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ELECTROFISHING ELECTROCUTION: CASE STUDY IN FORENSIC MEDICINE

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Abstract: Electrofishing is a fishing method allowed in our country only for research purposes. Law prohibits the use of this method for fishing. However, many anglers use the method to catch fish from private ponds for marketing and consumption. The method is not so harmful to fish as we will see, but, in case of non-compliance or ignorance of the method of correct use of the device, it can result in the death of the individual or individuals involved in their use for the desired catch. The article presents the case of 2 brothers, aged 47 and 50 respectively, who died few minutes one after each other in close vicinity, due to the use of a partially improvised electrofishing installation and non-compliance with electrical safety measures. Measures well known to researchers practicing this method for scientific purposes, in accordance with the law in force on the territory of our country.

Keywords: electrofishing, electrocution.

INTRODUCTION

Electro-fishing is the method of passing electricity through water to stun fish to catch them. The stunned fish float to the surface and they are collected using a dip net. In a properly equipped boat, the hull of the boat acts as the cathode and the wires dangling from booms on the front of the boat act as anodes. When the fish enter the zone of influence of the system, the swimming is inhibited at first, but is stimulated once the fish come closer to the anode. This phenomenon "forces" the fish to swim towards the anode until it is stunned. Our country prohibits the use of this method except for scientific research and there are not frequent the cases of death among fishermen using such accessories due to illegal fishing.

In our research we found only case presentations, without having statistical data about them, but only one article showed a reference about electrofishing. The others article were about accidents that occurred during fishing with normal methods [1, 14].

Today's fishing rods are built from lightweight durable materials such as fiberglass or carbon, fiber-commonly called graphite. Carbon fiber is a material consisting of fibers about 5-10 μm in diameter and composed mostly of carbon atoms.

The passage of electrical current may leave no visible mark on the skin, may cause burns, or through the body can cause organ damage, from loss of consciousness to cardiac arrest or other injury. In some certain circumstances, even a small amount of electricity can be fatal [2].

This report describes two fatal cases of two brothers, caused by an illegal fishing practice involving an electro-fisher SAMUS 725 MP [3] (Fig. 1).

CASES DESCRIPTION

First case, a 47-year-old male fatally electrocuted while fishing using electricity diverted from a fishing converter connected to a car battery and a fishing rod made from carbon fiber whose one end of the rod conductor was attached to the fishing converter.

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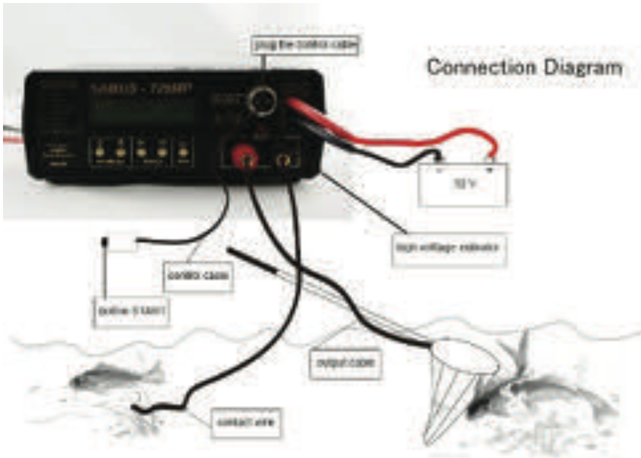

Figure 1. Electrofishing setup with SAMUS 725 MP.

Figure 2. The pond.

Figure 3. The boat.

At one end of the other wire, he attached a metal hook connected to the fishing converter and the other end into the water and a third conductor connected to the fishing converter with one end made from a plier attached to the car battery. The fourth wire connected to the fishing converter and the free end was hold in the right hand to change the intensity.

All these pieces of evidence were find in the boat. The deceased found with the body in the boat, holding between that and the abdominal wall the rod. His head and the right hand were above the boat, into the water, holding in this hand the free end of the fourth wire, the trigger. Even after death, the switch remained closed, so that the current continued to flow by heating the carbon rod, which caused his electrical mark on the abdominal wall.

After that, the 50 year old male (case 2) entered into the water to see what was happening with his brother (from case 1), who did not answer, and when he approached the boat he shouted that he felt the electric shock and then fell into the water. Apparently, the later deceased drowned after has been immobilized by electric shock in the same way as his brother.

At autopsy, on external examination, no injury produced by electricity noted on the body. On internal examination, the evidence of drowning and prolonged submersion was present. The deceased had apparently drowned after incapacitated by electric shock.

MATERIALS AND METHODS

We performed to a complete forensic examination, ranging from the anamnestic, criminology data, collecting data from the accident scene, to the final

Figure 4. The improvised electrical installation.

step: full forensic autopsy of the body of the deceased.

A container of water was collected from the accident scene for determining electrical conductivity. The analysis of the water samples taken from the pond performed within the Biochemical Analysis Laboratory within Constanta County Health Service revealed water pH (7.48), salinity and ionic concentration of significant ions were determined. Water salinity: 0.63 determined by the method of constant physical-chemical volumes.

Measurement of the water conductance performed within the Physics Laboratory of the Faculty of Applied Sciences and Engineering from University "Ovidius" of Constanta.

The accident scene

The pond depth of 1-1.5 meters, a length of 1000 meters, width of up to 500 meters. The fishing boat was made of fiberglass, with a length of 5 meters, width of up to1.5 meters, found at 10 meters from shore, with an improvised electrical installation in the boat (Figs 2 - 4).

In these cases, were identified the place, the equipment used and the impressed shape of the rod to the skin (Fig. 5: A, D)[4].

In drowning cases, after water inhalation, the lungs may be overinflated ("emphysema aquosum"), they can be crepitant and they can fill the thoracic cavity, but on the other side, they can have a normal weight in cases of drownings after cardiac arrest reflex or vaso-vagal reflex . They can present some areas of subpleural petechial haemorrhages after the rupture of the alveolar walls and subpleural bullae of emphysema (Fig. 5: B, C, E, F).

In these cases, the signs of drowning were more pronounced on corpse found in the water. The person from the boat was short-circuited which led to the loss of consciousness and then stucked with his head in the water and implicitely death by drowning.

RESULTS

Working hypothesis

Based on the experimental values provided by the Electrostatic Discharge Association (ESDA, 2010, Rome, New York) [8-10], we can estimate the range of the values for the electrical quantities involved in the situation presented above, as follows:

Electrical resistance of the skin in contact areas 1, 2:

$R_{c1} \in [200,600]\Omega; R_{c2} \in [200,600]\Omega$ (1)

Resistance of the human body between points of contact:

$R_{c1-c2} \in [40,100]k\Omega$; (2)

Channel 1 resistance (through the human body):

$40.4k\Omega \leq R_{HB} \leq 101.2k\Omega$ (3)

Considering the value range for the frequency of the device used $f \in [5,100]Hz$, considering the electrical capacity of the human body between the two contact points $C_{HB}=100\ pF$ and the dependence of the capacitive reactance of the frequency and capacity, $X_{CHB}=1/2\pi f C_{HB}$ we can estimate the value range of the capacitive reactance of the human body and, implicitly, the value range of the electrical impedance of the human body:

$X_{CHB} \in [16,318]M\Omega$ (4)

Considering Diagram 2 in the Figure 1, we will express the impedance of the human organism between the contact points for the applied voltage:

$1/Z_{HB} = \sqrt{(1/(X_{CHB}^2)+1/(R_{HB}^2))}$ (5)

Comparing the value of electrical resistance and the value of capacitive reactance of human body, it resuls that for the frequency range used by SAMUS 725MP, the electrical impedance of channel 1 can be approximated $Z_{HB} \cong R_{HB}$ ($R_{HB} \cong X_{CHB}$), so the value range for electrical impedance of human body between contact points can take values in the range: $Z_{HB} \in [40.4,101.2]\ k\Omega$.

Let us now evaluate the effective intensity of the electric current on channel 1

$I_1=U/Z_{HB}=U\sqrt{(1/(X_{CHB}^2)+1/(R_{HB}^2))} \simeq U/R_{HB}$ (6)

The range of values for the current intensity on channel 1, in the hypothesis $U \in [0,1.5]kV$ is $I_1 \in [0,37]\ mA$: If we take into account the hypothesis of wet contacts (palms), then the actual value of the current on channel 1 (human body) will be in the range [0,40] *mA*.

Comparing with the maximum value of the current intensity through the human body (37 mA), correlated with the time interval corresponding to the exposure, we find that the effects on the body are [11, 12]: increased blood pressure, shortness of breath, temporary cardiac arrest, followed by irregular functioning and transition to heart fibrillation.

Channel 2 is represented by the metal conductors, the carbon fiber rod section.

The potential difference applied to this channel is the same as in the case of channel 1, but the behavior of this channel is practically purely resistive. We will

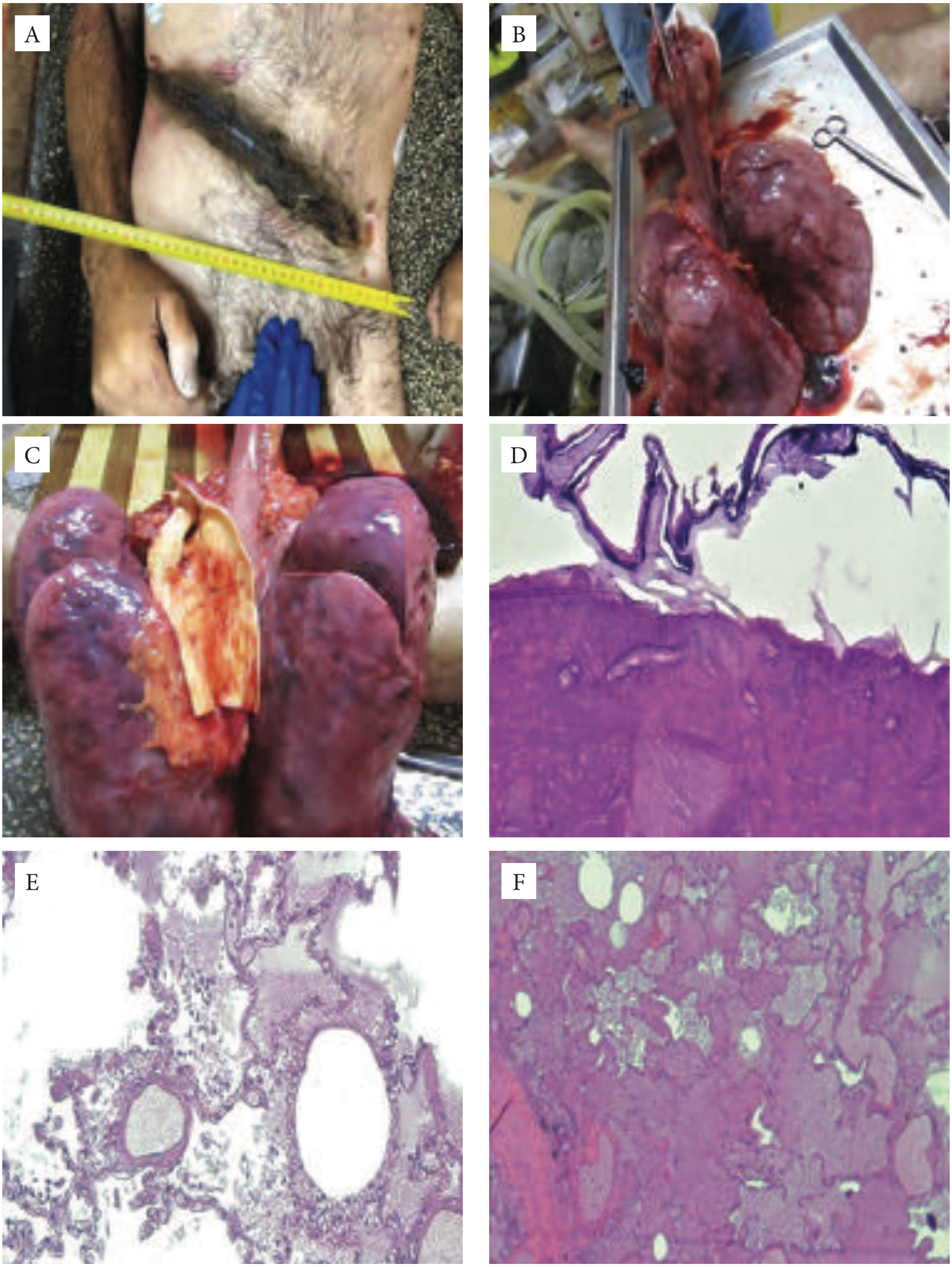

Figure 5. Anatomical and histological aspects of diagnostic tissues found during autopsy. A. Electrical mark on the abdominal wall. B. The lungs of 47-year old male found in the boat. C. The lungs of 50-year old male found in water. D. Intraepidermal cleft formation, coagulative necrosis in the epidermis, basal cell layer with nuclear elongations (arrow), collagen fibres fragmentation (10x, H&E). E. Alveoli with various sizes, some over-distensions, itralumenal blood cells, alveolar edema (10x, H&E). F. Increased distension of the alveoli, thinning of the alveolar septa, with numerous blood cells and marked edema (10x, H&E).

further evaluate the electrical resistance of this channel (R_{CR}).

The conductive element is made of steel, of geometric dimensions: length $L=1,3\ m$, diameter $D = 8\ mm$, resistivity $\rho_{steel} = 4,60 \times 10^{-7}\Omega m$ at the reference temperature $t_{ref}=20^oC$.

The electrical resistance at 20°C can be expressed by the relation and the average electrical resistance of channel 2 until reaching the stationary heat transfer temperature is:

$$\bar{R}_{CR}=R_{CR}^{20}\ [1+1/2\ \alpha(t-t_{ref})]=\rho\ L/S\ [1+1/2\ \alpha(t-t_{ref})] \quad (7)$$

Noting with $d_{steel}=7850\ kg/m^3$, the density, with $c_{steel}=490J/kg \cdot K$, the specific heat of the steel and noting with $\eta=0.1$, the fraction of the heat released by Joule effect absorbed by the steel conductor, with, the time interval until reaching the stationary thermal equilibrioun results that:

$$Q_{steel}=\eta Q_{Joule} \quad (8)$$

or

$$d_{steel}\ SLc_{steel}\ (t-t_{ref})=\eta\ (U^2\ \tau)/\bar{R}_{CR} \quad (9)$$

By replacing equation (7) in equation (9), we obtain:

$$d_{steel}\,\rho_{steel}\ L^2\ c_{steel}\ (t-t_{ref})[1+1/2\ \alpha(t-t_{ref})]=\eta U^2\ \tau \quad (10)$$

Noting with $x=t-t_{ref}$ and with $a=(\eta U^2\ \tau)/(d_{steel}\ \rho_{steel}\ L^2\ c_{steel})$, the equation (10) becomes:

$$1/2\ \alpha x^2+x-a=0 \quad (11)$$

The positive solution (with physics significance) of equation (11) is:

$$x=t-t_{ref}=(\sqrt{(1+(2\alpha\eta U^2\ \tau)/(d_{steel}\,\rho_{steel}\ L^2\ c_{steel}))}-1)/\alpha \quad (12)$$

From equation (12) we can evaluate the temperature at which the stationary heat transfer between channel 2 and the external environment is established: t~581°C.

As there was direct contact between the victim's abdomen and the section rod for tens of seconds (after the rod reaches 581°C), a thermal burn occurred in the contact area.

Channel 3 is represented by the ion channel, which should have ensured the electro-narcosis of the fish in the pond. Based on the definition of the conductivity σ of the aqueous solution $\sigma=1/\rho=1/R \cdot l/S$ we will represent the constant of the cell C, expressed by the relation $C=l/S$ which allows the expression of conductivity of the aqueous solution as: $\sigma=1/\rho=1/R \cdot l/S=C/R$.

For the pond water, based on the analysis performed by Physics Laboratory of the Faculty of Applied Sciences and Engineering from Ovidius University of Constanta the salinity of 0.63 g/l and Ph of 7.48 was obtained, and the concentrations of the main ions are in Table 1.

Conductivity of the aquatic environment: $\sigma=0.342S/m$

We evaluate the constant of the electric cell considering that the length of the immersed electrodes is l=0.5 m, their area is $S=12.56 \cdot 10^{-3}\ m^2$, while the ion channel resistance is:

$$R_{ionic}=1/\sigma \cdot l/S=1/0.342 \cdot 0.5/(12.56 \cdot 10^{-3})=116.4\Omega \quad (13)$$

The intensity of the electric current on all ion channels determined by the immersed electrodes, in the conditions of the potential difference applied between them in the field can be estimated in the interval $I_3 \in [0,12.88]A$.

Table 1. Concentration of main ionic species in the pond water

Ionic species	Concentration (mg/L)
Cl^-	386.1
Ca^{2+}	44.88
Mg^{2+}	29.18
Na^+	250.48

Second case

With the penetration of the second person, also uninsulated, into the water, one of the ion channels formed a closed contour through the person's feet. The intensity of the current corresponding to the blue channel in the figure was in the range [30,80]mA, which determined the same sequence of manifestations as in the case of the first person (increased blood pressure, shortness of breath, temporary cessation of the heart, followed by irregular functioning and transition to heart fibrillation) [13].

DISCUSSION

The macroscopic morphological changes due to the effect of the electric current represented in the present article are mainly in the skin level. The skin lesions depends on density of the current passage, the conductivity, time of exposure, resistance, voltage and they can be represented by small burns to carbonization of the body [5, 6].

In electrocution, the current enters the body at one point (the entry site, often the hand) and then leaves it at an exit point (often to the feet). The mechanism which leads to deaths can be cardiac arrythmias, ventricular fibrillation ending in an asystole, respiratory paralysis from spasm of the thoracic muscles, tetanic

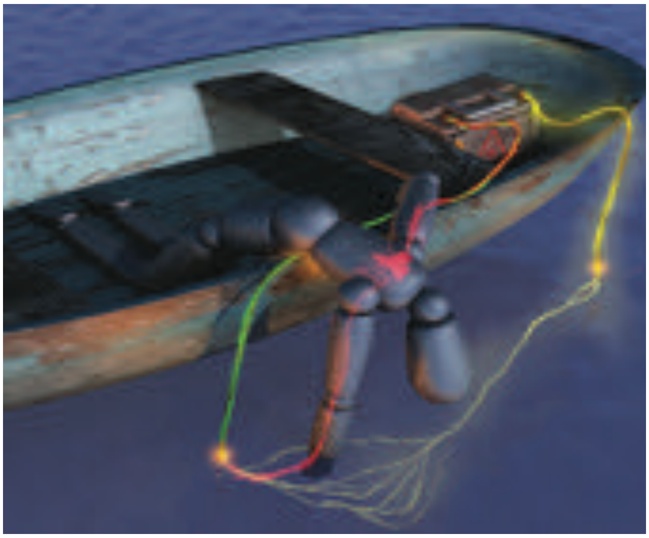

Figure 6. Geometric sketch of the accident.

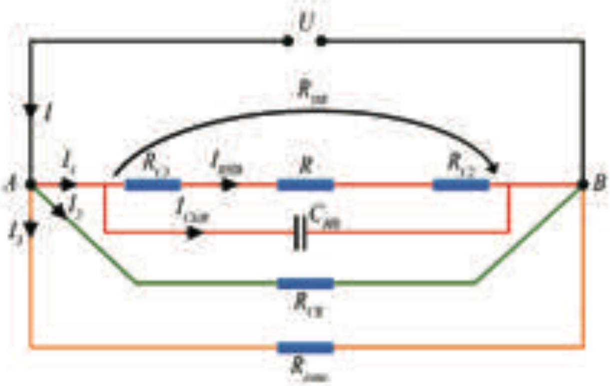

Figure 7. Equivalent electrical diagram.

Figure 8. Current channels after the second person enters the pond.

muscle spasm which make the victim unrelease the live conductor. If the current passes through the cefalic extremity, his effect is directly to the brain stem so the cardiac and respiratory centers are paralyzed.

Furthermore, we know that the direct current is less dangerous than alternative current. According to Ohm's Law, which use potential difference, current and resistance, explaineds what relevancy of electrical has to the biological damage [7].

In order to prove which was the main cause of the accident we have studied from physics point of view the hole process which has led to the death of the brothers. The equivalent electrical diagram of the currents created by the source of power used by the anglers to catch the fish has been represented in Figs 6 and 7.

In the physics study, we started from the simplified electrical scheme in which we considered three electrical current channels. Channel 1, crossed by the current of effective intensity, through the victim's body; channel 2, crossed by the current of effective intensity, through the rod section and through the hotel conductor; and channel 3, through the aquatic environment between the two artisanal electrodes.

In conclusion, after analyzing the equivalent circuits of the elctrofishing device, the given situation of the two fishermen, the position in which they were found by investigators, analysis of electrical and chemical parameters of water samples, measurements of electrical capacity of the elements involved according to the data technical specifications, electrical conductivity, resistance of the equipment and in accordance with the results of the forensic autopsy and the histopathologically examination of the corps (performed by the team of forensic medical doctors of the Department of Forensic Medicine operating under the tutelage of "Ovidius" University of Constanta), we can conclude:

The death of the first individual in the boat occurred due to the fact that the trigger was not isolated, at the closure of the embodiment the fisherman was short-circuited, the current that passed through it led to increased blood pressure, loss of respiratory capacity by neuromuscular blockage caused by short-circuit current, which led to the loss of consciousness. The loss of consciousness led to his fall with his head in the water and implicitely death by drowning.

The second person was electrocuted, this time due to the fact that he enteres the water without protective equipment, being short-circuited on the lower part of the body, the entry and exit points of the electric current were the fisherman's feet.

From the mathematical calculations based on the modelling of the circuit portions that constituted the ensemble responsible of the death of the two individuals, results currents of intensities higher than 35 mA, intensities that are responsible for the installation of all above mentioned sensations, according to [11,12], namely the increase of the blood pressure, distorted heart rate, respiratory arrest. Loss of consciousness followed by drowning in this case.

Conflict of interest

The authors declare that they have no conflict of interest.

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