MEDICINE ON THE EDGE

THE THAI CAVE RESCUE

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In 2018, a Thai school football team was rescued from a flooded cave system. The rescue has gone down as one of the most remarkable rescues of the modern era, incorporating superhuman feats of endurance, precision planning, extreme medicine, extreme diving, human performance factors, anaesthesia and luck. It has sparked a Hollywood movie, Worldwide media attention and innovations in dive medicine. It was performed by "amateurs" who were nonetheless experts in their field.

In more detail....

On 23rd June 2018, the Wild Boars football team of 12 schoolboys (aged 11-16 years old) and their 25 year old football coach entered a cave system (Tham Luang Nan Nong) in the Chang Rai region of Northern Thailand. A flash flood then caused flooding in the system, cutting off the exit and marooning the team in a cave in complete darkness, without food, clean water or any means of communication, approximately 2.6Km from the entrance. The alert was soon raised, and a team of Thai Navy divers arrived and attempted to find them. However, it soon became apparent that there were very few cave divers in the World who were able to navigate this tricky cave system, with narrow swim throughs, strong water currents of almost zero visibility. Help was sought from an international team of amateur cave divers and after 9 days the boys were found by British cave divers Rick Stanton and John Volanthan. During that time, the coach was instrumental in maintaining the boys' morale and ensuring health standards in such a cramped confinement. Once found, it initially took 3-4 hours of diving from entrance through six segments ("sumps") of submerged cave, to where the stranded team were.

Once found, attention turned to the daunting task of getting the boys out, with significant time pressure imposed by worsening weather and fears of even greater flooding in the cave. Amongst the people contacted for assistance was Richard Harris, a Consultant Anaesthesiologist with over 30 years' experience in cave diving.

The team went through multiple different rescue scenarios, but it eventually became apparent that the only way to rescue the stranded boys and their coach was to anaesthetise them and 'buddy-swim" with them through the intricate cave system to the entrance. This was because the exit route to the cave was flooded in 6 places, requiring underwater swimming through narrow spaces for over 1Km in total. Without diving equipment there was no way that the team could be rescued. They could not drill a rescue tunnel or divert water away from the cave system - torrential rain from the Monsoon continued to fall.

Anaesthetising people and diving them as a rescue strategy had never been attempted before and it was uncertain whether it was even feasible. None of the stranded boys had ever dived before and the stark reality of the dangers of this were realised when a Thai Navy SEAL diver drowned in the cave system whilst returning from delivering food to the team prior to the rescue. The bravery, skill and teamwork of the rescuers cannot be over-stated in the planning and executing this rescue.

ANTICIPATED PROBLEMS

Malnutrition

The boys had been without food for nine days and had resorted to drinking water dripping from stalactites. Once found, food and water was brought by divers through the caves, but nevertheless, the boys were in a weakened state, potentially affecting rescue. This also made things more complicated anaesthetically, since each boy had lost significant weight.

Diving novices

None of the stranded had ever dived before. Even experienced divers can find diving stressful, which can induce panic and drowning. Cave diving is ultra-specialised and even more stressful - very few recreational divers cave dive.

Difficult dive profile

Although the depth of water was <4.5m, it was fast flowing, with currents and eddies.

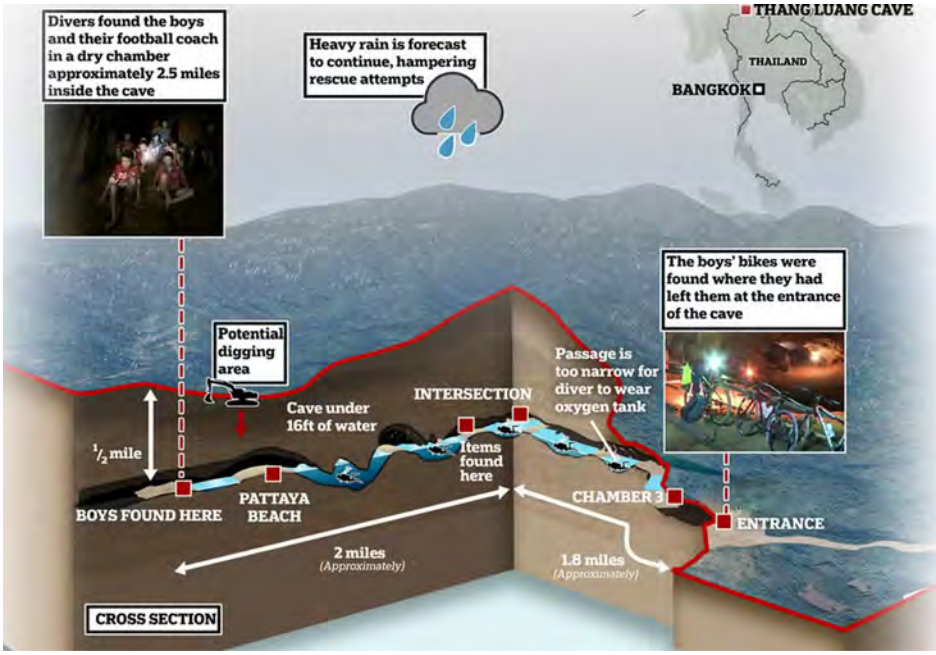

Figure 1: Map of underground tunnel system highlighting how far in the boys were trapped. Image from BBC.

Figure 2: Edgar Pask was subsequently known as "the bravest man in the RAF who never flew an aircraft" - as an inventor, he once described his one failure as an inability to develop an oxygen mask which would allow Sir Winston Churchill to smoke a cigar whilst at altitude[1].

In addition visibility was limited, with very muddy, turbid water, with 1.1Km of the 2.6Km escape route being underwater. There were 6 sumps, requiring 6 separate dives in-between areas of non-flooded caves.

Anaesthetising children and then diving with an anaesthetised child

This had never been performed before. In fact, the only previous record of an adult ever deliberately being anaesthetised and then immersed in water was during World War II, when Sir Robert Macintosh anaesthetised his colleague, Edgar Pask, paralysed him for hours with tubocurarine and then tested the efficacy of life jacket designs in an unconscious human subject[1,2].

The difficulty in protecting the airway and the risk of drowning, or becoming apnoeic whilst under anaesthesia and being unable to ventilate the children thus resulting in death was very high.

Dosing and re-dosing with anaesthesia agents

The risk of under- or over-dosing the children was very real. Actual body weights were unknown, so estimates needed to be made. All non-inhalational anaesthetic agents are administered on a per kilogram basis, and as any anaesthetist will confirm, not knowing the correct weight of a patient markedly increases anaesthetic risk.

Psychological issues of children

Almost all children undergoing anaesthesia are nervous. To be anaesthetised and then subjected to a long dive, having never dived before, would markedly increase anxiety and stress levels. In addition, emergence from anaesthesia during the dive and pulling their face mask off and thrashing about could cause both child and rescue diver to drown.

Hypothermia

The water was approximately 23'C which predisposed to hypothermia, given the length of time for each dive rescue. In addition, general anaesthesia also predisposes to hypothermia - a very real concern in this rescue.

Hypoxia

The cave had limited fresh air inlets. An oxygen analyser brought in by the rescuers showed that the ambient oxygen concentration had decreased to only 15% - and the children were all hypoxic. This was thought to have occurred gradually, with an element of acclimatisation occurring.

Medico-legal aspects of rescue

The chances of success were completely unknown, and the risk of death during the rescue attempt was high. It was unknown what the response from the Thai authorities would be if a child died under anaesthesia during the rescue.

THE RESCUE

The detailed rescue was published in Diving and Hyperbaric in 2020[3], but is summarised below.

The rescue began 15 days after the team first entered the cave, and lasted for three days - during which time multiple dives were made through the cave system. On each day, divers carried a full face mask, dive regulator, wetsuit and extra oxygen tanks into the cave for those being rescued that day. Four boys were rescued on the first and second day consecutively, with the rest being rescued on the third day. Those rescued each day were fasted prior to each dive.

Ketamine was the obvious anaesthetic agent to be used. It has been used extensively in pre-hospital and extreme environments, has a relatively wide therapeutic index, can be used in spontaneously breathing patients, is relatively cardiovascularly stable (important in dehydrated patients), may decrease vasodilatation (and subsequent hypothermia) and is effective when given intra-muscularly. However, correct dosing was a concern - not knowing the weights of the boys made things tricky - thus doses had to be arbitrarily divided into "small" (for those boys 40Kg or less) and "large" (for those

Figure 3: Full face diving mask.

boys 50Kg or more). Moreover, ketamine increases salivation and has a well-known dysphoric "emergence phenomenon" which could be potentially disastrous underwater. Atropine (an anti-sialagogue) and a small dose of alprazolam (0.5mg) were also used to counter-act these problems.

The alprazolam was given to each boy orally, who was then fitted into the wetsuit. Atropine (20mcg/Kg) and Ketamine (5mg/Kg) were then injected intramuscularly - the initial dose given by Richard Harris, who estimated the initial dose according to approximate weight. Further doses of ketamine of "small" = 40Kg (100mg), or "large" = 50Kg (125mg) were packaged in pre-filled syringes and given to the rescue divers (all non-doctors who had been taught by Harris) for administration during the dive itself. It is extraordinary that every boy required top up doses of ketamine during the outward transit, and these were often administered by one go the British cave divers with no resulting complications.

Once the child was anaesthetised, yet still breathing spontaneously, they were fitted with a full face mask and dive regulator and submerged to check for breathing, and absence of water leaks into the mask. The chosen full face mask was designed for use in contaminated environments and had a mechanism to maintain positive pressure inside the mask relative to surrounding water pressure throughout the respiratory cycle - essentially what we would call CPAP (continuous positive airway pressure) in medicine.

Should a child become apnoiec, pressing the regulator purge button delivered a burst of positive pressure inside the mask which appeared to inflate the lungs and often stimulated spontaneous breathing.

A dive cylinder was attached around the chest and abdomen via bungee cords. The cylinders contained a mixture of 80% oxygen and 20% nitrogen (in case they became apnoeic during the dive, there would be an element of "pre-oxygenation", with the nitrogen being, theoretically, protective against atelectasis). Given the shallow nature of the dive, oxygen toxicity was not considered a risk

Once checked thoroughly for leaks and depth of anaesthesia, the child's hands and feet were loosely bound (so as not to snag on any rocks or crevices), and the diver swam with the anaesthetised child through the cave system, carefully maintaining contact with the guideline .

That the journey was executed in zero visibility with 13 anaesthetised subjects without once having the mask contact a rock and become dislodged is testament to the shill of the four British cave divers who dived all the boys out. At each air chamber, the rescue diver checked the face mask for leaks and, if the child was moving or showing signs of emerging from

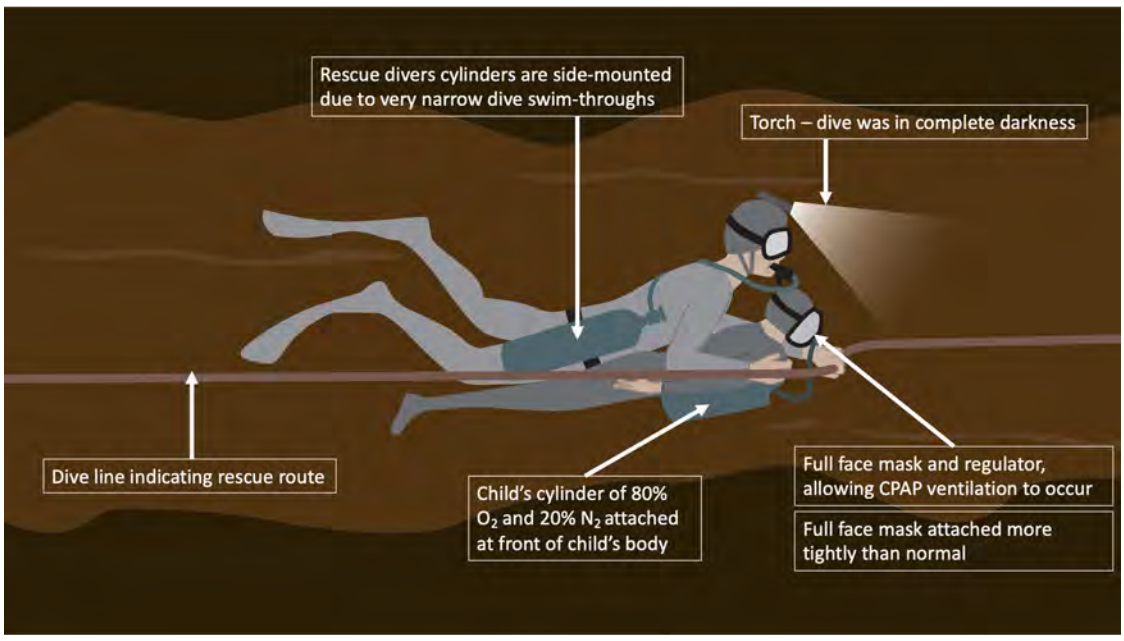

Figure 4: Image from Diving and Hyperbaric medicine reference - annotated by author.

anaesthesia, was given a "top-up" dose from a pre-filled syringe of ketamine. Each child needed between three and four "top-up" doses, given intramuscularly through the wetsuit, often in very difficult conditions (minimal light, fast flowing muddy water, tight air chambers).

On the first day, each rescue dive took approximately three hours, but this decreased to approximately 90 minutes by day three.

On arrival at the cave system area where foot rescue was possible, each child was handed over to the Thai medical team who had a field hospital situated nearby.

All children (and their coach) were successfully rescued - with no recollection of the events of the rescue. One developed transient laryngospasm (successfully treated with bag-mask ventilation) and three showed radiological evidence of mild aspiration - not requiring treatment. There were no other injuries.

HUMAN FACTORS

This rescue would have ended as a disaster without successful human factors training. Communication, teamwork, leadership, adaptive decision-making and continual shared situational awareness allowed the team to work efficiently and to overcome a continuing changing environment with new challenges being constantly introduced. To be able to work as a team literally meant the difference between life and death in this situation. Medics in every field can learn from this experience - to treat each other with respect, listen and address others' concerns, to have open communication and a horizontal, collective style of leadership ensured the smooth running of this team. Without adequate human factors input, this rescue would never have been a success.

IMPLICATIONS FOR DIVE MEDICINE

This rescue was remarkable. Prior to this, the thought of deliberately anaesthetising a diver, submerging them and leading them through a narrow cave system would have seemed ludicrous, if not suicidal. This has shown that the airway can be protected in an unconscious diver underwater - at least for a short period of time if an appropriate full face mask is worn. This has provided some reassurance that in-water recompression for decompression sickness - breathing oxygen at shallow depths (<10m), allowing pathological nitrogen bubbles in the body to re-dissolve in the bloodstream and be excreted in the lungs whilst underwater could be executed safely[4]. Such a process would never be initiated for an unconscious diver, but the concern, even in conscious victims is that oxygen toxicity whilst underwater could cause a seizure with almost certain drowning if a normal scuba regulator was used. This rescue provides reassurance that provided an appropriate full face mask is worn, there would be time to return the diver safely to the surface if such an event occurred during in-water recompression (re-submerging underwater).

CONCLUSION

The fact that the team was initially found safe and sound owes much to the skill and bravery of their football coach to keep the boys together, keep their morale up, ensure hygiene measures were in place in the cave and to keep them drinking fresh water from the walls. The rescue itself was an international collaboration of skills, planning and dedication - the bravery, innovation, and teamwork of the rescuers cannot be over-stated. This was a truly remarkable rescue involving extreme medicine in every sense - physically, emotionally, environmentally and psychologically and deserves to be recognised as such.

Footnote:

The Pask Award, named in honour after Sir Edgar Pask is awarded to anaesthesiologists by the Association of Anaesthetists of Great Britain and Ireland "who have demonstrated exceptional bravery in the performance of their clinical duties, in a single meritorious act or consistently over a long period"[5]. Dr. Richard Harris was awarded this in 2018. He has also been officially recognised and honoured in Thailand and Australia for his pivotal role in the rescue.

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