Review articles

Lost at sea: the medicine, physiology and psychology of prolonged immersion

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Abstract

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In most countries, immersion represents the second most common cause of accidental death in children and the third in adults. Between 2010 and 2013, 561 deaths worldwide involving recreational divers were recorded by the Divers Alert Network. Consequently, there is no room for complacency when diving. Being lost at sea is a diver's worst nightmare. In 2006, a diver was lost at sea off the coast of New Zealand for 75 hours. It is unprecedented that, after such a long time immersed in temperate (16–17˚C) waters, he was found and survived. His case is presented and utilised to illustrate the many physiological and psychological factors involved in prolonged immersion and what might determine survival under such circumstances. We also briefly review options for enhancing diver location at sea and a few issues related to search and rescue operations are discussed.

Introduction

In most countries, immersion represents the second most common cause of accidental death in children and the third in adults.[1] World Health Organization (WHO) statistics report almost 375,000 immersion deaths each year; the actual figure worldwide is probably four or five times as high.[2] Of the water-related deaths, deaths of divers are uncommon; however, the Divers Alert Network (DAN) recorded 561 deaths worldwide involving recreational divers between 2010 and 2013.[3] Consequently, there is no room for complacency when diving. The harsh environment that divers expose themselves to can only be temporary, it is technology which allows humans to explore underwater environments for longer than a breath hold and enter such potentially hazardous surroundings.

Following immersion in cold water (there is no definitive definition of cold, in this context we include any water temperature below thermoneutrality (35˚C water temperature); the rate of cooling will depend on many factors). The surface interval between dives allows not only for de-gassing but also for rewarming and fluid and energy balance. It is this return to homeostasis which ensures survival following immersion. There is a preoccupation that many in-water deaths are ascribed to hypothermia. However, various factors contribute to the rate of cooling and death as a result of cold water immersion including cold shock, physical incapacitation leading to swimming cessation, drowning, hypothermia and dehydration.

A number of media reports have described incidents when divers have become separated from their boats and have endured prolonged immersions, some successfully rescued, others not.[4–8] Perhaps the most poignant of these was the death of six divers who went missing off Peleliu in the Republic of Palau; three bodies were recovered.[9] Over two days, one diver recorded a series of notes on her waterproof slate, which told of multiple sightings of vessels and planes – "*we can see you searching, but you can't see us*."[9] The chances of finding the person alive diminish with each passing hour and a successful rescue relies upon the physiology and psychology of the diver, good use of available equipment, the expertise and bravery of search and rescue services and sometimes luck.

In February 2006, a diver was lost at sea off the coast of New Zealand for 75 hours. It is unprecedented that after such a long time immersed in temperate waters he was found and survived. It is also of great value that he wrote a book about his experience,[10] and allows such candour to learn from errors made and highlight good decision-making or survival strategies used to hopefully prevent further accidents. His case exemplifies and illustrates many aspects of prolonged immersion that 'bought him enough time to be rescued'. In this review, we discuss these under two main headings – physiological and psychological – as well as summarising some issues related to search and rescue (SAR) of lost divers. We are grateful to Robert Hewitt for permission to access his medical records and to identify him in this publication – *me te mihi nui mo o manaakitanga* ("*with deepest thanks for generously allowing his experience to help others*").

Case report

On the afternoon of 09 February 2006, the media reported a missing diver had been found. What made this remarkable was that he had been missing at sea for over three days in 16−17°C water. The patient was an experienced navy diving instructor of Maori descent (of the Ngati Kahungunu 'iwi' [tribe]) participating in a recreational boat dive at Mana Island, off the southern end of the North Island of New Zealand, close to Cook Strait. Rob wore a bespoke, well-fitting, 5 mm 'Farmer John'-style neoprene wetsuit, hood and gloves. When he surfaced he was several hundred metres away from the boat which had relocated to pick up other divers as he drifted away in a strong current. He remained floating on the surface for the next 75 hours. He had been diving for crayfish which he ate along with several 'kina' (sea urchin, the roe of which is considered a delicacy by Maori) over this time. Other than the water content of this food (approx. 80%), he had nothing to drink except occasional raindrops collected in his mask and wetsuit dive jacket. He had attempted to use his dive jacket to protect himself from the sun; however, an hour or so before he was discovered, his jacket had been washed away. On that final day, he described increasing confusion and disorientation, but said he was still passing urine twice a day until found. He was discovered floating not far from where he was last seen, dressed in his wet suit trousers, hallucinating but alive. During the intervening three days, he had been caught in the strong tides that sweep unpredictably through Cook Strait.[11] It was estimated that he had drifted back and forth for approximately 60 km. During that time, an intensive air, land and sea search had been fruitless and it was only by chance that he was spotted by Navy diving friends.

He was recovered, conscious, at 1602 h into a rigid inflatable boat and then transferred to a larger vessel where he was hosed down with fresh water to get rid of the sea lice on his body. He was then wrapped in a space blanket and woollen blankets and given 1.5 L of warm fluids orally without nausea or adverse effects. Initial vital signs recorded by the ambulance team at 1719 h were Glasgow Coma Scale 15, pulse 90 beats per min, blood pressure (BP) 136/48 mmHg, respiratory rate 18 breaths per min (bpm), aural temperature 35.7°C, oxygen saturation 100% and blood glucose 5.1 mmol·L^{-1}.

He was evacuated by helicopter to the Emergency Department of Wellington Public Hospital, a tertiary centre. On admission, he was conscious, fully orientated, and in very good spirits. His main complaint was of discomfort behind his knees for which he received paracetamol 1 g and codeine phosphate 60 mg orally. He was very sunburnt to the face and lips, with skin markedly erythematous but not blistered, and lips swollen and peeling. His temperature at 1814 h was now 36.6°C, heart rate (HR) 97 beats per minute, supine BP 123/36 mmHg, jugular venous pressure -1 cm and respiratory rate 22 bpm. He had mild abrasions behind both knees and in his groins. His initial examination was otherwise unremarkable. An electrocardiogram (ECG) was normal except for mild sinus tachycardia. He received one litre of normal saline (0.9S) over one hour, with repeat vital signs of HR 103 per min, and BP 139/61. A further 5 L 0.9S were infused over the next 14 h.

Initial investigations were haemoglobin 152 g·L^{-1}; white blood cell count 17.0 (x10^9·L^{-1}, normal range (n.r.) 4–11); neutrophils 14.2 (x10^9·L^{-1}, n.r. 2–7.5); platelets 242 (x10^9·L^{-1}, n.r. 150–500). All biochemical parameters, including glucose, creatinine, liver function tests and acid-base balance were within the normal range except for a mildly raised urea and magnesium. Urinalysis was positive for ketones, and a trace of lysed red cells. An initial creatinine kinase (CK)-MB isoenzyme (looking for evidence of rhabdomyosis) was elevated at 18.8 iu·L^{-1} (normal range: 0–6.6 iu·L^{-1}), whilst a repeat total CK the next morning was 942 iu·L^{-1} (normal range: 60−174 iu·L^{-1}), evidence of rhabdomyosis.

He was given free oral food and fluids and was mobilizing independently the next morning, although he felt slightly unsteady on his feet. His blood pressure remained stable, and heart rate had normalized to 80 beats per min. Repeat electrolytes were within the normal range. His heels had developed some erythema, thought to be early cellulitis, so he was commenced on oral flucloxacillin 500 mg orally four times daily and discharged into the care of relatives.

He later presented to his general practitioner with skin breakdown over the Achilles tendons bilaterally, with positive culture of *E Coli*, Group B heamolytic *Streptococcus* and a Gram-negative bacillus. He was referred to the plastic surgical department at Hutt Hospital with a 1.5 x 0.5 cm area of sloughed skin over the left Achilles tendon region, and a 1.5 x 5 cm wound with a necrotic base over the right Achilles tendon. Thirteen days post rescue he underwent bilateral debridement of his ankles and a split skin graft was applied over the right Achilles region, from which he made an uneventful recovery and was discharged three days post surgery. On outpatient review, all wounds were healing well.

The patient went on to make a full recovery, retired from the Navy, wrote a book on his experience[10] and became an ambassador for water safety promotion, especially amongst the Maori community in New Zealand.

Physiological responses to prolonged immersion

There are four phases of cold water immersion, from the initial responses known as 'cold shock', through to peripheral muscle cooling, progressive deep body cooling and finally the circum-rescue phase.[12] Each of these stages of immersion in cold water can be a precursor to or a cause of death given the right combination of factors and are discussed below in terms of Rob Hewitt's survival.

COLD SHOCK

Cooling occurs sequentially through the body tissues: firstly, the skin and cutaneous cold receptors respond to the superficial cooling upon initial immersion, which results in the 'cold shock response', consisting of an inspiratory gasp, uncontrollable hyperventilation, hypertension and increased cardiac workload.[13] In those not able to control their breathing, they may inhale a lethal dose of water to drown,[14] whilst in those with pre-existing cardiac conditions, the increased cardiac workload could result in cardiac arrhythmias possibly leading to ventricular fibrillation.[12] For those unaccustomed to cold water immersion, these responses peak in the first 30 s and gradually diminish within the first few minutes of immersion.[13] In the wet-suited diver, the initial impact of immersion in cold water is mitigated and these physiological responses are also reduced in those who are aerobically fit[15] and repeatedly exposed (habituated) to cold water;[16] repeated exposure (Rob had completed over 1,000 dives in a range of water temperatures) would have habituated him to cold water.

PERIPHERAL MUSCLE COOLING

After cooling the skin, the next body tissues to cool are peripheral muscles and superficial nerves (second phase of immersion). Cooling of these tissues can impair physical performance, reducing dexterity and consequently the ability to perform manual tasks crucial for survival, such as tightening straps or equipment or even coordinate swimming. Swim failure can occur without central hypothermia, and has been attributed to peripheral muscle cooling.[17] It has been found that maximum muscle power falls by 3% for every degree reduction in muscle temperature.[18] Rob made several attempts to self-rescue by finning towards the boat or land; these ended in either fatigue or apparent loss of consciousness (he writes that he passed out several times from the effort of swimming[10]). He initially considered removing his buoyancy compensator (BCD) to allow him to fin at a faster pace; had he done so, once unconscious or too fatigued to swim, he may have drowned. Instead, the BCD maintained his airway clear of the water which allowed him to rest and recover from the exhaustive exercise without the need to swim. At night he blew it up fully to cradle his head and neck and to raise himself as high as possible in the water. Keeping his BCD extended his survival so that a successful rescue could be made at a later point.

DEEP BODY COOLING

Deep body temperature regulation is a balancing act between inputs that cool the body (for example cold water, wind and waves[19]) and those that can increase heat production (exercise and shivering) or maintain heat storage (insulation from clothing, unperfused muscle and body fat). The temperature and duration of immersion endured in 17°C waters is likely to result in a fall in deep body temperature (from approximately 37°C) and may result in hypothermia (a deep body temperature below 35°C, immersion phase three[12]). Hypothermia affects cellular metabolism, neural activity and blood flow. The early signs and symptoms of hypothermia, confusion, introversion and disorientation occur with a deep body temperature of about 35°C.[20] Rob describes periods which demonstrate his confused and disorientated state, particularly during the third night and into the morning of the fourth day.[10] This may be indicative of deep body cooling and had cooling continued, loss of consciousness would occur at a temperature of approximately 30–32°C and death at a temperature below 28°C, especially if a severe dysrhythmia develops.[20]

His first recorded body temperature was 35.7°C, by which time he was wrapped in warm coverings and a space blanket and had received warm oral fluids. This suggests that he was able to generate and store sufficient heat to defend his deep body temperature above the level considered to be hypothermic. The initial temperatures taken during rescue were measured using an infrared tympanic thermometer (ITT), similar to those used to indicate fever in paediatric patients. In conditions where the auditory canal and tympanic membrane may have been exposed to cold water, these devices provide deep body temperature measurements that are on average 1°C lower than more invasive, but accurate deep body temperature measurements, e.g., rectal or oesophageal. Consequently, his deep body temperature may have been warmer than recorded. In light of basic research, ITT should be considered unreliable in recording accurate deep body temperatures in casualties immersed in cold water, and should not be used for clinical decision-making.[21,22]

Survival time and search duration

Advice about search duration is based upon the estimation of median survival time. For lightly clothed swimmers in water temperatures of 15°C, similar to that experienced by Rob, the 50% survival time would be 4.8–7.7 hours, depending on the model used.[23] At these water temperatures, individual differences and protective clothing are a great source of variation in cooling rates and, thus, survival during cold water immersion. Consequently, if the SARs are aware of the victims' characteristics, level of protective clothing or provisions, these predicted survival times may be extended by up to ten times in the hope of finding survivors, unless conditions deteriorate.[23] In this case, they were aware of Rob's physical characteristics and his clothing and equipment; this knowledge extends the predicted survival time[24] and consequently the duration of the search.

Physical characteristics

Rob is a large muscular male, 1.8 m tall, weighing 100 kg at the time of the incident. These factors combine to make an ideal body type for heat conservation, a large mass and smaller surface area to mass ratio, thus his deep body would cool more slowly than lighter, leaner people with a larger surface area to mass ratio.[24] In addition, for much of the time Rob adopted the foetal posture to minimise heat loss, this is sometimes called the heat escape lessening posture (HELP) and has been shown to reduce the rate of cooling and extend survival time in cold water.[25] It is also estimated that deep body temperature falls in men by approximately $0.1^{\circ}C{\cdot}h^{-1}$ less with each 1% increase in body fat.[26] Consequently, a person such as Rob with a proportion of subcutaneous fat has a smaller change in deep body temperature than a lean person. Furthermore when not exercising, peripheral muscles would be poorly perfused, acting to further insulate the deep body from a fall in temperature.[27] When exercising, the insulative contribution of muscle is reduced, due to increased blood flow to the muscles, facilitating heat transfer away from the deep body tissues to the superficial tissues and then into the water.[27] His high level of aerobic fitness would enable him to generate heat for prolonged periods of time (by exercising and shivering) and his body fat and large amount of non-perfused muscle would act to insulate the body from cooling and retain the heat produced, extending his survival in cold water.

Protective clothing

Rob's well-fitting 5 mm Farmer John-style neoprene wetsuit, hood and gloves would give additional buoyancy and act as an additional insulative layer. The wetsuit traps a boundary layer of water next to the skin which could be warmed,[28] thus reducing the thermal gradients for heat loss between the deep body, skin and water. Consequently, exercising whilst wearing a wetsuit reduces deep body cooling compared to non-wet-suited immersions, slowing the decline into hypothermia.[29] Black wetsuits may help to absorb heat radiated from the sun and may slow deep body cooling (Rob reported a sense of rewarming during sunny spells[10]). Wearing a wetsuit also helps to protect covered areas from skin damage caused by prolonged exposure to the sun; unprotected areas such as the face can become severely blistered and burned.

HYDRATION AND NUTRITION

As well as appropriate physical characteristics and protective clothing to limit cooling, long-term survival is also dependent upon nutrition and hydration. Sea water has a high salt concentration, approximately 3.5% sodium chloride in solution.[12] If sea water is ingested, it will add to cellular dehydration through osmosis, drawing intracellular water into the stomach and intestine, this can result in diarrhoea and increases the volume of urine produced to remove the excess salt; thus hastening dehydration.[12] During rough seas, Rob accidentally ingested sea water and subsequently vomited. Hydrostatic squeeze, peripheral vasoconstriction due to immersion in cold[30] and wetsuit squeeze[31] can also contribute to dehydration by increasing central blood volume which leads to increased diuresis; he reported that he continued to urinate despite his dehydrated state.

It is recommend that potable water should be conserved for the first day as most drunk in this period will be wasteful and lost as urine.[12] The delay in drinking stimulates hormone-mediated body water conservation pathways[32] and, thereafter, a greater quantity of fluid intake is retained. In addition, unless supplies of potable water are plentiful, they should be conserved and intake restricted to 500 ml a day.[12] Rob reported that, during periods of rainfall, he was able to collect rainwater in his mask and wetsuit jacket but this probably did not amount to even the minimum volume required. This combination of body water loss and lack of potable water made dehydration life threatening.

Unlike fluid consumption, starvation is far less of an imminent threat. Humans rely on energy to enable a wide variety of physiological and psychological functions. Once energy stores are depleted, fatigue, psychological impairment and body cooling set in when immersed in cold water. Consuming food increases metabolism and heat production, but requires an abundance of fresh water to excrete urea from protein metabolism.[33] Rob preserved his food supply for the first day before eating it. In hindsight, although he had planned to eke out what little he had, he admits this did not happen. The large bolus of protein whilst giving energy would hasten dehydration if potable water was not freely available. Limiting food consumption especially protein, whilst not a long-term survival plan, can assist with water conservation.[12]

CIRCUM-RESCUE PHASE

Rob's fight for survival did not end once he had been found. The circum-rescue phase, the fourth phase of water immersion, can result in collapse immediately before, during and after rescue.[34] Anticipation of imminent rescue can cause a reduction in sympathetic stimulation, reducing blood pressure and coronary perfusion resulting in cardiovascular instability.[12] Collapse during rescue can also occur after prolonged immersion (and hypovolaemia) whereby vertical lifting, sudden removal of the hydrostatic pressure, the reimposition of gravity on the body and impairment of baroreceptor reflexes (due to hypothermia) result in a blunted venous return, subsequently cardiac output and cerebral circulation collapse and a rapid loss of consciousness occurs.[34] The rescue services now routinely bring casualties on board in a horizontal posture, positioning the casualty to maintain cerebral blood flow and then give verbal encouragement to 'keep fighting for their lives' to prevent the reduction in sympathetic stimulation and its cascade.[12] These procedures were carefully followed by the rescue team. They were well aware that successful recovery from the water was not the end of this survival story, and that careful transportation and monitoring was required.

A further reason for careful treatment during rescue is to prevent skin damage from worsening. Percutaneous absorption occurs with prolonged water immersion.[35] This additional absorption of water by the skin does not improve systemic hydration status, but does lead to the breakdown of the skin and may occur more rapidly in sea water owing to its abrasive nature. Skin damage from salt water dermatitis and destruction of the stratum corneum results in breakdown of the 'waxy surface barrier' leading to maceration of the upper layers of the dermis and epidermis.[36] In Rob's case, the friction caused by his wetsuit and fins accelerated the destruction of the skin and, when found, his body was covered with sea lice feeding on his macerated skin, both of which would increase the opportunity for skin infections.

MEDICAL FOLLOW UP

Although his initial recovery was uneventful, high CK-MB levels were reported upon arrival in hospital and the following day, which were considered indicative of rhabdomyosis. Abnormally high CK-MB levels may be cardiac-related or provoked by prolonged bouts of exhaustive exercise;[37] in this case, exhaustive finning and shivering for prolonged periods of time. Troponin T assay was available and could have been used to diagnose pathological cardiac muscle damage even in the presence of significant skeletal muscle breakdown, but this was not considered to be indicated in this case.[38]

Psychological and behavioural responses

Rob's story is not only one of being bought time by his physiology and equipment, but also the psychological battles played out before separation from the boat, during his immersion and during recovery. His psychological responses during the incident match closely the psychodynamic model of core survivor behaviours observed during five specific phases of a life-threatening event: pre-impact, impact, recoil, rescue and post-trauma.[39,40]

PRE-IMPACT

The pre-impact phase incorporates the knowledge, training and relevant experience an individual possesses to support an adaptive survival response, e.g., emergency evacuation practice from a burning building, helicopter underwater escape training, etc. This knowledge, training and skill set establish a psychological state of preparedness for an emergency. The pre-impact phase can be subdivided into the *threat* and *warning* stages. In the threat stage the hazard is known but the risks are not compelling. During the warning stage, the danger is perceived although its full implications are not always appreciated.

Rob was a well-trained, professional and experienced Navy diver possessing a degree of underwater expertise exceeding that of the average sport diver. However, whilst acknowledging the inherent hazard in diving he perceived his personal risk to be lower than the actual risk, which led to his decision to dive alone rather than aborting his dive, joining another team or using a surface marker buoy. As indicated by the police search team leader, "*in some ways Rob almost contributed to his own demise. He took some short cuts*".[10]

IMPACT AND RECOIL

The impact phase occurs when a person realises that their life is under threat. The recoil phase begins once the immediate dangers have subsided and the survivor starts to show a gradual return of awareness and cognitive function although not always a full understanding of the predicament. The impact phase is usually sudden, violent and outside of the victim's control, although in some instances, such as in this case, it unfolds slowly and blurs psychologically into the recoil phase. During these impact and recoil phases, Rob evinced psychological coping behaviours common to those who find themselves in peril (e.g., prayer, thoughts of family and friends, planning, routines) although later he also demonstrated behaviours counter-indicated for survival, such as despair and suicidal ideation.

People and prayer

At various times Rob prayed to God and to those personified elements of the sea (Tangaroa), wind and weather (Tawhiri), etc. consistent with his Maori culture. He reports that he prayed every prayer that he could remember and to have repeatedly recited the Lord's Prayer. Later he would take out his frustration by swearing at God. People turn to prayer as a coping response in times of high stress[41] and recent research has shown that religious belief can compensate for a lack of control over a situation,[42] alleviate anxiety and stress,[43,44] strengthen self-control[45] and evoke feelings of inner strength and rest.[46]

He also reports verbalising the names of his partner and children. The extended family "*whanau*" is an important element of Maori society. This recalling of family members, reciting their names as a litany and even talking to them individually has been identified as a coping behaviour under stress by various shipwreck survivors. In one study, some of the most frequently heard phrases were, "*I remembered my wife and children and this seemed to give me strength*"; "*thoughts of my home kept me going*"; "*had I been single I'd not have survived*".[47] In one instance, a shipwreck survivor would recite the names of his children one after the other whilst paddling his life-raft, like a litany.[48] Reciting prayers and names of family members as a litany or mantra serves to increase the hope of surviving and to reduce anxiety through both physiological and psychological mechanisms.[49,50]

Physiologically, reciting prayers and mantras enhances and synchronizes the inherent cardiovascular rhythms, slowing breathing to approximately six breaths per minute, which coincides closely with the timing of the endogenous circulatory rhythms.[49] Psychologically, the processing efficiency theory proposes that, under stress, working memory is taken up with worry, anxiety and intrusive thoughts that consume limited working memory capacity and deny resources for processing important task-relevant information.[51] Correspondingly, prayer and recitation compete for these same cognitive resources enabling the suppression of worrying thoughts and a reduction in anxiety.

Planning and prioritising

Survival requires goal-directed planning and action; such planning also keeps the brain engaged, implies hope in a future, prevents 'brain inertia' leading to apathy and is a coping technique frequently used by long-term survivors. Conversely, an empty mind (that is, one with a complete absence of spontaneous mental activity and goal-related thought content) is a characteristic of the clinical demotivational states of aboulia and psychic akinesia.[52] Rob reports drifting into a comparable state of demotivation having, "*no thought* […] - *just nothing* […] *I actually thought about nothing* […] *there was nothing going on in my mind*".[10]

Conversely Rob created a 'wish list' of objects that he wanted in life and things he wanted to do. Later he would revisit his wish list prioritising his objects and activities and further refining his list to more abstract desires (e.g., personal love, harmony). This planning and mental listing is commonly reported amongst survivors. Hostages will mentally plan to travel, often to sail single-handed, around the world and will work out lists of provisions, books, equipment and everything else needed for their voyage.[53]

Routine

It was found amongst prisoners-of-war that those close to giving up and relinquishing life could be recovered if they were made to do something, no matter how trivial.[54] A survivor requires two types of routine: one to break up the day and the other to fill up the day. A routine also serves to increase the amount of spare capacity in working memory for planning and decision making. Here Rob set himself the simple but important task of repeatedly and systematically checking all his gear. This action also provides a task with meaning that supports the goal-directed behaviour necessary for survival.

Despair and suicidal ideation

Day three of a survival ordeal is often when the victim reaches a psychological low in their struggle to survive. As one shipwreck survivor, who spent 14 days in a life-raft reported, "*the second day was the longest, the third day was the hardest. After that, those who succeeded in making a mental and physical readjustment to life on the raft remained hopeful*".[55] Rob writes that on the third day, "*I was probably at my lowest point and I thought, just give up, you're not going to make it. I had tried to swim and get to the island so I felt like a failure. With that in mind I felt like giving up life itself. That's when I look a big breath, rolled over and put my face in the water.*"[10] This response is mirrored in the account of a deckhand who accidentally went overboard. After many hours in the water and various ships passing him by, he became dispirited and repeatedly tried to drown himself by letting himself sink and gulping down seawater.[39]

Rescue

Although little research has been conducted into the psychological aspects of rescue it is known that survivors in the rescue phase have a need for contact, comfort and a compelling need to talk about their experience, often becoming garrulous. This was noticed amongst survivors of a sinking, who were reported to have a "… *compulsive need to tell the story again and again, with identical detail and emphasis*".[56] Similarly with Rob who "… *began to talk and talk"*. Finally, one of the officers said "*man, you talk a lot!*".[10]

Post-trauma

It is stated that Rob took several months to recover to a state of normal physical and psychological functioning. This follows the usual progress of post-traumatic recuperation. His wife reported that since the event he had changed, becoming more self-reliant and confident, less dependent on others and more appreciative and understanding of his family. Undergoing a life-threatening experience can have psychological repercussions that may be pathogenic, often producing some degree of psychological debility, or they may be salutogenic, producing health-enhancing effects and positive outcomes for the individual.[57] Not everyone is severely affected by experiencing extremis and different people can react differently to the same life-threatening situation; consequently, it is not the situation *per se* but the meaning that people attach to their experience in that situation that is the determining factor. Salutogenic effects usually result through the successful application by the survivor of strategies to cope with their adversity.[58] This appears to be the case with Rob's psychological coping responses to his survival situation, the meaning he interpreted from his experience and the subsequent salutogenic effects of his ordeal.

Diver location and search and rescue operations (SAR)

As pointed out in the introduction, a successful rescue depends on many factors. Divers have relied for decades on physical devices to make them more visible on the surface. These include fluorescent head hoods; whistles on BCDs (almost always unheard over the noise of the sea and boat engines) and especially the 'safety sausage' – a brightly coloured (usually red or orange) inflatable plastic tube two to three metres in length. Many dive centres and resorts insist on divers carrying one of these, but their range of visibility from a large vessel is only about half a nautical mile and far less from a small dive tender or when, as is often the case, flattened against the water surface by the wind. A bright yellow flag on an extendable pole was shown in a Health and Safety Executive (UK) study to be more visible than the safety sausage.[59] A surface marker buoy (SMB) attached to the diver is in common use in some countries such as the UK. In the mid-1960s, one author (FMD) was involved in trials of dye markers and flairs, but these have never gained popularity. At night, dive torches and flashing strobes may help, but only a minority of divers carry a fully charged torch on every dive whatever the time of day. The most effective systems to use may be location and activity specific. However, it is recommended diver location planning is undertaken prior to the dive, that divers 'carry' a range of location devices (visual, auditory and technology based) on all dives and are conversant with their operation.

Modern technology to enhance diver safety is slowly catching on in the recreational diving industry. Personal locator beacons (PLBs) in a watertight case are now marketed, but there is some concern that their power may be insufficient to act reliably as an Emergency Position Indicating Radio Beacon (EPIRB). Other options utilize GPS positioning and distress messages to nearby vessels equipped with the Automatic Identification System and there is also a German-manufactured system designed for diving operations. Both, however, require the dive boat operator to invest in the system. None of these have been adopted widely for recreational diving activities. Rob's use of his available equipment ensured his immediate survival (drowning prevention due to floatation and insulation to slow the rate of deep body cooling). However, what was not included on the dive boat or with his personal dive equipment was any of the above means of identifying his location. At the time that the incident happened, diving SMBs were rarely used and PLBs specifically for diving were prohibitively expensive; this is not the case today.

In New Zealand in 2011, a diver deliberately went missing off the Otago coast, generating a massive air and sea search. Two days later, he turned up at a police station, hundreds of kilometres away. The authorities charged him NZ $50,000 for wasting police time.[60] The costs of SAR operations are huge (one example from Costa Rica is quoted as in excess of US $3 million[61]) and SAR personnel, many of whom worldwide are volunteers, are potentially at risk of injury or death in any operation. Whilst the lead organisation responsible for SAR may differ (e.g., Her Majesty's Coastguard in the UK; Police in New Zealand; the Australian Maritime Safety Authority), many nations now have excellent cooperative plans involving various authorities and organisations, including volunteers. In some jurisdictions, delivery of SAR operations is free to the victim, whilst in others the individual is charged for at least a proportion of the cost. Personal insurance schemes for divers are recommended and readily available, providing worldwide cover for such eventualities.

Concluding remarks

Prolonged immersion in cold water, strong currents and rough seas, exposure to the sun, wind, minimal food and dehydration were some of the conditions that Robert Hewitt had to contend with during the 75 hours he was immersed off the West coast of North Island, New Zealand. Hewitt's incredible account highlights the extreme nature of the environment, the challenges he faced and how a combination of his experience, physical characteristics, equipment, actions, psychology and luck helped him to survive. This report highlights a number of crucial lessons which can be learned to prevent future accidents from occurring. Perhaps the final comment should be "*expect the unexpected and plan accordingly*".

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