at CEM (n = 138) was 124 h,

TABLE II. NEUROLOGIC DEFICITS IN MISKITO DIVERS WITH DECOMPRESSION SICKNESS (n = 229).

	Positive	Negative	Missing Data
Any Neurologic Deficit	94%	3%	3%
Motor Deficits	79%	17%	4%
Sensory Deficits	60%	6%	34%
Urinary Deficits	48%	12%	40%
Reflex Abnormalities	45%	1%	54%
Loss of Consciousness	20%	0%	80%

and the median was 72 with a range of 18 to 816. Mean time to presentation at HNA (n = 59) was 98 h, and the median was 24 h, with a range of 4 to 1056 h. A few divers reported visiting a shaman healer prior to presentation. At least 1 prior episode of DCS or AGE was reported by 24% of the patients (n = 229).

The vast majority of divers presented with neurological deficits that included motor, sensory, and urinary deficits as well as reflex abnormalities (**Table II**). In divers with motor deficits (n = 182), the most common patterns of injury were paraparesis and paraplegia (**Table III**). Almost three-quarters of the divers had motor deficits involving only one or both lower extremities with sparing of the upper extremities. Cranial nerve deficits were rarely reported. Loss of consciousness was reported by 20% of divers; however, the majority had regained consciousness prior to presentation. In many cases, the presence or absence of less severe symptoms was not documented. However, dizziness and pain, including chest pain and headache, were the most commonly reported symptoms. Diving-related complications (n = 229) included urinary tract infections in 27%, decubitus ulcers in 3%, otitis media/externa in 2%, and pyelonephritis in 1%. Depression was reported in 1% of divers. Comorbidity (n = 229) included parasites in 25%, positive skin test for purified protein derivative in 6%, malaria in 5%, and tuberculosis in 1%.

Treatment

Prior to the availability of hyperbaric chambers, treatment of divers presenting in the acute to subacute period was limited to oral steroids and physical therapy. During this period, CEM only admitted 12–14 divers per year. In 1991 and 1997, chambers were installed in CEM and HNA, respectively. The number of divers admitted to CEM rose to 51 per year 4 yr after installation. Almost all of the divers received at least one HBO treatment after the arrival of the chambers. Overall, 63% and 61% of divers (n = 229) received hyperbaric oxygen therapy and systemic steroids, respectively. At CEM in Ahuas, divers received U.S. Navy Treatment Table (USNTT) 5 and/or USNTT6 depending on the severity of the illness and the availability of oxygen. At HNA in Puerto Cabezas, divers received a variety of treatments, including USNTT5, USNTT6, and treatments at lower pressures. Many of the physicians continued to use oral steroids, depending on the severity of illness and availability of the medications. There were no reported complications due to steroids.

Outcome

Many divers reported some degree of spontaneous improvement prior to presentation. Despite long delays to treatment, records indicated that divers responded to HBO (Table III). Ambulatory status at the time of discharge was as follows: normal gait, 19%; abnormal gait, 19%; required one crutch, 10%; and required two crutches, 16%. Only 5% were not ambulatory and missing data accounted for 31% of the cases. Sub-group analysis was hampered by missing data and more severely injured divers in the HBO group.

DISCUSSION

The Miskito divers in this series seem to be representative of the entire group in terms of age and number of years diving (1,3–5,7). In addition, the extremely provocative diving practices appear to be the norm in this region (1,3–5,7), including among the self-employed divers in this series. The weakness of this study is that it does not address mild cases of DCS in this population. However, the previous publications provide valuable insight (3,4). In an 11-d on-board study, one of their authors observed as Miskito Indians made daily provocative, repetitive dives. Due to the presence of an on-board observer, the captain intentionally chose more conservative depths of less than 90 fsw. Nevertheless, by the end of the trip, six of eight divers had reported joint pain, mainly in the upper extremities. Of the remaining two, one had experienced headache and the other both headache and back pain, symptoms that could be attributed to DCS. Therefore, it seems that the true incidence of "mild" DCS in this group on a single trip was 75–100%. Divers also reported fatigue, dizziness complicated by ear barotrauma, generalized pain, and back pain (3,4).

One of the strengths of our series is that it describes the patterns of neurological injury in a large number of cases as reported by the treating physicians at two centers. To answer the first question posed by this study, the majority of severe DCS in this series was manifested by paraparesis or paraplegia (53%) and could be localized to the thoracolumbar spinal cord. Another 20% presented with weakness or paralysis of one lower extremity, suggestive of a Brown-Sequard Syndrome of the thoracolumbar spinal cord. Cervical spinal cord involvement, resulting in quadriparesis or quadriplegia, was documented in 6% of divers in this

TABLE III. PATTERNS OF WEAKNESS IN MISKITO DIVERS ADMITTED FOR DECOMPRESSION SICKNESS (n = 182).

	Presentation	Discharge
Normal	0%	30%
Paraparesis	27%	15%
Paraplegia	26%	3%
Lower Extremity Monoparesis	14%	15%
Lower Extremity Monoplegia	6%	0%
Quadriparesis	4%	2%
Hemiparesis	4%	2%
Hemiplegia	3%	0%
Quadriplegia	2%	0%
Missing Data/Other	14%	33%

series. Hemiparesis and hemiplegia (without apparent cranial nerve involvement) occurred in 7% of divers in this series, suggestive of a Brown-Sequard Syndrome in the cervical spine. Similarly, self-reported survey data (5) in another group of severely injured Miskito divers (n = 49) indicated thoracolumbar and cervical spinal cord injury in 59% and 8%, respectively.

Of divers in this series, 20% reported loss of consciousness, indicating a brainstem lesion involving the reticular activating system or bihemispheric dysfunction. Hypoxia, as a result of running out of air, is one potential etiology. However, the majority of divers reporting loss of consciousness had fixed neurological deficits on awakening. Therefore, it is more likely that AGE due to rapid ascents was responsible for the loss of consciousness.

This study provides valuable insight into the functional outcomes of divers with severe neurological DCS and AGE with long delays to treatment. To answer the second question posed by this study, almost a third of divers in this series had normal motor function and the majority were walking unassisted or with crutches on discharge. Similarly, the St. Luke Unit (3) reported long delays to treatment. They maintained a policy of treating all Miskito divers with hyperbaric oxygen, regardless of delay. Improvement in neurological DCS/AGE occurred in approximately 40% of divers after delays exceeding 12 and even 30 d. Dunford and others concluded that HBO improves neurological function in a proportion of the population, despite extended delays (3). Subgroup analysis in this series was plagued by more serious injuries in the HBO group, lack of a scoring system, and missing data. Therefore, it was not possible to determine the impact of HBO, steroids, flying after diving, or delay to presentation on outcomes.

Lastly, what can be done to help prevent injuries in this population? Miskito people lack employment opportunities. Despite knowledge of the inherent dangers of diving, workers and their extended families rely on the income. Implementation of safe diving practices, including treatment for substance abuse, could make a tremendous impact on the health and well-being of the population. However, it remains to be determined whether the lobster divers and the industry as a whole would be willing to accept less profit in exchange for less risk.

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