ACCIDENTAL IMMERSION HYPOTHERMIA

IN THE SOUTH ATLANTIC

International Review of the Armed Forces Medical Services-

Official organ of the International Committee of Military Medicine-

Vol. LXIX 4/5/6-June 15th, 1996-p126-139

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Abstract

Argentina has suffered 5291 cases of accidental drowning and immersion between 1980-1988. The so called littoral provinces comprised 24.32 percent. The group of victims between 5 to 14 years old comprised 35.19 per cent of the total. There were 56 shipping casualties between 1976 and 1991 in the Patagonian coast. The fishing and general dry cargo comprised 42.8 per cent of the casualties. Thirty per cent of ships were stranded and only one ship sunk. About 51.78 per cent occured in the autumn-winter seasons. During the South Atlantic conflict of 1982 there were many cases of cold water exposure but perhaps the most representative is the sinking of the cruiser ARA *"General Belgrano"* where 15 percent of the casualties were probably due to the wounds and later abandonment in the rafts [40] . A state of the art on accidental immersion hypothermia (AIH) is offered.

KEY WORDS:

HYPOTHERMIA, TEMPERATURE, COLD WATER, IMMERSION

En la Argentina se han registrado 5291 casos de muertes por inmersión entre 1980-1988. El 24,32 por ciento correspondió a las provincias litoraleñas. El 35,19 por ciento del total correspondió a víctimas entre los 5 y 14 años de edad. Entre 1976 y 1991 se registraron 56 naufragios en las costas patagónicas, de estos el 42,8 por ciento correspondió a pesqueros y buques de carga. El 30 por ciento de los barcos encallaron y uno solo se hundió. El 51,78 por ciento de los casos se registraron durante los meses de otoño e invierno. Durante el conflicto del Atlántico Sur de 1982 se registraron varios casos de exposición al agua fría de mar pero quizás el más representativo haya sido el hundimiento del crucero ARA *"General Belgrano"* donde el 15 por ciento de las bajas probablemente se debieron a las heridas y a la evacuación ulterior en las balsas [40]. El artículo ofrece una actualización del cuadro de hipotermia global accidental por inmersión (HGAI).

Historical vignette

During the 1982 *Conflict of Malvinas* the Argentine cruiser *"General Belgrano"* (former *USS Phoenix*) was sunk by two British Mark 8 torpedoes. It had a 1091-man crew (377 were 18 years old conscripts). The cruiser was navigating at 35 knots, the water temperature was 2°C, there were gales of 100 km/h with a wind chill factor of -20°C and waves were 9 meters high. There were 368 casualties. About 25 percent of the survivors including a surgeon had to plung in the frigid sea. Ten percent of the rafts presented inconveniences. One of the young men aboard the first raft died later of hypothermia. According to *Marsh*, 69 survivors suffered from hypothermia and 18 died from this condition [7]. During that same period there was a remarkable case of a three days survival on land and sea experienced by the Argentine Naval pilot *Capitán de Corbeta Philippi* whose Skyhawk A4-Q was truck by a British Sidewinder AIM-9L in a fierce battle on the *Strait of San Carlos* during which the *HMS Ardent* was sunk. Water surface temperature was about 7°C and the pilot managed to swim to the *Soledad island* where he remained three days wet with an average daily temperature of 0°C and gales of 80 km/h. *(The odyssey of a Skyhawk pilot-Proceedings-May 1983-p11)* I have calculated that the pilot must have had a breath-hold duration of approximately 20 seconds. His moderately hard swimming to the coast must have caused him a heat production of 365 kg.-cal/m^2/h. This action was later depicted in a well known dramatic painting by *R.G.Smith* called *"Bomb Alley"*. The combined air attack on *HMS Sir Galahad* and *HMS Sir Tristam* produced great damages and according to British medical sources there were some cases of immersion hypothermia although no precise figures were published [40]. The *HMS Coventry* received three bombs of 1000 pounds from an A-4B Skyhawk. British survivors were forced to run to the rafts or jump to the sea. There were only two deaths in the sea from immersion.

The *Atlantic Conveyor* received an Exocet AM-39 air-to surface missile from an Argentine Super Eténdard. The celerity displayed by the British helicopters reduced the need of rescuing the survivors from cold waters. They had the great task of evacuating casualties from the 50-foot-high deck. Most of the 12 men who died were in the water. A number of cases of hypothermia in the life-rafts required treatment.

Geographic considerations

Argentina posses a surface 2,701,800 square kilometers and an Atlantic coast of 4,697 kilometers. The *Paraná* river has 4,800 kilometers length and ranks eighth among the world largest rivers. The *Río de la Plata* has 230 kilometers in its outflow and drains an area of 4,333,400 square kilometers. Four hundred lakes are found in the Patagonian provinces of *Neuquen, Chubut* and *Santa Cruz*. A substantial percentage of islands are scattered in the cold fueguinian zone. *Ushuaia*, the southernmost city of the world is located in Tierra del Fuego. Separated from this last by the stormy *Strait of Le Maire* we can find the legendary *Isla de los Estados* (485 square kilometers). During the 18 and 19th centuries up to nine ships per year wrecked near its treacherous coasts, especially in the north-east and south-west areas. Many ships burned in the cold waters of *Cape Horn* when wheat had spontaneous combustion in the holds. Four hundred ships of different flags have wrecked in this area causing 10,000 casualties. In the summer of 1906 twelve ships sank with all hands.

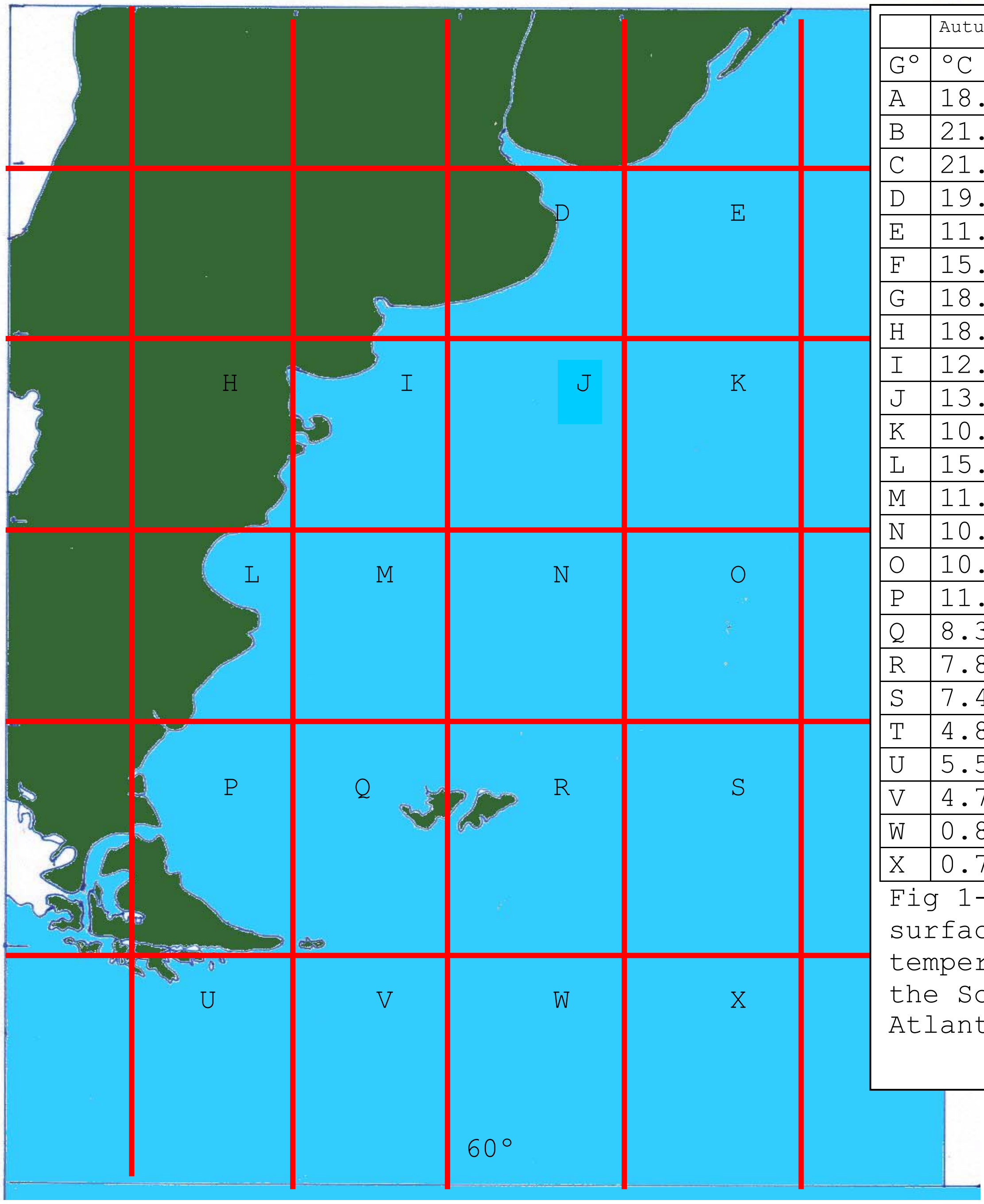
The cold water

The temperature of thermally neutral water, where heat loss balances heat production for a nude subject at rest is about 33°C. **Significant risk of hypothermia usually begins in water colder than 25°C.** According to deep body temperatures, water can be classified as stimulant (35°C), depressant (35-30°C) and critical (30-25°C) . *Figure 1* shows the average surface water temperatures in the different areas of the South Atlantic. *Figure 2* shows the mean temperatures in the North Sea during the month of December.

Cold perception

An individual behavior in a cold environment is often a function of his subjective assessment of cold and thermal discomfort rather than of actual exposure time, physiological status, prior acclimation to the cold or deep body temperature [18].

The perceived cold sensations may be a very poor and possibly dangerous predictor in cold water immersion situations. Cold water may accentuate the overshooting phenomenon which is observed in cold air.



	Autunn	Winter	Spring
G°	°C	°C	°C
A	18.5	-	18.4
B	21.5	19.0	20.8
C	21.1	18.2	21.6
D	19.0	11.2	15.5
E	11.5	11.3	12.5
F	15.5	12.1	15.3
G	18.6	16.5	18.7
H	18.0	16.1	17.7
I	12.9	9.2	12.5
J	13.5	9.0	12.9
K	10.4	7.2	9.6
L	15.4	10.2	13.7
M	11.3	7.5	9.7
N	10.6	7.4	9.3
O	10.3	5.7	8.6
P	11.8	6.7	9.8
Q	8.3	5.8	8.0
R	7.8	5.3	7.6
S	7.4	4.3	8.0
T	4.8	3.2	7.0
U	5.5	4.5	4.2
V	4.7	2.3	5.3
W	0.8	1.4	3.1
X	0.7	-1.4	1.7

Fig 1-Average surface water temperatures in the South Atlantic.

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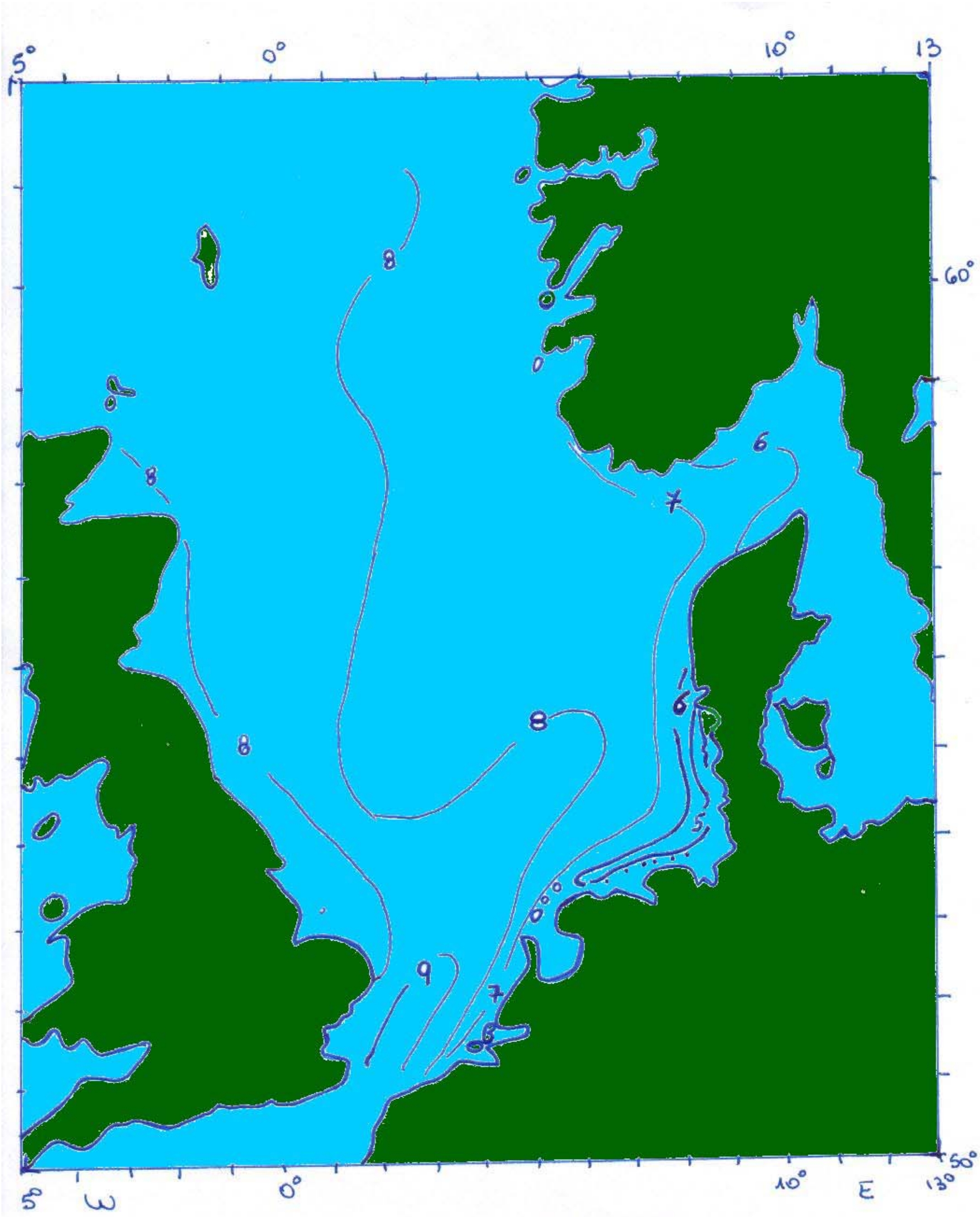

Figure 2-Mean values of the North Sea surface temperature (in º C)for the month of December

(*Drt.hydrogr.Z.Erg.H.B.,Nr 17, 1986 .Becker et al; Atlas der Temperature an der Oberflache der Nordsee)*

The Overshooting Phenomenon

This phenomenon is characterized by sudden temperature drops being perceived as cold sensations of greater magnitude. Receptors react very quickly not only to temperature but to rate of change, so sudden temperature drops may be perceived as

more pronounced cold sensations as if reflecting much colder temperature differences [8,12] .

Body heat production

The survival in cold waters depends on balancing heat loss with heat production [20]. The major sources of heat production are through thyroid thermogenesis and the action of adenosine triphosphatase (ATPase) on the sodium pump of all membranes.

Besides the constant basal metabolic production there is a component due to physical exertion which varies from zero to 20 times the basal component. The average heat need of a hypothermic patient is 500 kcal.

Body heat store

Bridgman in his paper about the thermal status of Antarctic divers estimates **body heat store (S)** through an specific formula taken from *Burton et al*. The formula states that:

$$S=3.48\ mTb\ (kJ)$$

where: 3.48 is the average value of specific heat capacity of human tissues, m=mass of subject(kg) and Tb=Mean Body Temperature [1] .

Body heat loss

Normally 65 percent of heat is loss through radiation, 20 percent through evaporation and the rest by conduction and convection. **The main mechanism of heat loss during cold water immersion is conduction**. Thermographic analyses indicate that the areas of the body which contribute most to heat loss during immersion are the groin, the neck, the axillas and adjacent lateral thorax. Conduction is the transmission of heat by the passage of energy from particle to particle. The thermal conductivity of water have been estimated to be 1,000 times greater than cold air at a similar temperature. The rate of loss of body heat in water is approximately 25 times that in air because of differences in specific heat and thermal conductivity.

Convection is the process by which heat is transferred by movement of heated fluid such as air or water. During cold water immersions exercise stirs the surrounding water and increases heat loss from convection. *Table 1.* Exercise has been shown to increase the mean fall in rectal temperature in men immersed in water at 5 and 15°C but not at 25°C. Vigorous movements such as swimming result in increased loss due to vasodilation in skeletal muscle. **Persons immersed in cold water without sufficient insulation should not attempt to exercise to keep warm or to swim ashore unless is less than 20 minutes away.**

The heat loss to surrounding water can be calculated from an specific formula which includes a constant which converts the total insulation value into **Clo**. The Clo is a unit of thermal insulation, equivalent to 0.155 $°C.m^2.W^{-1}$. It is measured using a heated copper manikin either in air or immersed in water [25,26].

The recording of core temperatures

The core temperature is the register at the innermost part of the body, that is 37°C . **In the general practice any thermometer that registers at least as low as 32°C allows separation of mild cases from severe hypothermia** [6]. The core temperatures are usually measured in the rectum **(Tre)** by using a thermistor inserted 10 cm beyond the anal margin and ensheated by a polypropilene sheat.

Some investigators monitory the auditory canal temperature **(Tac)** while others register the central arterial temperature **(Tar)**. *Cooper et al* consider that esophageal temperatures correlate best with myocardial and central venous temperatures. *Nunneley et al* define survival hypothermia as a Tar higher than 34°C [4,6,7] . *Bridgman* from the *British Antarctic Survey* studied the thermal status of five Antarctic scuba divers before, after and during immersion on 26 dives in the sea. He registered the Tre and the mean skin temperature **(Tsk)**. This last was derived from a modification of the formula given by *Hardy* and *DuBois* [1,14].

Central thermoregulation

The centre of thermoregulation is localized in the **anterior and posterior hypothalamus**. There is a connection between shivering and thermoregulation. After destruction of the hypothalamus man can no longer maintain a uniform body temperature. There is a lack of evidence for facial cooling affecting central thermoregulation [27]. Nomograms have been made for estimation of tolerance times to cold water immersions [34].

The three thermal zones

The human body has three thermal zones: 1) A superficial zone, including skin and subcutaneous tissue which has a normal temperature of 34°C, 2) An intermediate zone, composed of the skeletal muscles which has a temperature of 35°C and 3) A deep zone formed by the body cavities which has a temperature of 37°C.

When the body is exposed to cold there is a progressive cooling from the superficial zone to the deep one.

Since human beings are **homeothermic** they tend to maintain constant temperature regardless of changes in the environmental temperature. Women are able to preserve more heat than men because they have more fatty subcutaneous tissue.

The importance of fatty tissue

The variables in accidental immersion are: a) Water temperature **(Tw)**, b) Immersion time and c) Insulation provided by subcutaneous fat. a) **Distribution**: The subcutaneous fat is generally deposited most thickly over the areas which have minimal vascular heat conservation. Age has little effect on fat distribution. The fat pattern in normal middle-aged men closely resembles that in overweight young men [10]

b) **Insulation properties**: Fat accounts for 50 percent of effective insulation over the trunk, 33 percent over the proximal limbs and only 3 percent over the hands and feet. The insulation value of subcutaneous tissue and fat probably not exceeds 0.9 Clo even with maximum vasoconstriction. Immersion hypothermia is inversely proportional to overall fat thickness[3].

c) **Fat and tolerance for swimming in cold waters**: The most important determinant of cooling rate during unprotected immersions is subcutaneous fat thickness. A case was reported about a man who survived 9 hours largely unprotected in water at -1°C . According to *Martin* the man with more fat is able to maintain the temperature when swimming but not at rest.

An obese swimmer may maintain a normal Tre for 2 hours without shivering in 16°C water [15]. A recent study by *Veicsteinas et al* showed that resting muscle would also play a part in tolerance[38]

d) **The studies of human mean skinfold thickness (MST)**: *Nunneley et al* studied MST by using a sophisticated computer model in an effort to improve specification of protective clothes. Their results indicate that subcutaneous fat strongly affect heat loss even with heavy clothing. It would be possible to develop graphs to cover individuals of varying skinfolds thickness but this degree of sophistication may not be practicable in an operational service environment [15,25,26].

The effects of shivering

The thermoregulatory heat production of a human being in cold water highly correlates with shivering. Maximum shivering thermogenesis in humans is approximately 4.5 times the resting rate of heat production [23]. Although shivering is affected by core temperatures it is primarily driven by skin temperature. Alcohol can reduce 15 percent shivering thermogenesis in cold water. A normally dressed man can mantain heat balance by shivering in water only as cool as 20°C.

Once the rectal temperature (Tre) falls below 35°C shivering decreases and is replaced by muscle rigidity hence heat loss accelerates. Rewarming only the trunk may have less effect on shivering.

As the severely hypothermic victim cannot shiver effectively, this is less crucial than in moderately hypothermic victims.

The effects of alcohol

Alcohol a) Diminishes the perception of cold, b) Decreases the role of heat production, c) Increases cold-induced diuresis enhancing the development of dehydration and hypovolemia. During the first hour of cold-water immersion urine flow rate can be more than six times normal (approximately 8 ml/min), d) The increased peripheral blood flow (flushing) produced by alcohol is abolished in cold water immersion, e) Fatigue enhances thermoregulatory impairment by alcohol [13] *US Navy* divers obtain 11 percent of their calories from alcohol.

Sidorov et al have put emphasis in the importance of early detection of alcoholism in "risk groups". *Ross* and *Ross* in two questionnaire surveys of 2200 private and professional pilots found that about 16 percent of the respondents admitted to heavy drinking. This last can be defined as an average of more than two drinks daily. In certain countries alcohol is responsible of 35 percent of the aviation accidents. Argentina ranks 7th among the countries which consume more alcohol and Laennec's cirrhosis is its seventh cause of death. There has been a decline in wine consumption but a substantial increase in beer consumption especially in the laeger type. This last has skyrocketed from 8 lt a year in 1980 to 22.9 lt a year a decade later.

The types of drinks are another variable. The *Pisco* (Quechuan Indian for "bird") is a brandy made from muscat grapes which contains 40 percent alcohol. Its consumed mostly in Chile and Peru. The Brazilian cashasha contains 30 percent of alcohol.

The consumption of 5 1/3 standard drinks by a 70 kg pilot eight hours before a flight would result in a blood alcohol concentration at flight time below the specified 0.04 percent by weight (8.7 momol per litre). Yet the literature reviewed by *Modell et al* showed that pilot performance at such a time could be seriously impaired. This is even more dangerous when flying or navigating on cold waters [24,40].

The nutritional factor

When diets are low in carbohydrates (CHO) the subjects find it difficult to maintain an endurance running schedule. Twenty five elite Australian male triathletes training about 3 hours daily reported consuming a diet in which CHO contributed 60 percent of the calories. According to *Steinman and Hayward* depletion of CHO reserves would potentiate rapid cooling[8]. The male personnel serving in the *Royal Navy* may spend up to 60 percent of their services at sea. They obtain their energies from CHO (43 percent)and from fats (42 percent;17 percent of saturated fat).

The circadian rhythms

The rhythmic variations of several hormones, body temperature and sleeping patterns are regulated by changes in the environmental light-dark cycles. The *Seasonal Affective Disorder (SAD)* is most linked with such variations. *Tables 2* and *3* show the characteristics observed in the city of Río Grande (Tierra del Fuego).

Behavior

We can summarize the effects observed in the victims of cold water immersion as: a) Impaired judgment, b) Panic and c) The loss of the "will to live". In the state of panic two dreadful factors are added: a) Confusion and b) Irrationality. Psychological preparation is often the critical factor in survival. *Enander et al* have published in Sweden an interesting paper with theoretical considerations showing the negative effects of thermal stress on various aspects of human performance and behavior.[11]

-The effects of immersion hypothermia on the different organs-

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-The brain-

Hypothermia, under controlled circumstances, results in decreased cerebral requirements thereby the brain is protected from anoxia during a considerable period following circulatory arrest. Notwithstanding immersion hypothermia is quite different from induced controlled hypothermia[32]. The cerebral blood flow declines about 6 percent for each 1°C decrease in body temperature, resulting in a significant depression of sensorium. Loss of conscience is common between 27-30°C [41]. Late onset neurologic deterioration secondary to cerebral edema has also been described. The electroencephalogram is isoelectric below 20°C and pupils are dilated below 30°C. The patient may appear dead as a result of the cardiovascular responses to hypothermia at a time when successful resusitation and complete neurologic recovery is still possible.

The diagnosis of death therefore should not be made until sufficient warming (greater than 32°C) has been achieved. Unfortunately, patients who are brain dead are poikilothermic and therefore extremely difficult to warm.

-The heart-

After the initial few minutes of cold-water immersion a sympathetic discharge occurs which increases the heart rate. As a result of the vasoconstriction there is an increase in the blood pressure and cardiac output. In this moment atrial and ventricular ectopic beats can be observed[16].

Sinus bradicardia and atrial fibrillation are the most common induced dysrhytmias and they usually require no treatment.

This patients are prone to suffer ventricular fibrillation being its causes: a) the rapid changes in pH, b) myocardial hypoxia, c) hyper and hypocapnia, d) hypotension and e) myocardial irritability with increased sensitivity to mechanical stimulation. The most trustworthy indication of an imminent ventricular fibrillation is a prolonged QRS. There are several ECG disturbances.

The **Osborn wave** or J wave is a positive deflection at the end of the QRS complex that is frequently seen in hypothermic patients. Other findings are the prolongation of the PR, QT and QRS intervals and T wave inversion. At 20°C the ECG flattens out. *Figure 3* [37] A full minute or even longer may be required to detect a single heart beat in a severely hypothermic patient. *Martin et al* postulates that it may not be necessary to wait until the heart has been warmed to 28°C to attempt defibrillation [22,23] .

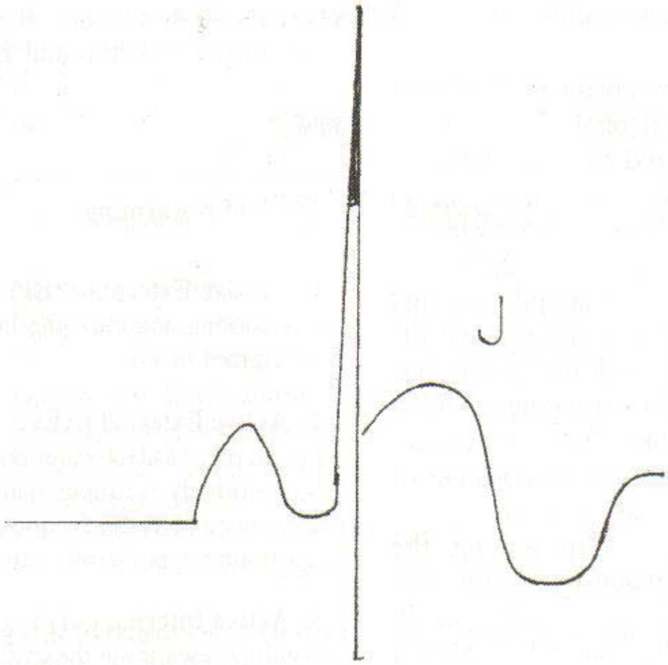


Fig. 3 : The Osborn wave (J wave)
(Adapted from Trevino et al. : The characteristic Electrocardiogram of Accidental Hypothermia. Arch Intern Med,Vol. 127, March 1971).

The pacemakers are not useful for severe sinus bradycardia. Atrial pacemakers won't work because of slowed A-V conduction and ventricular pacemakers may induce ventricular fibrillation.

The victims of cold-water immersions should be handled gently and not subjected to unnecessary resusitation procedures because the cold and bradycardic heart is very irritable and fibrillation is easily induced.

-The vessels-

The marked peripheral vasoconstriction reduces muscle and skin blood flow, shift venous return to deep vessels and enhances countercurrent heat exchange in these deep vessels.

In this way we will have a warm truncal "core" and a "shell" of cold tissues in which will occur a lactic acidosis and some electrolyte changes. Immersion in water below 21-12°C is associated with vasodilation probably due to paralysis of vascular smooth muscle. This vasodilation wouldn't significantly contribute to heat loss.

-The lungs-

The sudden immersion in cold water induces an initial reflex gasp followed by hyperventilation. This initial gasp increases the risk of drowning [7]. The pulmonary hyperventilation increases up to five-fold due to elevation in both tidal volume and respiratory rate [35,36]. Such hyperventilation may enhance reduced arterial PCO_2 with subsequent confusion and increased muscle tetany.

There is a decrease in underwater breath-holding times as well. Development of pneumonia is a frequent complication of immersion hypothermia and may be the result of cold-induced bronchorrhea, aspiration and intrapulmonary leukostasis.

Pulmonary edema has been observed in survivors of severe hypothermia.

-The kidney-

The peripheral vasoconstriction and the hydrostatic squeeze on tissues below the water's surface produce a central hypervolemia which supresses plasma renin activity and plasma aldosterone. All this causes increased urine flow rates.

Immersion hypothermia is associated as well with a shift from inter to intracelullar compartments. Let us remember that bretylium is metabolized by the kidneys.

-The blood-

1. The oxygen dissociation curve is shifted to the left, making it more difficult for hemoglobin to unload oxygen to the tissues.
2. Blood gases present certain characteristics. From a reference temperature of 37°C each 1°C decrease will increase pH by 0.015 and decrease PCO_2 and $P0_2$ by 4.4 percent and 7.2 percent respectively [8]. Uncorrected blood gas levels in a hypothermic patient may therefore be falsely low for pH and falsely elevated for $PaCO_2$ and PaO_2.

3. Most autonalyzers require entry of the body temperature and perform this calculation automatically. If this is not done, the formula for correction is as follows: Add 0.147 pH unit for every degree of Celcius below 37°C. In spite of this, *Orlowski* considers that there is a substantial body of literature documenting that arterial blood gases do not need to be temperature corrected in the presence of hypothermia. He bases his statement in the works of *Rahn*[28] and *Ream*[29].
4. Acidosis may result from elevated PCO_2 as well as poor tissue perfusion leading to lactic acid accumulation.
5. Blood viscosity increases 5 percent with every °C decrease in temperature.
6. *Eastman* and *DeVries* studied in the Antarctica the *Trematomus nicolai* whose blood has antifreezing molecules (glycopeptides) which besides reflecting a miracle of adaptation offers as well interesting medical possibilities [9].

-The liver-

Some authors consider that the detoxification and conjugation functions of the liver are depressed. Low temperatures probably do not produce in the human liver metabolism the effects that are commonly observed in animals. In any case it would be prudent to avoid maximum dose levels of antiarrhythmic drugs which have a hepatic predominant metabolic route like lidocaine hydrochloride. The therapeutic concentrations of this last are 1.55-5.0 F/ml. The therapeutic concentrations of bretylium tosylate are unknown [13].

-The endocrine system-

The cathecolamines and adrenal steroids output are increased during cold-water exposure. Plasma norepinephrine can increase to three times the preimmersion level. The effects of temperature and water immersion on plasma cathecolamines and circulation have been deeply studied by *Weiss et al* from the *University of Heidelberg (Germany)*.

An increase in blood lactate, free fatty acids,thyroxine, triiodothyronine and blood glucose has been observed.

Hypothermia inhibits the release of insulin making tissues refractory to its action and decreases the utilization by the body which results in hyperglycemia.

-The metabolism-

Hypothermia lowers metabolic requirements. At 20°C the metabolic rate is 50 per cent of normal [33].

-The intestinal motility-

The sympathetic nervous system inhibits colonic motility by releasing norepinephrine which: 1) blocks cholinergic synaptic transmission to the myenteric plexus and 2) hyperpolarizes smooth muscle cells.

-The muskuloskeletal system-

The peripheral vasoconstriction which accompanies cold-water immersion is particularly strong in the limbs and as a result temperature may decline quickly in this area. The exposure of the limbs should be considered when using the *SAR Medevac litter* which keeps the patient's head above water in case of mishap.

After the first 5 minutes of immersion, grip strength begins to fall at a rate of approximately 1.8 percent/minute. Conduction velocity decreases in large fibers of the peripheral nerves and twitch time is increased. Low skeletal muscle glycogen levels are associated with more rapid body cooling during water immersion in humans.

Low muscle glycogen levels do not impair rewarming time nor alter after-drop responses during passive rewarming after mild-to-moderate hypothermia. Water temperature can elicit electromyogram alterations through two mechanisms: a) an intrinsic mechanism due to local variation in muscle temperature and b) an extrinsic mechanism acting upon the control system of the muscle contraction. In frigid waters the reduction of circulation in distal extremities, ears and facial prominences and the reduced tactile perception may jeopardize the safety and the mission of a diver. Topical vasodilator ointments have been studied for this cases.

-Clinical considerations-

Table 4 shows the **signs and syntoms** encountered at the various temperatures. *Table 5* reveals the **variables which correlate with death**. *Table 6* presents the **prognostic factors** in submersion accidents according to **Orlowski score** and the **Glascow Coma Scale** [32]. *Table 7* presents the **different types of rewarming**. *Table 8* the **warmed intravenous infusions**. *Table 9* the **treatment of Accidental immersion hypothermia** and *Table 10* a **suggested scheme for dealing with victims in Tierra del Fuego.**

-The prolonged submersions-

Orlowski defines prolonged submersions as an estimated submersion of 15 minutes or more, considering a good outcome when minimal or no neurologic deficit is observed. He published seventeen reported cases (1960-1984) of prolonged submersions with good outcome. All but two victims were males and 13 of 17 were less than 19 years old. Of the recorded water temperatures, all were 10°C or less.

In 10 cases water was ice-covered. Core body temperatures varied from 21°C to 32°C and did not correlated with water temperature, submersion time or body surface area. Methods of rewarming varied considerably and did not seem to correlate with rapidity or ease of resusitation. On June 10th,1986 a 2½-years-old girl fell in a creek near *Salt Lake City* (USA) where water temperature measured the next day was 5°C.

The child was removed from the water 62 minutes after the rescuers received the initial call. This is the longest time ever reported. *Siebke* published another case in Norway[32] . The girl of *Salt Lake City* was in *Glasgow Coma Scale* score of 3, and had a Tre of 22,4°C. She received among other things warmed (40°C) isotonic intravenous fluids. Later she was transferred to the operating room for **Extracorporeal Rewarming (ECR)**.

The ECR was discontinued (total bypass time=53 minutes) when the core temperature reached 37°C. She was discharged after more than eight weeks of hospitalization. A year after the submersion the child was functioning at her age level. On December 10th, 1989 an accident took place at the 200 m deep *Lake Yehuin (Figure 4)* 60 km north of Río Grande (Tierra del Fuego). The tragedy occur between 11 AM and 3 PM. Only four corpses were found of a crew composed of three adults and 8 kids. Casualties most probably have been due to hypothermia. *Figures 4,5 and 6*. On April 15th a 4 years old boy fell in the Northern Dock of Buenos Aires and remained 15 minutes under the waters. He was rescued alive. *(Clarín, April 18th, 1995)*

-The mammalian diving reflex-

The mammalian diving reflex observed in seals and other air- breathing animals acts as an oxygen conserving adaptation in response to submersion and allows prolonged survival by decreasing the oxygen requirements. *Figure 7*. The heart, brain and lungs continue receiving their blood supply while the blood flow to tissues resistant to hypoxia (gastrointestinal tract, skin and muscles) is markedly reduced. There is a significant bradycardia which reduces the cardiac output preventing an excessive rise in blood pressure. The mammalian diving reflex is most active in infants and young children and may not offer much protection for adults[31].

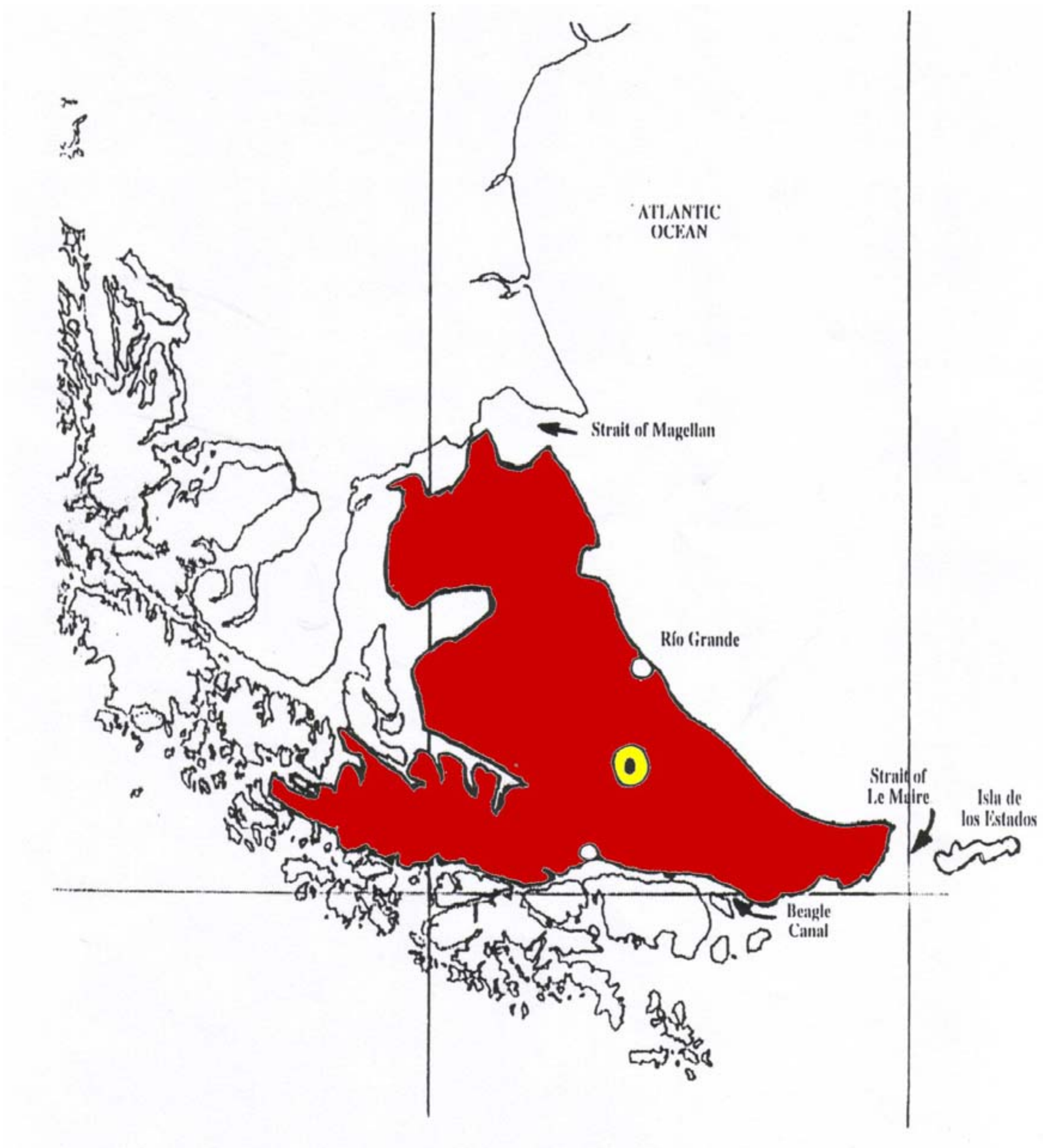


Figure 4-The big island of Tierra del Fuego (Political division is not shown) comprises 20.392 Km and a population (1992) of 69.450 inhabitants .The white “O “ shows the approximate location of Lake Yehuin. (Map modified from Derrotero Argentino-Parte III-Armada Argentina-Servicio de Hidrografía Naval)

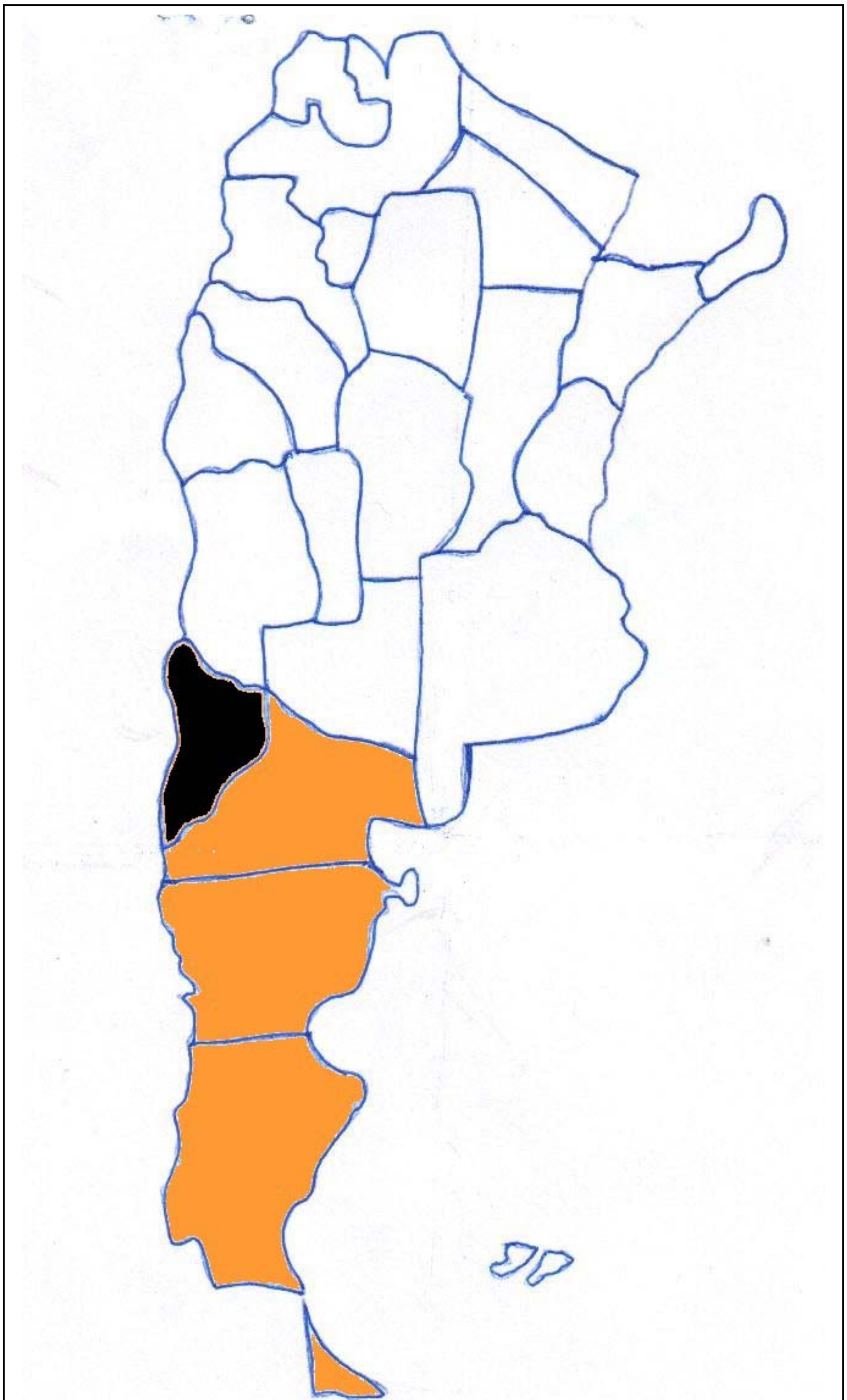


Fig 5-The action of excessive cold environment *(Code E 901.0 of the World Health Organization*) in Argentina. The Patagonian Provinces (Chubut, Neuquen, Río Negro, Santa Cruz,Tierra del Fuego (orange)including Antarctica and South Atlantic islands Comprised 138 cases (31.7% between 1980-1988). The province of Neuquen (pop.1980:90,037) registered 28 cases (black)

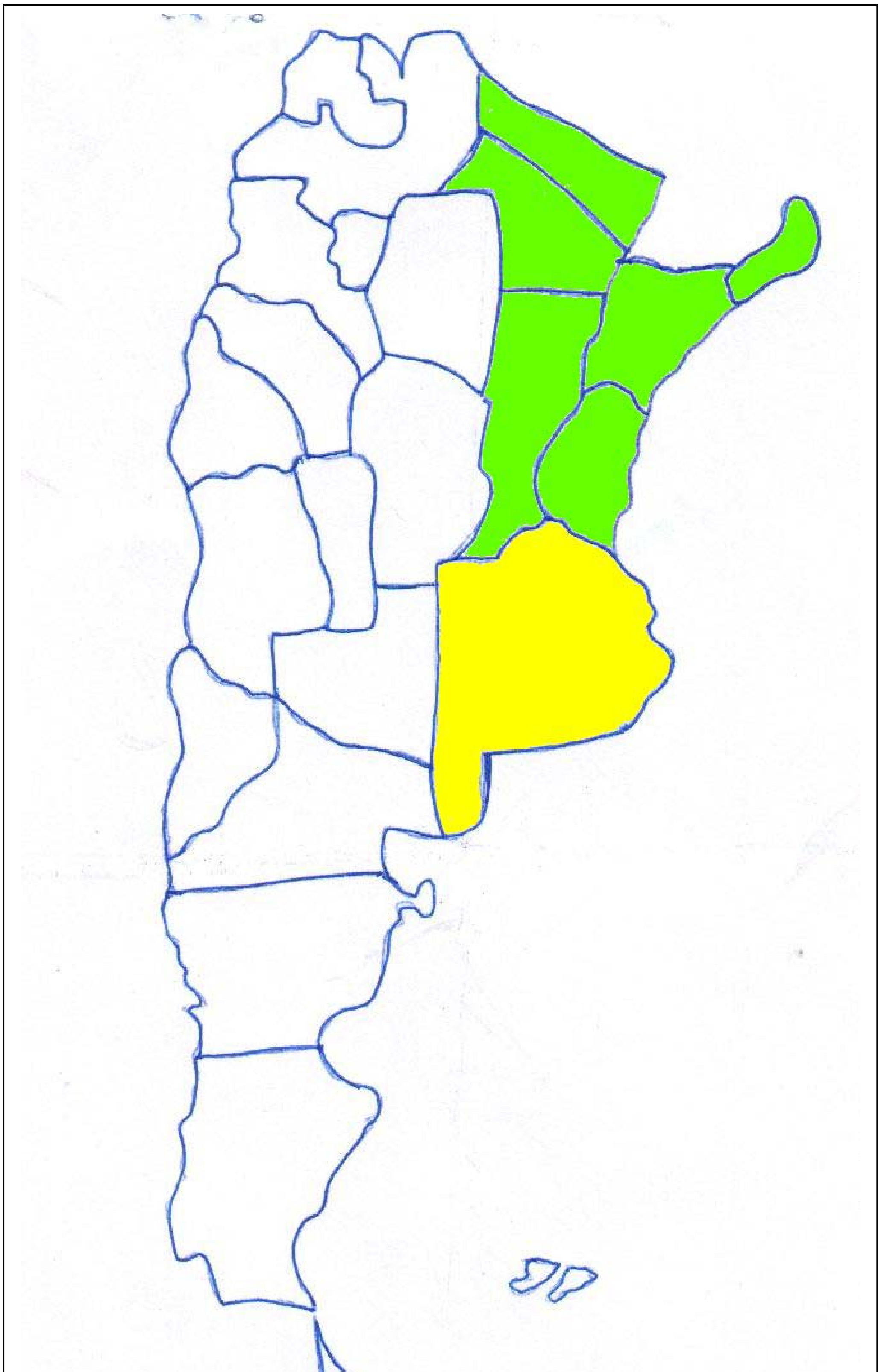
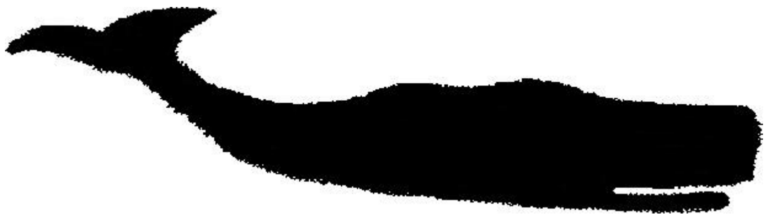


Fig 6-Accidental drowning and immersion in Argentina between 1980-1988.
The littoral provinces (green) registered 24.32% of the cases of accidental drowning and immersion. Buenos Aires alone (Pop.in 1983:11,625,000) presented 983 cases (18,5%) (yellow) (Dirección de Estadísticas de la Salud, Ministerio de Salud y Acción Social, Buenos Aires)



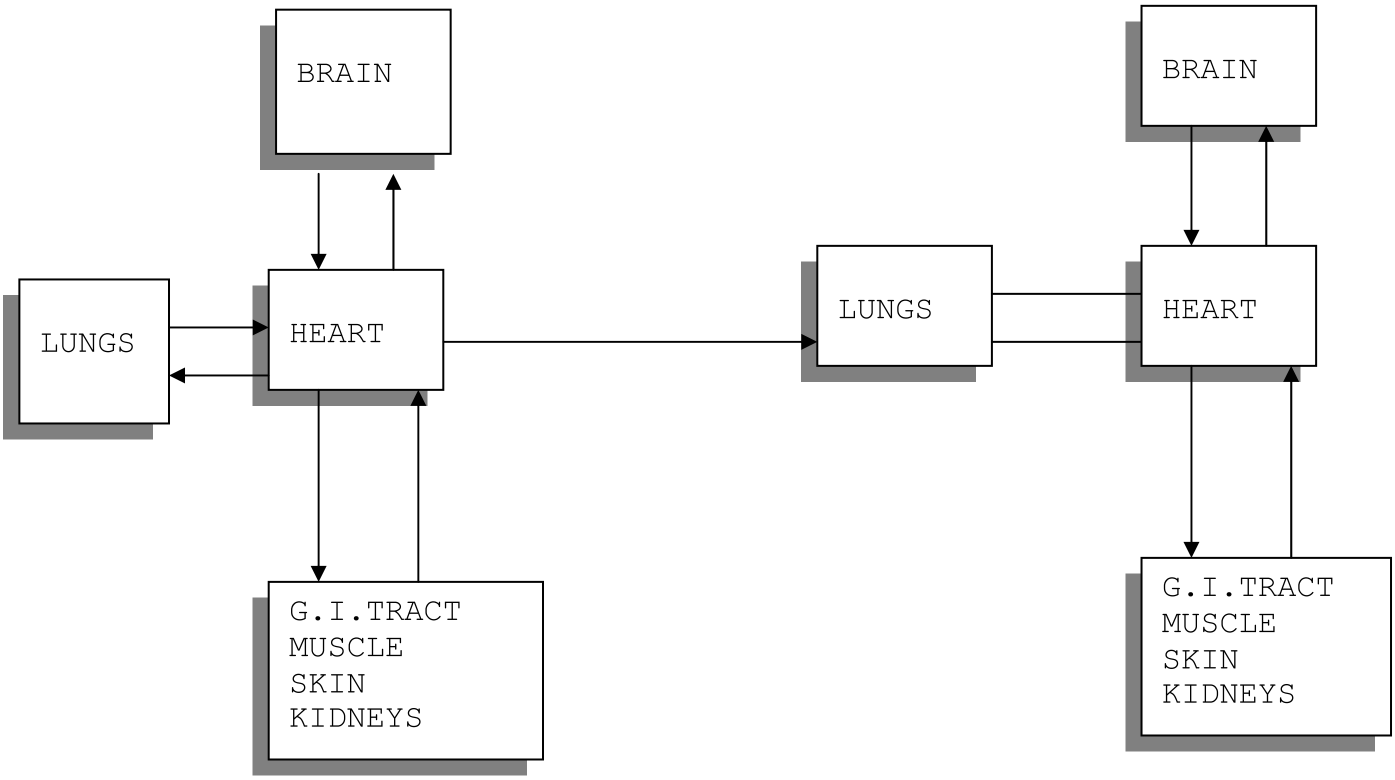


Figure 7-The Mammalian Diving Reflex-The heart, lung and brain continue to be perfused although the blood flow to the rest of the body is reduced.The diving reflex is observed in seals and other air-breathing diving animals.Is most active in infants and young children but may not offer much protection for adults (Sarnaik et al.:Near-drowning:Fresh, salt and cold water immersion.Clinics in Sport Medicine.Vol 5-Nº1,January 1986)

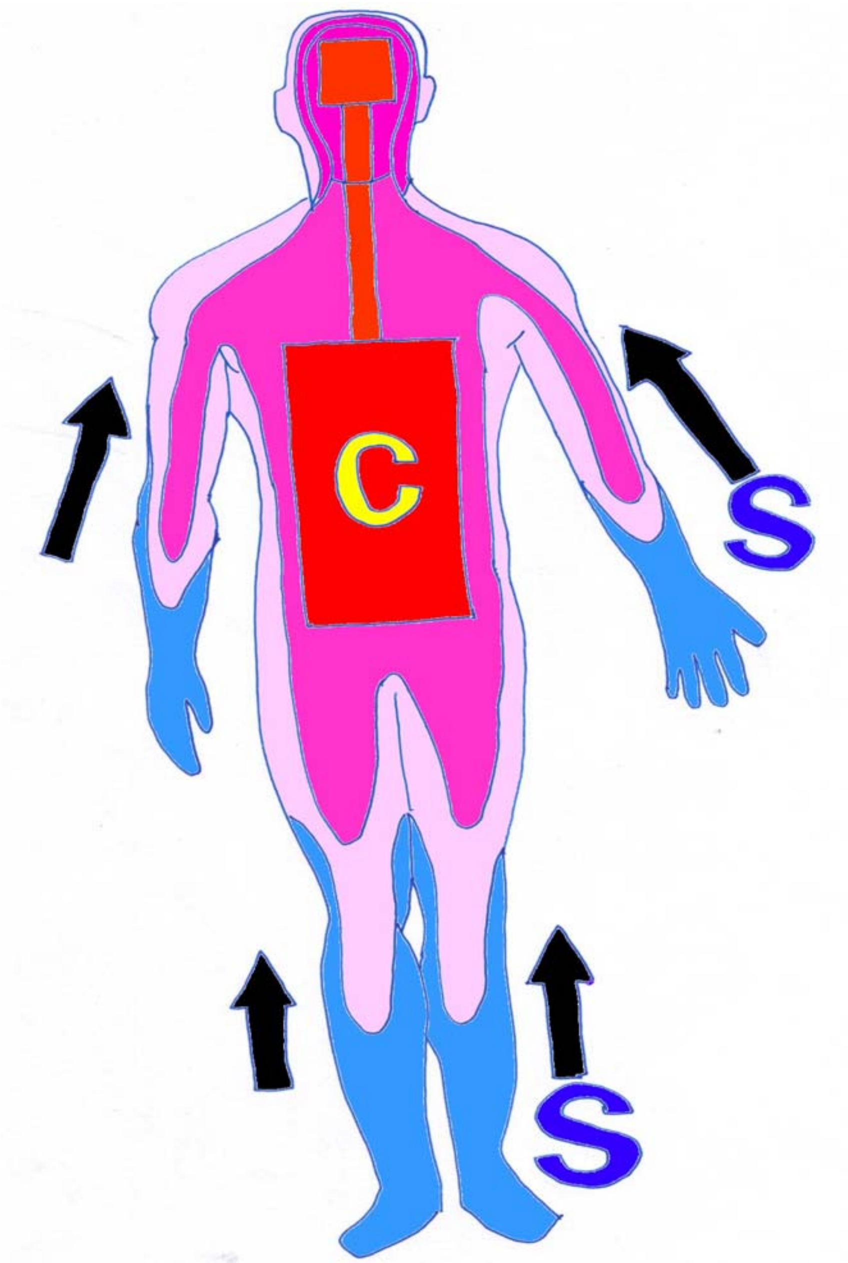


Figure 8-The Afterdrop Phenomenon (C) is the warm core and (S) is the peripheral “shell” (e.g.: skeletal muscle of the extremities). There is a declining gradient of temperature to the skin. Heat continues to be conducted from the core to the shell until stabilization. There is a cold venous return from the shell which reduces core temperatures and is especially evident in esophageal temperatures. This circulation from shell to core could be due to peripheral vasodilation from rewarding.

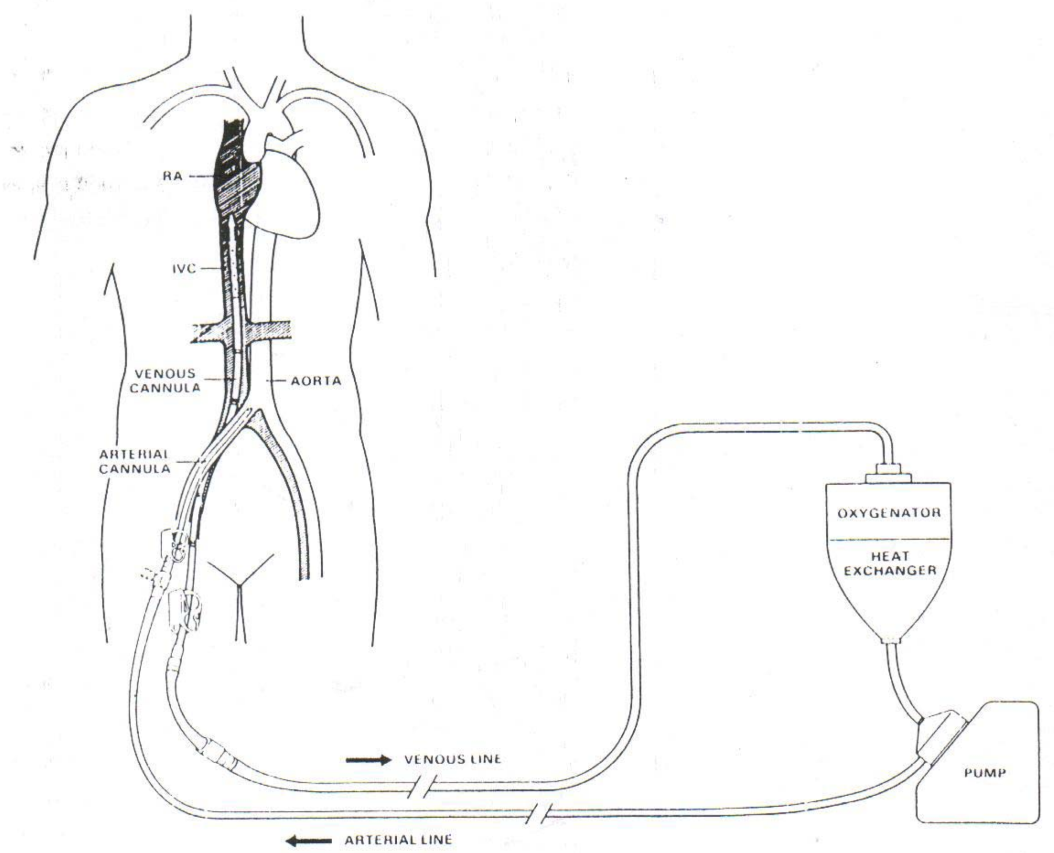
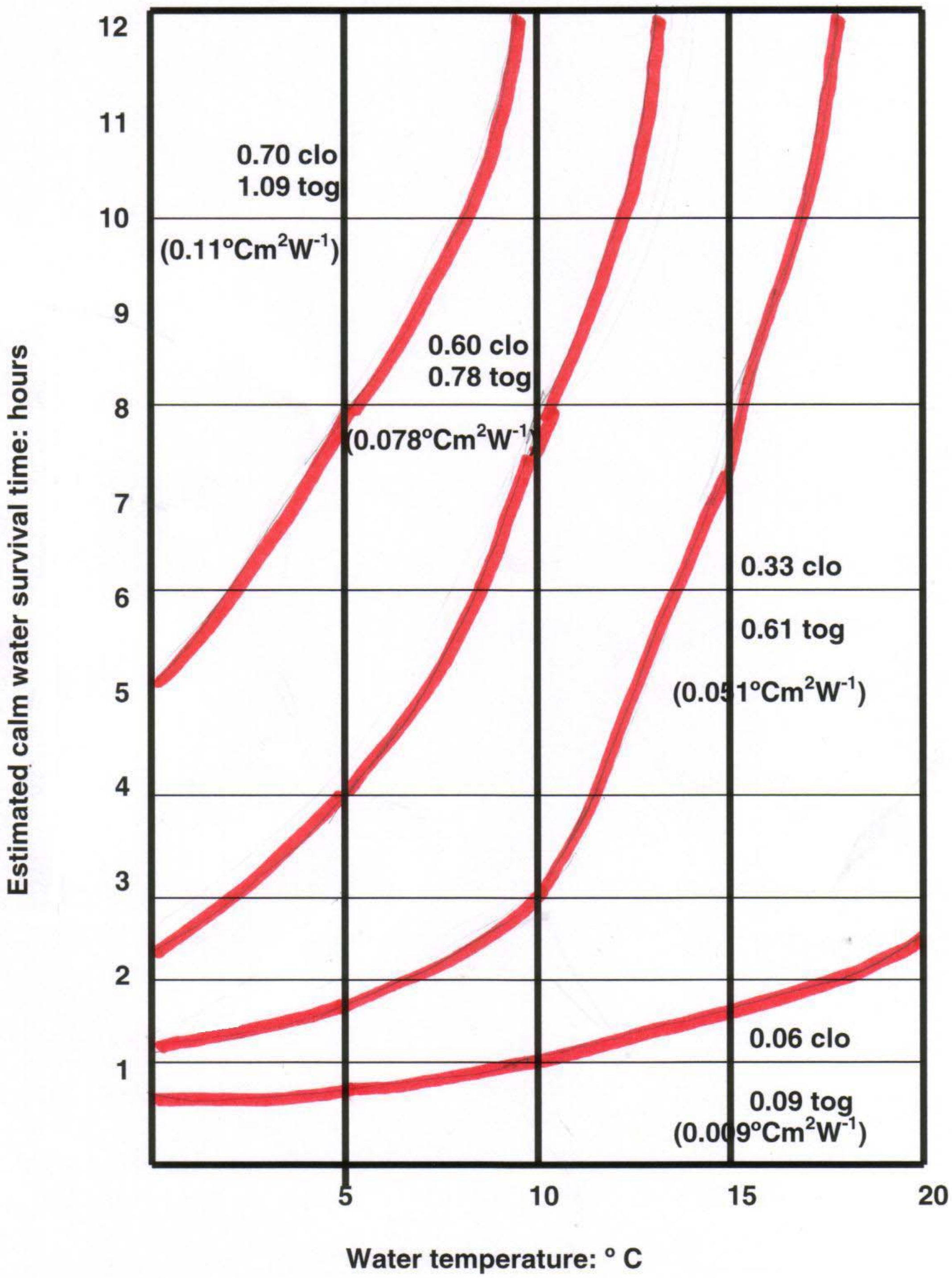


Fig 9-Percutaneous femoral to femoral bypass system for cardiac support and rewarming. Note location of venous cannula at junction of right atrium (RA) and Inferior vena cava (IVC*). (Laub et al.:Percutaneous Cardiopulmonary Bypass for the Treatment of Hypothermic Circulatory Collapse. Ann Thorac Surg 1989;47:608-11)*



Predicted calm water survival time plotted against water temperature for thin individuals (approx. 10th percentile mean skinfold thickness) wearing for levels of immersion clothing insulation. 1 clo=1.55 tog. *Air Standard 61/40A, Technical Basis for specifying the insulation of Immersion protection clothes. Air Standardization Coordinating Committee, May 10th, 1989.*

(Published: Gerding, EC-Accidental Immersion Hypothermia in the South Atlantic International Review of the Armed Forces Medical Services- (Belgium)-Vol. LXIX, 4/5/6-June 15th, 1999)

Fig 11. Sick bay of the MEKO Frigate where active external rewarming and warmed intravenous infusions can be applied to the victims of cold water immersions. The Argentine Navy has the MEKO 360 H2 class Frigates *"Almirante Brown"* and *"La Argentina"*.
(Kindly submitted by Wolfgang Bohlayer, Blohm & Voss GmbH Naval Sales +Marketing, Germany).

-Extracorporeal Rewarming (ECR)-

This method obviously implies a hospital with cardiac bypass rewarming capabilities. The advantages of the technique are: 1) The reinstitution of perfusion regardless of the cardiac rhythm, 2) Reduction of the high blood viscosity associated with severe hypothermia, 3) Rapid restoration of normothermia

The ECR disadvantages are: 1) Lack of general availability, 2) Risks of heparinization, 3) Vascular damage by catheterization 4) Shear stress to formed blood elements, 5) Embolic phenomena. Massive epistaxis and gastrointestinal bleeding have been reported. The main complication uses to be pulmonary edema and there are transient neurological deficits as well. *Figure 9*.

-The afterdrop phenomenon-

This phenomenon consists of a continued core cooling immediately after the removal of the cold-water victim from the frigid environment. It can occur even when the patient is insulated from heat loss and during the early stages of rewarming. *Figure 8*.

The afterdrop may be of few degrees Celcius or more pronounced. Part of this phenomenon could be a measuring artifact and not a true reflection of central venous and myocardial temperature.

Hayward found an afterdrop in rectal and tympanic membrane temperature but not in esophageal temperature while rewarming volunteers.

-Protection of the air crew-

According to *Brooks et al* the Sea King helicopter was most at risk from sea water immersion while the single-engine Otter has been the most vulnerable to fresh water immersions. In the 20 years review of the *Canadian Forces* the time to rescue in all cases was under 3 hours. *Table 11* [2] . This data should be most important for the Argentine naval pilots of the Agusta Sea Kings who have flied so many times over the cold waters of the *Beagle Cannal* carrying medical teams. *White el al* consider that the *U.VIC Thermofloat jacket* is quite fit for pilots in cold enviroments[39] . *Steinman Alan M.et al* have published an interesting paper in 1987 on the buoyancy of anti-exposure garment ensembles[35,36] . There has been considerable discussion among fixed-wing pilots flying maritime patrols about the possibility of substituting a quick-donn suit for the constant-wear variety currently in service.

It's been suggested that the pilot has enough time prior to ditching to scramble into the suit. This could apply to certain Tracker accidents who had a reasonable serviceable aircraft but not where the crew were struggling desperately to keep the aircraft airborne[36,39].

According to *Capitán de Fragata Pereiro,* during the 1982 South Atlantic conflict the crew of the *Argentine Second Naval Air Squadron of Movile Logistic Support* had to choose between using the Anti-Exposure suit and the regular leather flying-jacket which represented so much for them. *Bagian et al* from the *NASA-Johnson Space Center* have studied the effectiveness of the space *Shuttle Launch Entry Suit (LES)* and raft for 24 hours of protection against cold water.

-Suggested basic insulation for seamen on deck-

Immediately over the skin silk, polypropilene or *Capilene* should be used. On top of this one wool, polyester fleece or Thinsulate and over it, and against wind and shed water, it's been suggested garments made of nylon, *Gore-Tex®* or *Supplex®*[3,21] .

Men dressed in water-permeable clothing can be considered almost "nude" when immersed in the cold South Atlantic waters. Even using the right protection water leakage and perspiration reduce the **Clo** value[25,26] . We should bear in mind as well that in the case of the cruiser *"General Belgrano"* some survivors were quite covered by oil which turned them slippery making it hard to haul them into the rafts. In 1989 *Kaufman et al* published an interesting paper on insidious hypothermia during raft use which could also be considered for the case[19] . *Figures 10 and 11*

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Table 1

Variables which determine human cooling rate and/or ability to achieve thermal equilibrium during immersion.*(Nunneley, Sarah A.et al-Brooks Air Force Base-USA)*

ConvectiveCooling
Water temperature
Water motion

Body dimensions
Mass
Surface-to-volume ratio
Subcutaneous fat thickness

Physiological factors (individual variability)
Shivering
Work
Vascular response
Fatigue

Clothing insulation
Thickness and compressibility
Water permeability of fabric
Integrity of seals
Pumping action

Table 2

The sun rise above the horizon at the city of *Río Grande (Tierra del Fuego)*(Lat:53 48s,Long:67 45w)during the different seasons. There's a certain resemblance with the elevations observed at *St John's Newfoundland-Canada.*

Autumn		Winter		Spring		Summer	
Max	Min	Max	Min	Max	Min	Max	Min
36°	13°	36°	13°	60°	36°	60°	36°

Table 3

Average light hours at the city of *Río Grande(Tierra del Fuego)*.Theres a minimum of 8 h 52 min during the winter solstice (June 21st) and a maximum of 18 h 54 min during the summer solstice (December 21st) *(Ing.Christian Rusquellas- Asociación Amigos de la Astronomía-Buenos Aires-Argentina)*			
Autumn	Winter	Spring	Summer
16h 16 m	10h 20 m	16h 43 m	16h 47 m

Table 4

Behaviour of body temperature during cold water immersion with associated signs and symptoms encountered at the various temperatures	
Temperature(in °C)	**Symptoms and signs**
35°C	Confusion
33°C	Shivering decreases and is replaced by muscle rigidity Cardiac arrythmias
30°C	Unconciousness Pupils dilated
28°C	Ventricular fibrillation
25°C	Death-At 20°C the electro-cardiogram flattens out and the electroencephalogram is isoelectric

Table 5

Cold-water exposure and variables which correlate with death

Danzl et al (Crit Care Med 1989 Mar;17 (3):227-31) whose database included 428 total patients visits with 73 deaths within 24 hours, observed through a univariable analysis the following variables correlated with death:

1. Cardiopulmonary resuscitation(CPR)in the prehospital setting
2. Tracheal intubation
3. Nasogastric tube placement
4. Foley catheter placement
5. Elevated serum potassium level
6. Elevated blood urea nitrogen(BUN)level
7. Elevated creatinine level
8. Low hemoglobin level
9. Low core temperature
10. Low systolic or diastolic blood pressure
11. Low heart rate

The following variables were not found to correlate with patient death:
a)Immersion, b)Major trauma, c)Significant illness (e.g diabetes, pneumonia),d)White blood count, e)arterial pH, f)PaCO2,g)Calcium, h)Phosphorus, i) Creatinine kinase, j)Age and k)Sex.

Table 6

Prognostic Factors in Submersion Accidents

Orlowski score	**GCS Glascow Coma Scale**
Unfaborable Pronostic Factors 1.Age <3 years 2.Estimated maximum submersion time longer than 5 minutes 3.No attempts at resuscitation (MTM or CPR)for at least 10 minutes after rescue 4.Patient coma on admission to emergency department 5.Arterial blood gas pH <7.10	**Eye Opening** 1. None 2.To pain 3.To speech 4.Spontaneous **Best Verbal Response** 1.None 2.Incomprehensible 3.Inappropiate 4.Confused 5.Oriented **Best Motor Response** 1.None 2.Extension (descerebrate) 3.Flexion(decordicate) 4.Localizes pain 5.Obeys commands
Score <2 =90% chance of recovery Score <3 =5% chance of recovery	Score <5 =80% risk of poor outcome(death or permanent neurologic sequelae)

Table 7

-<u>Types of rewarming-</u>

1. **Passive External(PE)**: Consists only of protecting the patient from further cooling and allowing his own intrinsic mechanisms to rewarm him (*e.g.*-a waterproof layer).
2. **Active External(AE)**: Application of heat to the external surface of the patient. *e.g:* a) Hot water bottles in neck, lateral and central thorax and groin. b) Body-to-body warming (lateral chest to lateral chest). *Hesslink* has shown the superiority of **radio frequency energy** against hot (41°C) water immersion for rewarming hypothermic patients[17]
3. **Active Internal(AI)**: Application of heat to the core of the patient while avoiding rewarming the external surface *e.g:* a) Heated humidified air at 40°C, b) Warmed intravenous infusions, c) Gastric or colonic lavage, d) Peritoneal lavage, e) Mediastinal lavage, f) Hemodialysis, g) Extracorporeal Rewarming (ECR)

Table 8

-<u>The warmed intravenous infusions</u>-

a) **What to administrate**: Warmed dextrose 5% in water or Normal Saline. Hypothermic victims can't metabolize lactate so **don't administrate Ringer lactate**

b) **How to administrate**: Initially 500 ml fairly rapid and the remainder of the liter over the next hour. Warmed IV solutions can be easily administered in limited spaces such as ambulances or helicopters without reliance on AC current through **portable IV warmers.** This devices warm fluid to 37°C at rates of 60-120 ml per hour and use re-chargeable batteries which provide a minimum of four hours heavy field use. They accept fluids from standard gravity bag or from pressure infusors (flow rate: < 10 ml/h to 120 ml/min). Weigh less than 6 kg and the set up time is less than 30 seconds. This device is currently pending on the US FDA.

Table 9

-Treatment of accidental immersion hypothermia-

A-Position of the patient

1. The patient must be gently placed in a horizontal position. If he is found face down near-drowning should be suspected and managed accordingly.
2. Remove all wet clothing and give a maximum insulation with a waterproof layer.

B-Evaluation

1. Take axillar temperature (The esophageal temperature is more accurate but difficult to do on the field and there is always reluctance to measure rectal temperature). Temperature should be registered every 30 minutes.
2. Remember one is not dead until warm and dead! The resuscitative effort, once it is begun should be vigorous and prolonged. No oral fluid, food or alcohol !
3. A full minute should be allowed to detect pulse and respiration.

   Some helicopters produce 94.9 to 96.4 dB during their manoeuvres al 80-120 knots thus regular sthetoscopes are of a limited value.

   Pulse and blood pressure should be registered every 15 minutes.

   If necessary initiate **ABC's** (Airway, Breathing and Circulation) but remember that an unnecessary CPR may unchain ventricular fibrillation.

C-Action 1.*Core temperature > 30 ℃:*

a)Examine in search of multiple trauma

b)Active External Rewarming

-Hot water bottles

-Body-to-body warming

2.*Core temperature < 30 ℃:*

a) Without cardiac arrest:

1.Active Internal Rewarming

a)Endotracheal or nasotracheal intubation

b)Administrate heated humidified air at 40°C

b) With cardiac arrest:

1.CPR

2.*Defibrillation required:*
2 watt-sec/Kg up to 200 watt-sec.

3.*Drugs required:* Avoid maximum dose levels.

4.**Extracorporeal Rewarming(ECR)** is the metod of choice for severe hypothermia(<28°C) associated with a persistent nonperfusing cardiac rhythm or ventricular fibrillation[5]

Table 10

-A suggested scheme for dealing with victims of Accidental Immersion Hypothermia in Tierra del Fuego-

1.Emphasis is placed on a fast and reliable communication system among the Estancias and between them and the different forces *(e.g: Civil Defense Headquarters, Coast Guard, Police etc).*

2.Quick Search and Rescue (SAR) units with trained teams and capable of delivering Passive External (PE) and Active External(AE) Rewarming on board. This implies the joint efforts of Naval and Coast Guard units. Helicopters are a superb help for this tasks and may be joined by private helicopters of the local petroleum company.
A seaman falling in the stormy waters of the *Strait of Le Maire* and a pilot who had to eject on the *Beagle Canal* should thus receive a immediate rescue and treatment. The same applies to accidents in the fueguinian lakes.

3.A prompt medical information system between all Naval hospitals and main medical departments through a **Wide-Area Network (WAN)** interconnected through a satellite.

4.The victims shuld be able to obtain the benefit of **Extracorporeal Rewarming (ECR)** in at least a main hospital of Tierra del Fuego.

5.There should be as well the possibility of a fast evacuation which could be a non-stop flight to Buenos Aires (e.g: through a *Lear Jet*). Intermediate evacuations could be done with an ARAVA 102 to *Río Gallegos* and later to *Puerto Belgrano* or *Buenos Aires.*
We are dealing with a) Distances and b) Frequent adverse metereological conditions. A non-stop flight with a Fokker 28 from *Ushuaia* to *Buenos Aires* takes 4 hours. This flights used to be done by noble Electra 188. The ARAVA 102, although small and egg-shaped was tested in two wars in Israel(1973 and 1982) and in medical emergencies in Cameroun. Typical evacuation distances have been 360 to 720 km. It may evacuate victims from *Río Grande* (or *Ushuaia*) to *Río Gallegos* who may later be transferred to a larger aircraft.

Table 11

Canadian Forces aircraft types involved in water immersions in the 1962-1982 period

N°	**Jet**	**N°**	**Propeller**	**N°**	**Helicopter**
8	CF-104 Starfighters	5	CSR-123 Otters	9	CH-124 Sea Kings
3	CF-101 Voodoos	4	CP-121 Trackers		
2	CF-5 Freedomfighters	2	CP-107 Argus		
2	CT-114 Tutors				
1	CF-100 Canuck				
1	F-86 Sabre F				

En Argentine on a enregistré, entre 1980 et 1988, 5291 cas de mort par immersion. Le 24,32% du total appartient aux provinces du Litoral dont le 35,19% correspond a des victimes entre 5 et 14 anes. Entre 1976 et 1991, 56 naufrages ont ete enregistres au bord de cotes de la Patagonie dont 42,8% etaient des bateaux de peche et des bateaux de charge. Le 30% de ces bateaux ont echouent et un seul a coulé. Le 51,78% des cas ont eu lieu pendant les mois d'automne et d'hiver. Pendant le conflict de l'Atlantique Sud qui s'est produit en 1982 on a enregistre plusieurs cas de mort au contact de l'eau froide de la mer, mais probablement, le plus representatif ait ete le coulement du Crucero *ARA "General Belgrano"* oú le 15% des pertes ont ete dues aux blessures et a l'evacuation posterieure en radeau[40]. L'article propose l'actualite du schema d'hipothermie globale par accident d'immersion (HGAI).