วารสารแพทย์นาวี
Royal Thai Navy Medical Journal

The Challenging Cave Rescue Mission of Twelve Young Boys and their Coach in Thailand 2018

Natthasak Woracharoensri
Somdej Phranangchaosirikit Hospital, Naval Medical Department, Royal Thai Navy, Chon Buri Province
Corresponding Author: Natthasakpcm22@gmail.com

Introduction

During 23rd June - 10th July 2018, 12 football players and their coach were trapped deep inside Tham Luang cave in Khun Nam Nang Non Forest Park, Chiang Rai province. This circumstance has never happened anywhere else in the world. Rescue teams faced tough situation. Due to the difficulties of landscape, awful weather, and limited time, the only possible way to rescue all football players was diving out through the cave. Furthermore, no one in the football team had diving skills and the routes in the cave were extremely dangerous. After preliminary consideration, and the fact that no one used the drug sedation during diving before, we thought that this way was the only possible way to evacuate and rescue all football players from the cave.

The medical teams from many parties worked together to find the most effective medical care, in wilderness setting and no previous medical information for rescue. There were only 48 hours of preparation before the operation. The medical teams had faced many challenging issues for designing plans to evacuate all victims with the highest safety process in very limited resources. The teams started diving plan for all football players and rescuers, using sedative during the evacuation, evacuation process, first aid plan, rescue process within the cave during the evacuation, the preliminary medical care at the field hospital nearby the cave, and the process of transferring the patients to the hospital. Fortunately, all operations were well supported by Public Health officers from both local and international parties. The special operations and collaborations can overcome all difficulties and ultimately success. The initial illnesses of football players after the rescue were hypothermia, pneumonia, otitis media, acute malnutrition, constipation, and contact dermatitis but all football players were well taken care of by the provincial hospital.

Finally, all 13 football players had returned safely to their homes and communities on 18th July 2018 which was the proudest day and the most valuable reward for all rescue teams.

There were many medical issues behind the operation and it will remain for discussion. Although the cave rescue situation was quite rare and may not happen in our country again, medical care in wilderness situation should be learned and explored for the person who was involve in military and emergency medicine will practice to make better care in different circumstances.

All victims survived. Even though this situation finished with a happy ending, there were also challenges and consequences from the rescue operation. Over the year, this article aims to address the challenging medical issue in this operation and will become a lesson learned for future services in the Naval Medical Department.

Medical Mission

The primary role of medical service in this mission is to design the medical support for victim's evacuation at the highest safety level as possible. This is the subterranean water rescue in the 4th longest cave in Thailand, which distance around 3.6 km depth at altitude 450 meters above sea level in monsoon season and no one among the victims can dive or swim.

Challenge #1: What is the appropriate escape option?

Many news agencies inform that we had 3 escape options which were diving out, drilling the mountain, and waiting for the monsoon to end. However, it didn't mean that we must select only one option. We needed to focus on whatever opportunity or chances to succeed. In fact, we have done everything to succeed.

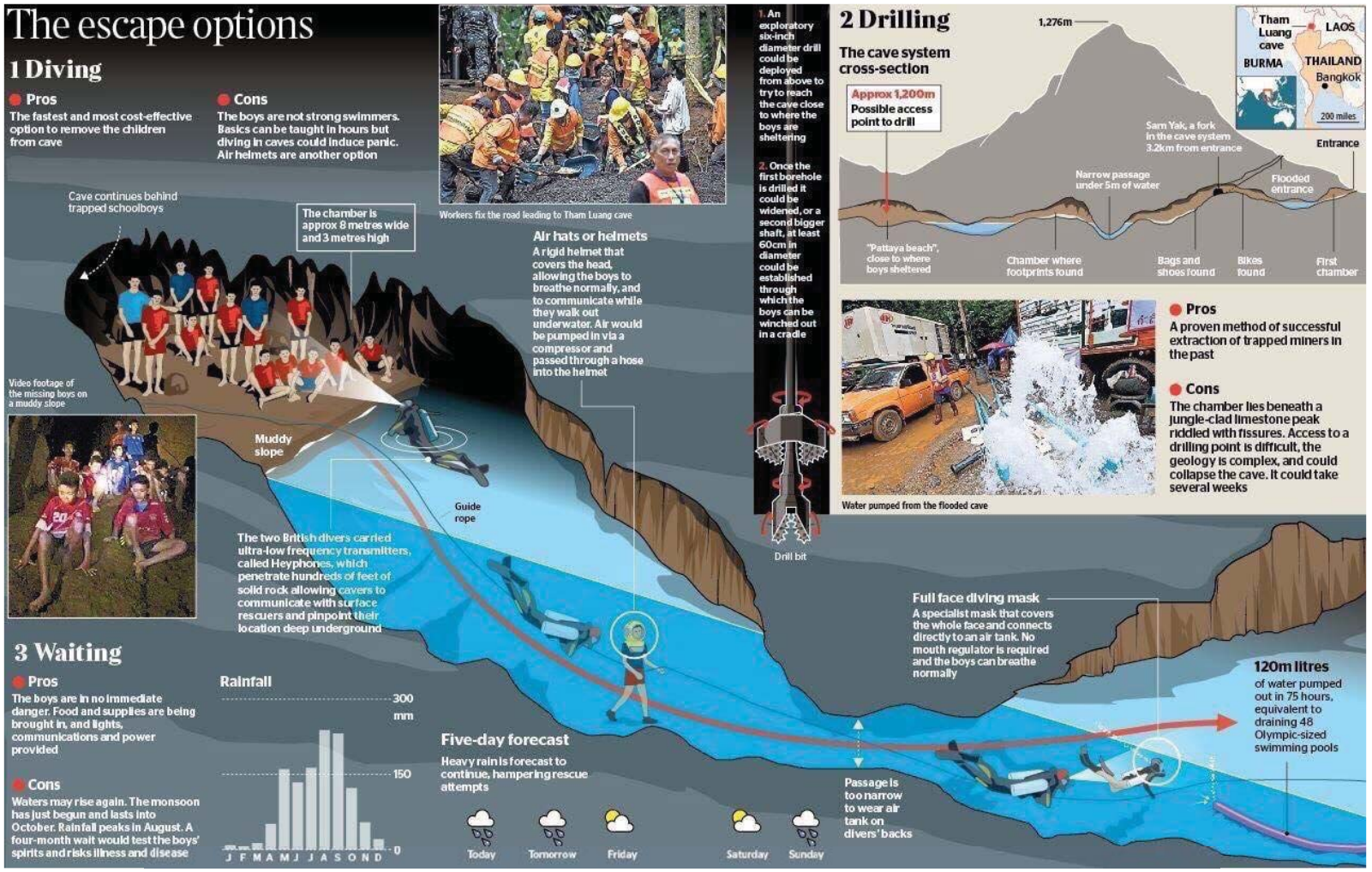


Figure 1 Infographic of the escape options in cave rescue Thailand (matt swift from twitter)

About ***the waiting option***, we performed this option for ten days. It didn't mean that we just wait and don't do anything. It's done to make the cave environment more suitable for diving as long as nature won't hinder. We tried to establish a life support measure. That included rope rescue line, oxygen tank line, telephone line, food support, electrical line, water pump line. Oxygen pipeline was used to increase the oxygen level in the chamber. However, this option had a limitation because this support line takes time to create and could consume human resources. We also had a restriction in oxygen level that decreases every day and infectious risk form poor sanitation increasing by time.

So, this option must be accompanied by ***the drilling option***. At first, it aimed to create a 1 foot hole to the nearest victim location for the additional necessary supportive measure. Moreover, opening a bigger hole to escape is a possible option.

However, the drilling position located on the mountain, the narrow space for working, and more than 150 meters for drilling required at least one month to complete so it seemed not to be the right choice.

The possible option was ***diving***. Many experts were against this solution because the children had zero diving experience and diving in a high-risk cave can cause you to develop a panic attack. However, we found the answer right away. The children didn't have to dive but putting them to sleep through sedation is a great way to take them out. In-cave oxygen level was still decreasing, not to mention about psychological status that dispirited by the time. Finally, all the rescuer agreed with these options and accepted the extreme risk during an evacuation because all of us realized that it was the only way to complete this mission.

At that time, no press or media explored the risk of diving out because the command center informed the three rescue options. So, the public opinion about the choice should not focus on risk for diving injury.

The additional reason that the commander's decision was diving out was because of a little rainfall in the last week (July 1 - 7). Since we started the mission, (July 8 - 10), when the cave was full of water, continuous pumping was done and it made the water level in the cave low. It's an excellent chance to succeed.

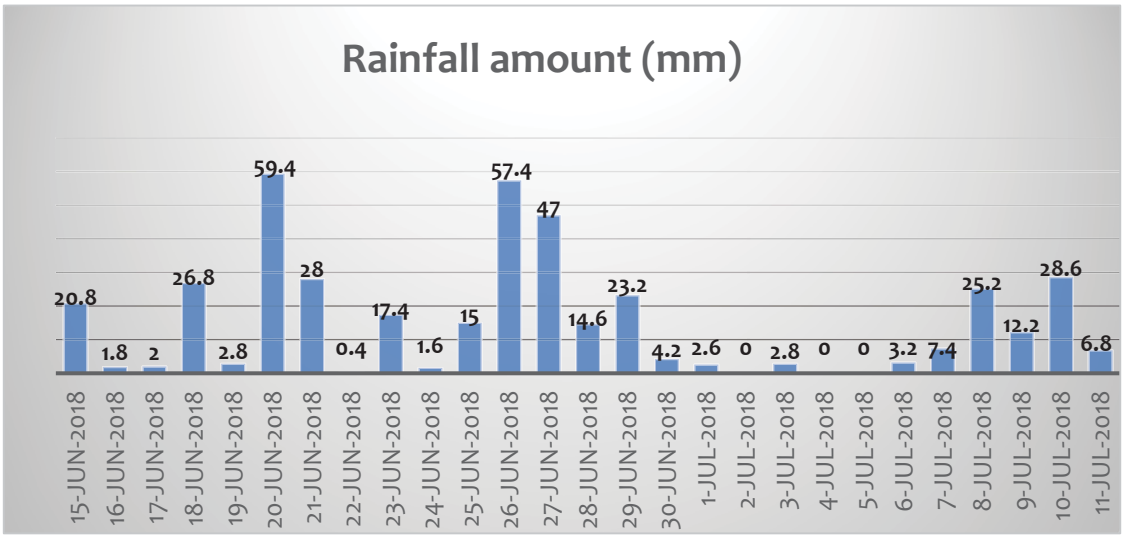


Figure 2 Daily amount of rainfall during cave rescue mission 15 June - 11 July 2018[1]

Challenge #2: Only 48 hours before the operation

There were only 48 hours left to prepare medical support before the operation. How do we create a maximum protective measure for diving out?

First, we performed the mission analysis to update the situation awareness of the team. (Table 1) This table made us realized that only the enemy of this mission was the nature. We must create a protective measure to prevent all harmful conditions both from the cave environment.

Table 1 Health hazard in cave diving operation

•	Altitude 450 meters above sea level (Altitude diving)
•	Water temperature 18 - 20 °C
•	Multiple dives, Multiple days, Fatigue, Stress
•	Oxygen level in cave 16 - 18%, Humidity 100%
•	Underwater visibility < 1 foot

We identified that the cave was dangerous for this operation.

First, you must know that the diver had to dive above 300 meters above sea level with a depth higher than 13.7 meters. This is called an **altitude diving**[2]. It can increase the risk of decompression illness. Every hour, the water depth in the cave varies according to the rainfall and the capacity of the pump. It was very hard to predict the water level and couldn't be avoided, so the diver in such condition was at risk every minute.

Second, the **water temperature** was 18 - 20 degrees Celsius. Diving from chamber 9 to chamber 3 required about 4-5 hours. Evacuation would really require more time. It would take many days, multiple dives and would cause accumulation of fatigue. So, we couldn't ignore the water temperature as it could cause hypothermia.

However, the biggest problem was **the oxygen level in the cave**, with only 16 - 18%. It reduces the exercise capacity of a rescue diver. In addition, with underwater visibility less than 1 foot so any mistake could be fatal.

After the decision, our medical team worked hard to evaluate, prepared well and made the treatment plan together. No matter what the result of this mission is, all rescuer team working under the same purposes to make all victims safe.

We collected baseline victim health status especially underlying diseases and drug allergy status. We made a list of emergency cases according to the severity and consequences. It is divided into 3 groups. (Figure 3)

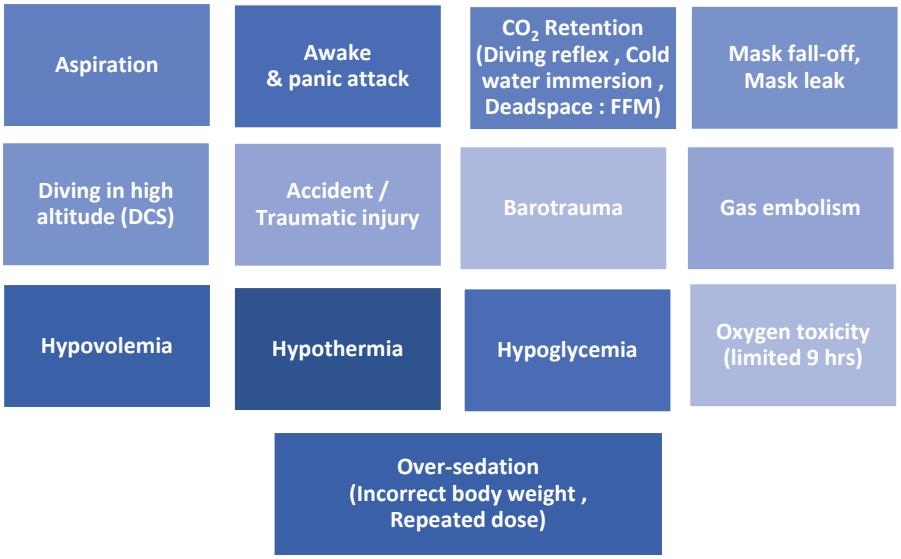


Figure 3 Risk concern for diving out[3]

Group A refers to conditions that might happen in the diving rescue resulting to life-threatening condition which can be prevented or managed during diving out. These conditions include aspiration, mask fall-off or leak, CO_2 retention, and victim regaining consciousness and panic attack.

Group B are conditions that can happen and can't be prevented, occurs by random opportunity. These conditions need urgent treatment in the field, such as a traumatic injury, diving-related injury (barotrauma, decompression sickness, or gas-embolism).

Group C refers to conditions resulting from physiological change from the rescue method, not requiring immediate attention or won't result to life-threatening condition. These conditions include hypoglycemia, hypothermia, hypovolemia, oxygen toxicity, and over sedation.

Every medical department of different services including the Army Medical Department, Naval Medical department as well as the Referral Center joined together. In addition, the Police Medical Department sent some medical equipment that can be used for the operation.

Challenge #3: How to make consensus for the first time using sedative cave rescue in the world?

In the rescue team's point of view, every person should work together to analyze data, synthesize, and conclude all concerned aspects. Moreover, this operation obtained the world-class expert cave diver so we could assume that this is the best team to perform this operation. Everybody in the team trusted each other to make the best to every task given.

The consensus from family or public was an interesting point at that time. It seems to be a secret work the command center let the society discuss the rescue option. Mostly think that drilling was the preferred method. No, anyone explores the risk of diving out. Even if there is some rumor about "buddy diving". The authorities inform the public that may delay for 3 - 4 days.

It is a kind of information operation to distract the public from the uncertainty, high-risk operation until every sector declares their readiness.

Challenge #4: Find the crucial success factor for the operation.

There were 5 factors needed to accomplish the mission[4].

First is the collaboration of the cave diver and all kind of medical team. In an urgent situation and high-risk operation, these people delegate and sacrificed themselves to operate this procedure. We must express gratitude for their participation. ***Second***, the victims must stay in sedative state and be calm during diving to avoid self-harm behavior in underwater. Otherwise, the diver may abandon the victim in case of a life-threatening condition. ***Third***, the appropriate full faces to prevent aspiration when diving out. ***Fourth***, try to eliminate the risk of hypothermia, which may cause a life-threatening condition. ***Finally***, to make sure that oxygen supply was adequate during diving out.

Challenge #5: What is the best regimen for sedation?

The property of deal sedative medication for this mission includes[5]:

1. Less or no respiratory depression
2. Sedative and Anxiolytic
3. No cardiac suppression (favor cardiac stimulation side effect)
4. Vasoconstriction effect
5. No vasodilator effects
6. No muscle relaxant effect
7. Not increase salivation
8. Avoid bronchoconstriction

Dr. Harris and Thai anesthesiologists agreed to use sedation cocktail.

The preparation before sedation and carrying the child out include stopping taking food for 6 hours and no water for 2 hours. After that, the child who was ready to go had to be dressed with wet suit and come to see Dr. Harris for evaluation and start sedation regimen that includes:

1. Alprazolam 0.5 mg per oral: This drug was used for premedication before starting anesthesia procedure and reduces the victims anxiety.

2. Atropine 20 microgram/kg intramuscular (Single dose): This medication was good to reduce hypersalivation from ketamine.

3. Ketamine loading dose 5 mg/kg intramuscular followed by 2.5 mg/kg intramuscular for rescue dose. Ketamine is a medication for starting anesthesia. Its effects were pain relief, memory loss, and sedation with little effect on respiratory depression and maintain blood pressure.

When the child falls asleep, the diver puts the full-face mask on his face. Tighten the strap and check for mask leak and test diving until become confident that everything goes on, as usual, and then the diver carries the child from the chamber nine. About indication for rescue, the dosage was assigned to the rescue diver to determine the repeated dose.

Challenge #6: How to carry the child with a full-face mask?

The full-face mask has a unique characteristic. It is a mask cover that holds diver faces, which is not necessary to bite the mouthpiece. Moreover, it creates a mild positive intrathoracic pressure that results in preventing alveoli collapses. The full-face mask has a push button to allow intermittent airflow that allows a rescue breath performed quickly.

At that time, the rescue diver must train and practice to take care of the child, manage the mask in case of mask leak or mask fallout with the assistance of the volunteer student who has an equal in weight, height, same education level, and also has no experience in diving.

From this practice, it made all the rescue team realized that the sedation is necessary to prevent harmful movement during diving and the appropriate mask caring is the crucial procedure to determine the mission successfully.

Challenge #7: How to prevent hypothermia?

The next problem was to determine the risk of developing hypothermia in the evacuation process. The risk factors were classified into 3 groups: *the intensity of cold*, *duration of exposure*, and *environmental condition*. The child must be submerged in the water with temperature of 18 degree Celsius. The estimated time for diving out was about 4 - 4.5 hours. Accompanying the high steam flow, no active muscle movement, and low body fat composition, all these factor creates a significant risk of hypothermia. The study from Dr. Haward[6] demonstrates the cooling rate in seawater immersion if the water temperature at the 18 degree Celsius, the cooling rate is around 0.015 C/min. In case of no insulation to prevent hypothermia, the victim's temperature will drop about 3.6 degree Celsius that makes the core temperature around 33 - 34 degree Celsius.

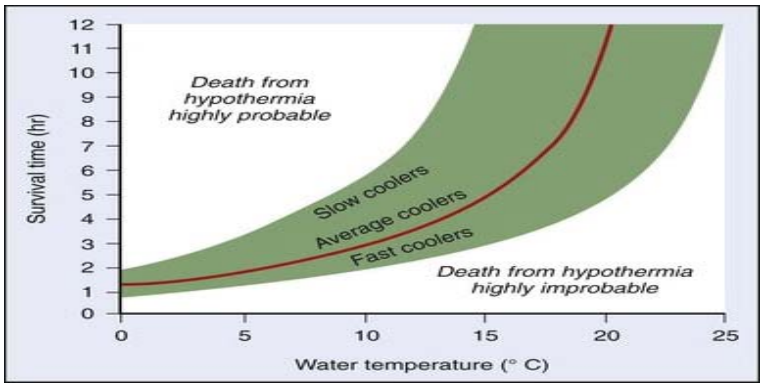


Figure 4 Survival time in the cool water immersion[7]

So, for this reason, we selected a wet suit with 5 mm thick cloth, long sleeves with a hood to prevent additional heat loss from the brain. However, the team intentionally left the hand and feet are for pulse and perfusion observation purposes.

Challenge #8: How to ensure victims get adequate oxygen supply?

Hypoxia is one of the reasons victims can develop cardiovascular collapse in this operation. To prevent this problem, we must be cautious about the mask position and also the composition of breathing gas. We decided to use pure oxygen for victim breathing all along the way out and the rescue team would check the pressure tank every operative station. The oxygen breathing tank must be changed if the pressure was below 800 psi.

Challenge #9: How to carry the victim after chamber 3 to front cave?

Figure 5 shows the simple anatomy of the cave passage[8].

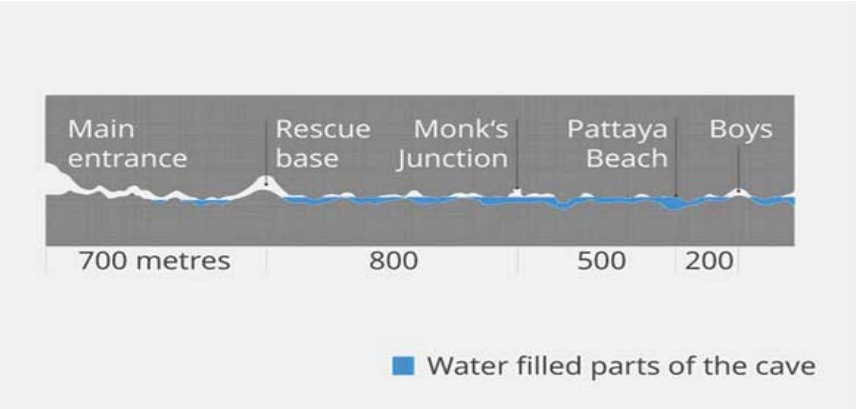


Figure 5 Evacuation route in the cave rescue

From the boys location to the chamber 3 (Rescue Base) there was water filled most parts of the cave. The rescue divers carry the child along the rope rescue until chamber 3. After this part it's distance 700 meters with the tough situation because it's an up and down hill passage with some area of water flooding. The child is emerging from the water in chamber three. We bring the victim to the upslope area. Pack him into the stretcher and make everything ready for climbing down 45 degrees slippery slope and to the narrow way (the passage only 0.6 meter) which the boy and the rescuer must submerge around 10 - 15 meters distance. The victim was pulled up with the rope through the narrow pathway, that means the team must carry the victim in a diving suit with full diving gear, the weight was around 30 kg. After that, we must bring them across the abyss with a distance of 65 feet with the pulley system and bring the child to the ground floor drift along the river, which some part of the water gets above the neck and the low cave ceiling. Before reaching the front of the cave, the rescuer must bring the victim to climb up around 500 meters before sending the boys to the army field hospital team. Figure 6 shows the different method and equipment for victim evacuation with more than

200 troop support from Thai and international volunteers. We use 40 minutes from the base to the front cave.

Figure 6 Obstacles challenge from chamber 3 to the front caves

Challenge #10: In case of emergency, what is the optimal care process in the cave?

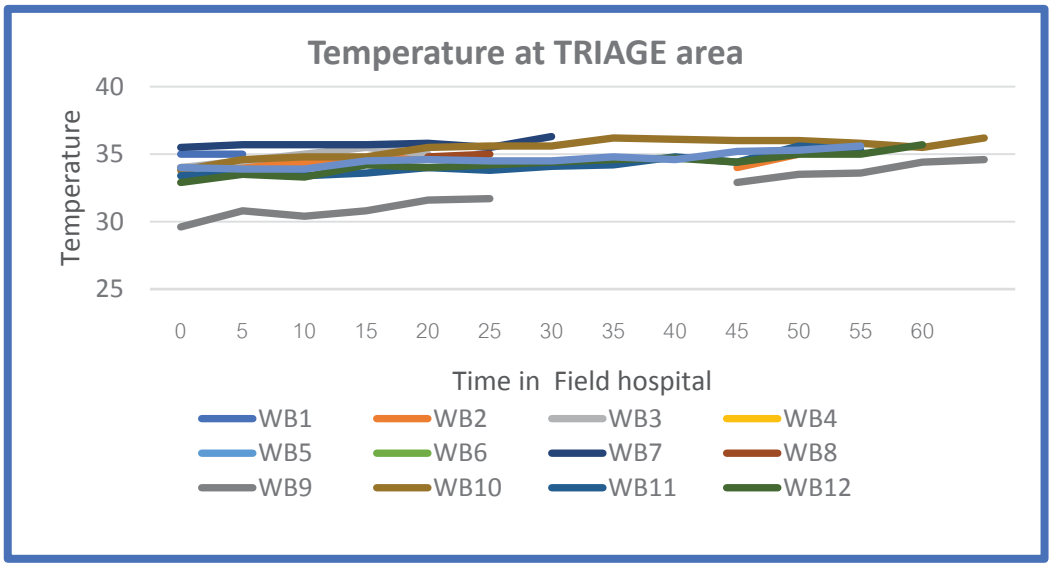
This schema presents the evacuation procedure from chamber 3 to the front cave.

We assigned 5 medical stations for evaluating and reporting the victim status along the way out. Because of limitations in terrain, full medical support can't be provided. Our team gives the priority for evacuation first. So, we don't lose the time for low priority medical procedures such as temperature measure, BP monitor, or try to rewarm victim in the cave.

The En Route Care, the victim inside the cave. Every medical station checked the essential physical sign including breathing, pulse, level of consciousness, measure oxygen saturation, Mask position, clear fluid content in the mask, and finally, the oxygen pressure in the container. In the case of an emergency (Bradycardia or impending cardiac arrest), we decided to use the intramuscular medication to rescue their life. Endotracheal tube intubation can perform at 2nd Medical station after chamber 3.

The 3rd and 4th stations re-checked position and victim status and prepares for the next obstacle. Until the rescue team brings the child to 5th chamber, at this point all of the advanced medical care can be performed (including ACLS, rewarming, etc.)

Initial Result in Field Army Hospital[9]



This graph shows all wild boar temperatures measured in the field hospital. It showed almost everyone develops hypothermia mostly for a mild degree (32 - 35 degrees Celsius), except for the coach. He developed a moderate degree of hypothermia because he had a low ratio of weight and body surface area, which was a significant risk factor.

The other vital signs were within normal range. About the potential causes develop hypothermia, we can conclude their significant aspects.

First, the victim stayed in a sedative state, with no heat production enough to combat heat loss even though everybody can develop shivering.

Second, we decided not to put the glove and shoe on to the victim before diving out with the intent to observe the pulse during the evacuation. As you see, the hand and feet are high vascular areas, so it creates a more significant heat loss during diving out.

Third, we use oxygen instead of air to prevent hypoxemia. But the nature of oxygen gas is a cooling gas which contributes to developing hypothermia in every wild boar victim.

Challenge #11: How we stabilized the victim before transfer?

As mentioned above, almost all victims developed a mild degree of hypothermia. So it became a lesson learned for Army field hospital to manage hypothermia before transferring to Chiangrai Prachanukroh hospital. The Care process and the method of the rewarming is shown in the picture. We designed 3 major care processes that include Triage, Stabilize, and Refer.[10]

Challenge #12: Finally, is the child safe?

The initial vital signs are shown in the picture. Six children were still suffering from mild hypothermia. That results from exposure to the cold air during air-transport but no hemodynamic alteration. A chest radiograph shows pulmonary infiltration, which indicates a mild degree of aspiration pneumonitis in three victims—other health-related problems from loss in the cave, is shown in table 2 (data from Pediatric Department, Chiangrai Prachanukroh hospital).

Table 2 Health-related problems of the victims

Problems		N
Hypothermia		6
Infection	Clinical early sepsis	10
	Pneumonia	3
Electrolyte imbalance	Hypophosphatemia	2
	Hypokalemia	2
	Hypomagnesaemia	2
GI	Constipation	9
Nutrition	Acute malnutrition	13
Eye	Keratoconjunctivitis	1
ENT	Otitis media	5
	Impact cerumen	2
Skin	Fungal infection	4
	Bacterial skin infection	2
	Herpes simplex labialis	1
Allergy	Allergic rhinitis	1
Hematology	Bleeding per gum	1
	Epistaxis	1

After two weeks of treatment and extensive evaluation, both physical and mental status, all the victims can return to their normal life and stay in a healthy status.

Conclusion

Thailand cave rescue mission was an extraordinary circumstance. Unconditional assistance from international experts and volunteers has shown miraculous result. But from the medical point of view, the knowledge, equipment and skills specific for wilderness medical care are limited. This serious problem can happen in extreme environmental situation such as forest mountain, cave or disaster. The interdisciplinary knowledge is crucial to design and create an advance medical care plan to ensure the victim safety in each situation. This issue should be a lesson learned for medical teams who were involved in the disaster management, and for Emergency Medical Service team to prepare and train in the future.

Acknowledgement

Richard Harris, B.M., B.S., F.A.N.Z.C.A. Aeromedical and anesthetist consultant from South Australian Ambulance Service, who depart from the diving holiday, with Dr. Craig Challen who devoted their 30 years professional diving experience and knowledge as requested by Thai government without hesitancy. Moreover, it was with his courage to initiate the sedative cave diving procedure which was never performed by the physician before. His confidence and humble character was extremely helpful for Thai medical rescue team who had too many irons in the fire before the operation day.

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