Diving expedition medicine – the Coral Cay Conservation experience

Karen E Richardson

Key words
Travel medicine, health surveillance, medical conditions and problems, epidemiology, medical kits, operations – diving

Abstract
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Objectives:
1 To identify the most commonly encountered medical presentations in the setting of a remote land-based tropical diving expedition.
2 To compare these findings with other styles of wilderness expeditions to determine what role the marine environment plays in aetiology and relative risk.
3 To formulate a strategy of medical risk management and provide suggestions for medical supplies for future diving expeditions of a similar nature.
Methods: Weekly reports and sporadic incident forms held by Coral Cay Conservation were reviewed retrospectively with regard to incident type, category, severity, time off diving, personnel involved and treatments used. Results were presented graphically and incident rates calculated to allow comparison with other published expedition data.
Results: 540 medical encounters were recorded in an 18-month period from a sample representing 82.6% of all reporting weeks. An incident rate of 20.4 medical encounters per 1,000 expedition-person-days was calculated from a total of 26,522 expedition-person-days. The aquatic environment was responsible for 50.2% of all treated conditions, and over half of these were ear infections (26.5% of total), and skin problems (9.6%). Specific diving illness was less common (10.4% of total – mostly ear barotrauma). Land-based illness/injury made up 49.8% of total encounters. The main categories were respiratory infections (11.7%), gastrointestinal (11.3%), orthopaedic/injury (8.1%), foot problems (7.0%), animal/insect bites (4.1%), eye infections (2.4%) and surgical or dental cases (1.7%). Only 3% of all cases were serious and required outside medical attention. The incidence of decompression illness was very low: 0.05 per 1,000 person-dives, (one per 20,000 dives).
Conclusions: The incidence of illness/injury on remote tropical diving expeditions is low and compares favourably with other expeditions. The marine environment was responsible for half of all cases seen. Planning of medical support for diving expeditions requires knowledge of specific diving-related illness such as barotrauma, and capability of treating medical conditions resulting from the aquatic environment.

Introduction

In recent years there has been an increasing trend towards travelling to remote and potentially hazardous places.[1] Remote expeditions, by their nature, entail greater risks and present unique logistical and medical challenges.[2–7] Risks vary considerably according to the environment and activity undertaken and each environment has specific hazards with which it is associated.[1,8–15] Little has been published to help individuals assess the risks of joining an expedition and almost nothing specific to the diving environment.

CORAL CAY CONSERVATION

Coral Cay Conservation (CCC) is a not-for-profit, non-government, international conservation organization that provides resources and education to help restore and manage coral reefs. Expedition staff submit weekly operational reports to CCC headquarters in London. These reports, written prospectively and reviewed retrospectively, form the basis of this study.

Coral Cay Conservation is used as a specific model here and the results of this study must be interpreted in context. On CCC expeditions, self-funded volunteers with recreational scuba training conduct scientific reef surveys. They dive up to six days per week in tropical waters with an aim to establishing protected marine areas that are locally sustainable. Volunteers come from all walks of life and range in age between 16 and 70 years. Anecdotally, the majority are university leavers or gap-year students. The expedition staff (also volunteers) usually comprises an expedition leader, scuba instructor, medical officer and one or more scientific officers. On occasions staff members fulfill multiple roles.

Projects are invited into host third-world countries. They aim to be largely self-contained and to leave a minimal environmental footprint. Basic amenities are crude. Power, fresh water, refrigeration and mainland access are often limited. Suitably qualified locals are employed as cooks, boat drivers and compressor handlers. Expedition members are fed communally, share chores and live on land in dormitory-style accommodation. Measures to protect participants from sun exposure, mosquito-borne infections, foot injuries,

Table 1
Coral Cay Conservation standard no-stop bottom times and maximum depths

	Standard profiles				Computer dives	Night dives
Maximum depth (msw)	18	20	25	30	30	12
Maximum no-stop bottom time (min)	37	29	20	14	37	37
Maximum surface-to-surface time (min)	43	35	26	21	43	43

dehydration, food poisoning, ear infections, diving diseases, alcohol excesses and sexually transmitted diseases are strongly encouraged along with adequate pre-expedition medical preparation and travel advice.

Prior to any new project, CCC officers undertake risk assessments of all new activities and sites. For risk management purposes, CCC defines 'remote' as within one hour of ideal urgent evacuation to the nearest recompression facility. Dive boats carry demand-valve oxygen and first-aid kits. Expedition bases have a minimum 24-hour oxygen supply and carry comprehensive medical stores, including chest drains, procedure kits, resuscitation drugs and intravenous antibiotics.

A conservative set of diving limits and standards are used to minimize decompression risk (Table 1). Strict rules enforce safety-conscious diving practice and one off-gassing day is required each week. Reverse profile diving is forbidden and dive computers are used primarily as depth-time meters. Maximum bottom time is limited to 37 minutes and depth to 30 metres' sea water (msw). Divers must prove qualification to minimum advanced open water level and demonstrate buoyancy competency. Novice divers are trained on site using PADI training systems and tables. Fitness to dive is screened in advance by a qualified diving medicine specialist. Divers are required to carry travel insurance that covers scuba activity.

Coral Cay Conservation requires a doctor on site for diving to proceed. The doctor attends the medical needs of all expedition members and also shares responsibility for public health issues, ensuring adequate fresh water and oxygen supply and maintaining the medical inventory kept on site. Each new post-in is asked to familiarise themselves with local recompression and hospital facilities and check evacuation plans already in place. They should have a minimum of two years' postgraduate clinical experience and six months in emergency medicine. Doctors are strongly encouraged to attend an expedition medicine course and gain familiarity with diving-related illness. Communications are maintained with the UK such that the expedition doctors can seek support and advice from CCC headquarters and/or the Diving Diseases Research Centre, Plymouth.

Aims

An awareness of likely presentations, both land and sea-based, is essential to allow advanced planning of medical support and equipment. The aims of this study are:

1 to define what the medical officer should be prepared to encounter on a remote tropical conservation diving expedition to a third-world country;
2 to compare these findings with other styles of expeditions to see what role the marine environment plays in aetiology, and
3 to formulate a strategy of medical risk management for future diving expeditions of a similar nature.

Methods

The research proposal was submitted to the Research and Development Co-ordinator of the Whipps Cross University National Health Service Hospital Trust. It was determined that ethical approval from the external independent NHS research ethics committee was not required. A single observer (KER) reviewed and interpreted the weekly reports and sporadic incident forms received from all staff over seven project sites in three expedition countries over an 18-month period from January 2005 to June 2006. Reports were written prospectively on site and submitted by e-mail at or near the time of writing. They followed a set format where free-text comments were elicited to a series of prompts. For example, the medical officer responded to: introduction, general health, hygiene, medical cases, areas of concern, supplies, requests and conclusions. Other staff provided information on local conditions and logistics. Reports are held electronically at CCC headquarters in London and data were transferred anonymously as text to an Excel spreadsheet.

Medical encounters were recorded in accordance with categories outlined by the Royal Geographical Society (RGS): gastrointestinal, medical, orthopaedic/injury, environmental, animal, foot and surgical/dental.[2,3] Medical encounters thus comprise all infective and skin conditions other than those pertaining to the gut or feet and all other medical complaints. All traumatic events were included in the orthopaedic/injury category, unless they related to feet. All marine animal encounters were listed under the animal category regardless of body site or mechanism of injury. The environmental category included heat-related illness and all diving-specific conditions. Unlike the RGS papers, eye infections were included in the medical rather than surgical/dental category.

Illness and injury were further subdivided according to

severity. Severity was defined as

- *minor* when the medical kit was opened but the participant continued with expedition tasks
- *intermediate* when significant enough to necessitate rest from expedition tasks without requiring outside help and
- *serious* if it resulted in a participant leaving the expedition, or their evacuation, hospital admission or death.

As diving was the primary expedition focus, severity was largely defined by time off diving and, where available, this information was recorded. Data on personnel involved, treatments administered, local events, weather conditions, water resources and sanitation issues were also recorded. No attempt was made to interpret uncertain diagnoses.

Data are presented graphically and using simple descriptive statistics. Medical events were calculated to determine incidence per 1,000 expedition-person-days (EPD), an EPD being one person on one expedition for one day. EPDs were calculated for all personnel at all sites over the entire study period, using CCC database figures for volunteers and weekly reports for staff members. Diving incidence was calculated per 1,000 person-dives, a person-dive being one person doing one dive. There were no data available on dives completed, therefore numbers of dives had to be estimated. On the advice of CCC senior staff this was done conservatively at 7 per diver per week out of a possible total of 13 dives per week. This allowed person-dives to be calculated directly from expedition-person-days.

Results

DATA SET

Between January 2005 and June 2006, over seven expedition sites in three countries, a total of 26,522 EPD were recorded. Data yielded 540 separate medical encounters, 20.4 per 1,000 EPD. Reports were available for 82.6% of all reporting weeks, thus medical encounter rates may have been underestimated by up to 20%. Egypt submitted 100% of reports showing 27 medical encounters for 720 EPD, 37.5 per 1,000 EPD. The Philippines had 263 presentations over 9,905 EPD, 26.6 per 1,000 EPD, with 82.6% of reports available for review. In Fiji 81.2% of reports revealed that 250 people sought medical attention in 15,897 EPD, 15.7 per 1,000 EPD.

MEDICAL CATEGORIES

The medical category dominated presentations with 282 out of the total of 540 (52.2%). Of these 143 cases (26.5% of all encounters) were for ear infections, 63 (11.7%) respiratory tract infections and 52 (9.6%) problems with skin. Sixty-seven incidents (12.4%) fell into the environmental category. There were 61 cases (11.3%) of gastrointestinal upset, 44 incidents (8.1%) of minor trauma or musculoskeletal disruption, and 38 problems (7.0%) with feet, many of which were slow to heal. Overall, animal encounters totalled 37 cases (6.9%). Only 9 cases (1.7%) fell into the surgical/dental category. Figure 1 compares the various medical category encounter rates per 1,000 EPD for the three countries.

Volunteers were affected in 447 cases (82.8%), expedition staff in 61 cases (11.3%) and local employees in 28 cases (5.2%). Four others also sought medical attention. If not clearly stated, the patient was assumed to be a volunteer, hence this category is probably over-represented. Between two and six expedition staff and three or four local staff were located at each site. Volunteer numbers varied between and within sites. Ranges (and averages) included: Fiji 6 to 35 (17), Red Sea 4 to 8 (6), Philippines 0 to 25 (10).

SEVERITY OF PRESENTATION

The severity of presentation was documented in 62.4% of cases. Figure 2 shows the percentage of cases falling into each category. Prescribed rest from diving could extend from

Figure 1
The medical category encounter rates per 1,000 expedition-person-days for the Coral Cay Conservation expeditions to the Red Sea, Fiji and the Phillipines and overall

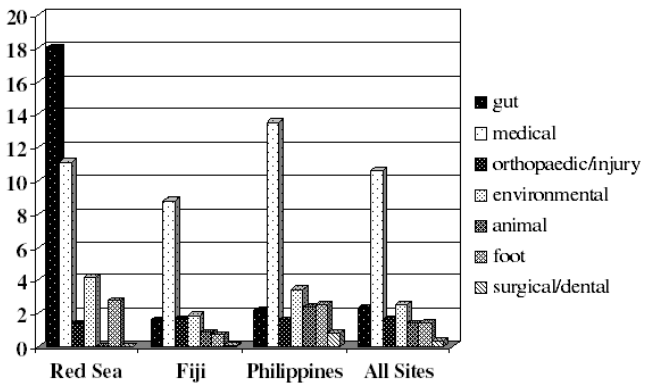
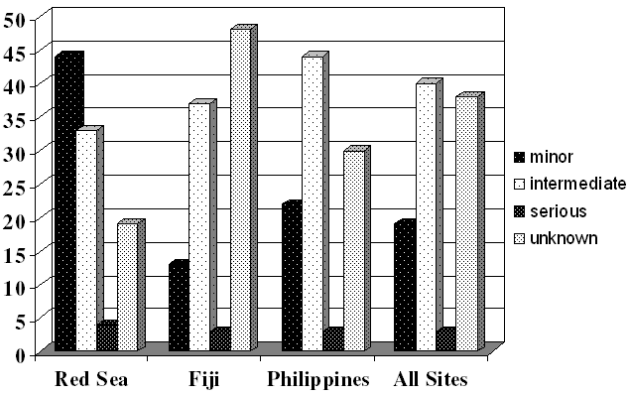


Figure 2
The percentage of cases falling into each severity category of presentation for Coral Cay Conservation expeditions to the Red Sea, Fiji and the Phillipines and overall



one dive to one month, but was most likely to last between one and five days. If time off diving was not documented, extrapolation from similar presentations suggested a predominance of intermediate conditions. Overall, 349 cases (64.6%) needed some time out of the water and 173 (32.0%) were able to continue diving. There were 17 cases (3.1%) that needed outside medical attention or left the expedition and one (0.2%) where diagnosis and severity remain unknown/could not be determined.

SERIOUS PRESENTATIONS

One diver who presented with numbness on her back two hours after an unprovocative dive to 12.9 msw for 38 minutes was evacuated to a chamber as a presumed case of decompression sickness. Full resolution of symptoms occurred following administration of a single US Navy Treatment Table 6 and the participant made an uneventful return to expedition diving one month later. One volunteer with persistent vomiting and diarrhoea was admitted briefly to hospital for intravenous rehydration. Three volunteers (one with a perforated tympanic membrane) chose to leave the expedition early because of recurrent ear problems. Three others sought outside medical review for a persistent ear condition, a skin complaint and a dental problem respectively. One volunteer was dismissed for inappropriate behaviour whilst inebriated. One was assessed in hospital after a series of collapses that were eventually diagnosed as an allergic reaction. Another was investigated locally for severe abdominal pain and repatriated home where he was later diagnosed with an undocumented form of cancer. One was reviewed for an incident that probably represented salt-water aspiration syndrome (SWAS). One volunteer needed an X-ray to confirm his ankle was only sprained whilst one staff member was treated with crutches and rest for two hairline fractures in his lower leg. One local staff member amputated a finger using power tools. He attended a local hospital where the wounds were debrided and closed. Two volunteers sought outside medical attention for reasons that were not made clear in the reports; however, neither of these required urgent evacuation.

PRESENTING COMPLAINTS

Figure 3 shows a more detailed breakdown of presenting complaints, organised to reflect likely aetiology. The aquatic environment was responsible for 50.2% of all treated conditions while land based illness/injury made up 48.8% of total encounters. A total of 215 episodes could be attributed to the marine environment; 39.8% of all medical encounters or 8.1 per 1,000 EPD. The incidence of diving presentations is given in Table 2. Diving incidents totalled 56; 10.4% or 2.1 per 1,000 EPD. An estimation of 21,951 person-dives was made giving a calculated incidence of decompression illness of 0.05 per 1,000 person-dives. The case of possible decompression illness, when retrospectively analysed, probably represents a transient neurapraxia of the lateral cutaneous nerve of the thigh.

Table 2
Incidence of diving presentations by number, and calculated per 1,000 person-dives

Presentations	Number	Incidence
Rapid ascent	1	0.05
Diving incident	1	0.05
Decompression illness	1	0.05
Possible decompression illness	1	0.05
Diver's ear	9	0.48
Middle ear barotrauma	31	1.41
Tympanic membrane perforation	1	0.05
Outer ear barotrauma	1	0.05
Reverse ear barotrauma	1	0.05
Sinus barotrauma	3	0.14
Reverse sinus barotrauma	1	0.05
Sinus unspecified	2	0.09
Barodontalgia	1	0.05
Odontocrexis	1	0.05
Salt-water aspiration syndrome	1	0.05
Total	**56**	**2.55**

There were 186 complaints relating to the ears. Middle ear infections and barotrauma clearly dominate the figures (Table 3). While ear conditions were generally poorly diagnosed, it is interesting to note that the vast majority of cases of otitis externa were unilateral.

TREATMENTS

Treatments were poorly documented, but the majority were provided from on-site medical kits. In all, 686 treatments were reported and those used most commonly (i.e., 1% or more of those documented) are shown in Table 4. Oxygen was required on only four occasions over 18 months. Intravenous fluids and nebulised medications were used on one occasion each. Resuscitation drugs and intravenous antibiotics were not used at all.

GEOGRAPHIC DIFFERENCES IN PRESENTATION

Specific illness patterns were noted for individual sites. The Red Sea project was dominated by gastrointestinal illness owing to an episode of food poisoning affecting all participants. This was the only site where CCC did not control the kitchens. Several expedition staff suffered foot lacerations in Egypt that failed to heal for the duration of their stay. There were no cases of ear infection that prevented expedition members from diving in the Red Sea. Increased salinity was postulated as the reason. In comparison, infective ear conditions clearly dominated at the Fiji (35%) and Philippines (37%) sites. A trend was noted of increased prevalence when precipitation followed long dry spells. The Philippines site, which had greater access to water for washing, had very few skin problems. However, expedition

members suffered plagues of mosquitoes after rainfall, possibly owing to standing pools of water on a poorly designed, flat and leaking roof. At the Ravinaki base in Fiji a superficial skin infection of unknown aetiology spread virulently, seeming to coincide with rainfall when the septic tanks were full. This condition was so prevalent it earned itself the nickname "the Rav ming".

Discussion

In 26,522 EPD only 540 medical encounters were reported. Ninety-seven per cent of these presentations fell into the minor or intermediate categories and on-site medical personnel had sufficient skills and equipment to deal with the situation. The breakdown of severity for CCC is similar

Figure 3
Breakdown of medical encounters by number and percentage arranged according to likely aetiology

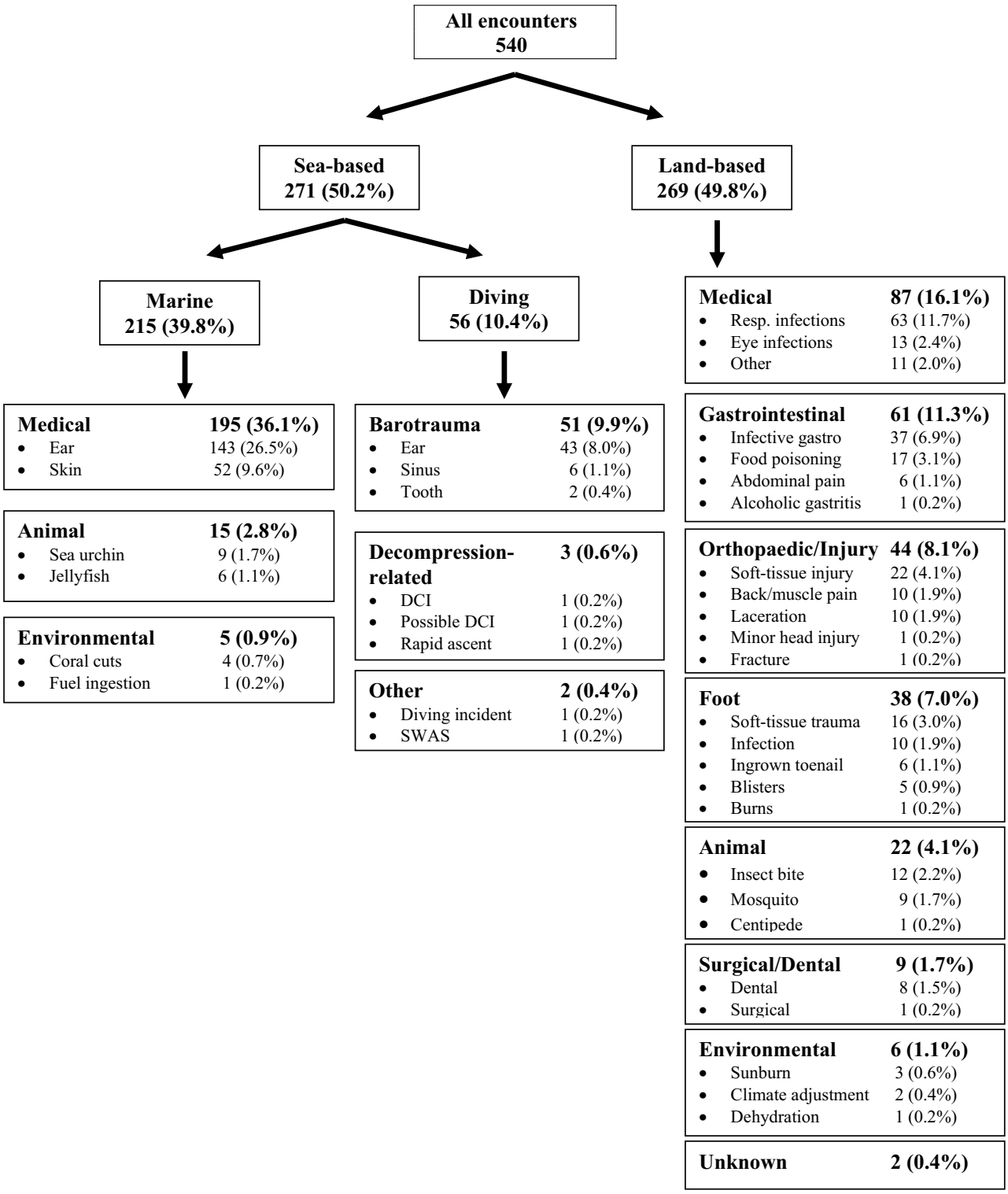


Table 3
Reported diagnoses for ear problems related to diving by number of cases, percentage of total presentations and incidence per 1,000 dives
(**MEBT** – middle ear barotrauma)

All ear conditions	Cases	%	Incidence
Total	**186**	**34.4**	**8.47**
Otitis externa	67	12.4	3.05
Ear – unspecified	46	8.5	2.10
MEBT	31	5.7	1.41
Otitis unspecified	14	2.6	0.64
Diver's ear	9	1.6	0.41
Otitis externa (bilateral)	8	1.5	0.36
Ear – impacted wax	4	0.7	0.18
Otitis media	2	0.4	0.09
Otitis mixed	1	0.2	0.05
Ear – water retention	1	0.2	0.05
MEBT with perforation	1	0.2	0.05
Outer ear barotrauma	1	0.2	0.05
Reverse ear barotrauma	1	0.2	0.05

for serious but almost reversed for minor and intermediate conditions when compared with the RGS data.[2,3] This finding is consistent with what was expected considering the nature of scuba diving. Only 17 cases (3.1%) required outside medical assistance or resulted in participants leaving the expedition and very few of the serious conditions were truly severe. Only one participant was evacuated by urgent means and with hindsight this was probably unnecessary. Thus, participation in a remote conservation diving expedition is not a high-risk activity.

Table 4
Treatments most commonly prescribed (1% or more of those documented) during Coral Cay Expeditions

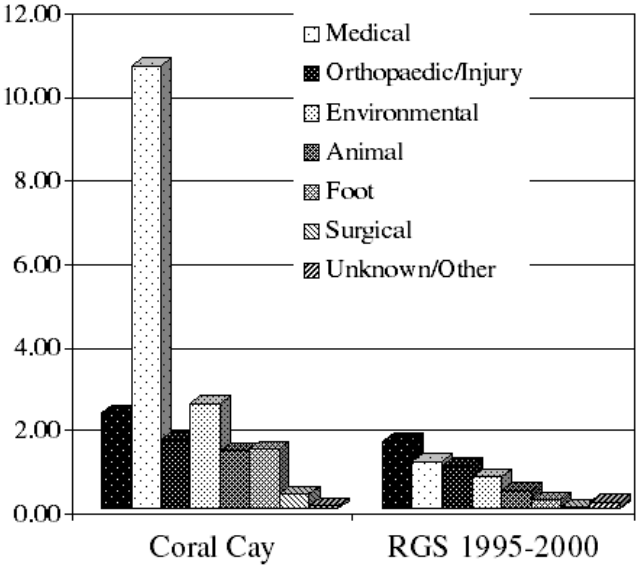
Treatment	Percentage
Ear drops	15.5
Oral antibiotics	11.7
Rest from diving	8.9
Oral decongestants	8.6
Wound-dressing kit	7.8
Wound cleaning	5.7
NSAIDS	5.7
Topical creams	5.2
Rest	5.1
Oral fluids	3.9
Oral antihistamines	3.8
Minor procedure instruments	3.8
Oral analgesia	3.4
Common sense advice	3.0
Betadine	2.6
Minor procedure	2.3
Wound dressing	1.7
Minor injuries treatment	1.5
Eye drops	1.3
Hygiene advice	1.2
Antacid	1.0

A limited body of expedition data exists and comparisons are made difficult by inconsistent denominators.[5,16–25] In addition, study populations, expedition tasks, geographical settings and reporting methods vary widely. Some consistent trends, however, can be seen across many expedition types. The RGS framework was chosen as a template for this paper to allow direct comparison to the largest body of published data on expedition medicine encounters.[2,3]

CCC data show incidence rates that are considerably higher than those of the RGS data (Figure 4). There are several possible explanations for this, including the shortcomings of retrospective surveys. However, it may simply be that diving expeditions are associated with higher rates of morbidity because of constant immersion in warm, tropical water. In the CCC data, the incidence of ear presentations alone is greater than that for all presentations in the RGS studies. Figure 4 shows the incidence rates per 1,000 EPD for these CCC data and those for RGS-registered expeditions between 1995 and 2000.[2,3]

A comparison can be made to other events in which young people commonly participate. A medical incident rate of 10 per 1,000 per day has been reported at a scout camp, 17 per 1,000 at a rock festival and 28 per 1,000 running a marathon.[26] In this context, the relative risk of medical misadventure on diving expeditions, at 20.4 encounters per 1,000 EPD is not excessive.

Figure 4
Incidence per 1,000 expedition-person-days by medical category forCoral Cay Conservation expeditions compared with those of the Royal Geographical Society (RGS)



This paper has a number of limitations. Shortcomings in data and methodology could lead to underestimation of incident rates by up to 20%. The experience and reporting thresholds varied considerably between doctors. Data may well under-represent minor medical problems and misdiagnose diving-related illnesses. However, the CCC data do provide a broad overview of likely illness patterns that will occur during a remote tropical diving expedition.

The present study has several factors in its favour when compared with other published data. While reviewed retrospectively, the data on medical incidents were collected and submitted by medically qualified personnel at or near the time of occurrence. Most other studies, including those of the Royal Geographical Society, used a retrospective survey completed by the expedition leader up to 12 months after the expedition date. In addition, response rates were generally poor (around 30%), whereas CCC data were available for 82.6% of all possible reporting weeks and have provided a large database.

A literature search was unable to identify other studies that were specific to diving or the coastal environment. Figures for these activities were infrequently included in papers reporting on expeditions of all types.[2,3] Many of the studies identified death rates for various activities, rather than the less serious medical incidents.[9,10,16,19,27] Only three studies documented medical cases at the time of occurrence.[4–6] No information on EPD was provided and the definition of an incident – an illness or injury that requires more than simple first aid – prevented any direct comparison with the present study.

In many studies of expedition health, gastroenteritis is the most commonly encountered condition, varying from 26 to 36 per cent of total incidents.[4–6,18,22] This is not the case in the CCC data, where gut conditions contributed only 11% to the total; however, the rate of 2.72 per 1,000 EPD is consistent with RGS figures and those reported by Johnson on walking tours (1.99) and expeditions (3.28).[19] Respiratory symptoms in most studies range from 11 to 21 per cent.[4–6,18,23,28] In the CCC data respiratory tract infections accounted for 11.7% of all presentations. Many studies show that orthopaedic conditions and traumatic injuries play a much greater role than seen here. Injury rates range from 13 to 50 per cent and vary greatly depending on the inherent risk of expedition activities.[2–4,16,20,21,25,28,29]

Animal encounters in RGS papers accounted for 8% of presentations, similar to the 7% seen in CCC data.[2,3] Insect bites and stings dominated in both studies, although sea urchin spine injuries were also troublesome. Foot problems made up a similar percentage of the total. Presentations of this type should be avoidable if participants adhered to basic preventative measures, such as wearing shoes and long, loose garments, and using insect repellents and mosquito nets. Surgical and dental presentations are consistently low across all studies reviewed.

Much has been published on the incidence of decompression illness across various demographics of diving populations.[30,31] In the CCC data, the estimated incidence cannot be known accurately as only one possible case was treated. In most reports, the denominator remains in question. Incidence rates of DCI quoted per 1,000 dives vary from 0.04 for scientific divers to 0.25–0.49 serious incidents for wreck divers in cold waters.[32,33] The rate of DCI in recreationally trained divers undertaking scientific surveys for CCC according to strict diving standards would appear to be close to that of employed scientific divers. CCC has been criticised in the past for having such strict and conservative diving practices. These figures, however, would seem to justify both their existence and their continued use, particularly given the remoteness of project sites from hyperbaric treatment facilities. Only five notable scuba incidents occurred during the study period. The single case of decompression illness would qualify as mild by the consensus definition published in workshop proceedings on management of mild or marginal decompression illness in remote locations.[34]

The diving expedition medical officer needs some knowledge of the treatment of diving injuries; however, medical conditions resulting from the marine environment were far more common. Some of the skin conditions may have originated on land, but were consistently worsened or failed to heal unless the participant abstained from diving and swimming. The single dominating feature of this study was ear conditions, which accounted for 34.5% of all presentations. Edmonds notes that "*although otitis externa occurs without indulging in aquatic activities, swimming increases the risk three to five fold",* and *"in divers, external ear infection is one of the most common and troublesome disorders encountered"*.[35] Taylor claims it is to be expected that aural barotrauma would be the most common cause of diving injury and this is so in the CCC data.[13] Doctors who deploy to a marine setting should be well equipped to diagnose, treat and implement preventative strategies for infective and pressure-related ear complaints. Antibiotics for treating ear infections, and equipment for performing ear examinations and toilets are essential.

However, common things occur commonly and all expedition medics should be prepared to deal with respiratory tract infections, gastroenteritis, minor trauma and foot injuries. They should carry a good supply of oral and topical antibiotics, rehydration solutions, decongestants, analgesics, minor procedure instruments, wound dressings and skin creams. Time off diving will be recommended for most presentations.

If suitable locality- and activity-specific precautions are taken and travel medicine advice sought well in advance of departure, life-threatening medical conditions, mosquito-borne infections, heat exhaustion, major trauma and decompression illness should be rare. However, due to the serious nature of these conditions and the remoteness of the setting, consideration needs to be given to providing oxygen

and resuscitation equipment despite the logistical challenges involved. It would seem prudent to plan routes of evacuation for all weather conditions and assess the standard of care in local hospitals and recompression facilities. This study highlights the importance of good pre-expedition planning and the need for further research on medical presentations encountered on remote diving expeditions.

Conclusions

The presenting complaints commonly seen on a remote tropical diving expedition include ear infections, gastroenteritis, respiratory tract infections, skin conditions, barotraumas and minor soft-tissue injuries. Medical encounters are consistent with those predicted by the findings of terrestrial expeditions, with the addition of conditions attributable to the aquatic setting. The marine environment plays a dominant role in aetiology and is arguably responsible for half of all cases. The relative risk of joining a remote tropical diving expedition is low and comparable to leisure activities in which young people commonly participate. Doctors deployed to a remote diving expedition should carry good supplies of oral and topical antibiotics, ear drops, nasal decongestants, rehydration solutions, topical creams, analgesics and wound-dressing kits. They should also give serious consideration to providing oxygen and resuscitation equipment.

Acknowledgements

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Karen Elizabeth Richardson, MB, BS(Hons I), PGDipMedSc(Hons), is currently a medical officer at the Submarine and Underwater Medicine Unit,
HMAS Penguin,
Middle Head Road,
Balmoral, NSW 2088,
Australia
Phone: *+61-(0)2-9960-0572*
Fax: *+61-(0)2-9960-4435*
E-mail: *<karen.richardson@mac.com>*

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