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Swimming and Loss of Consciousness

T. Suzuki, N. Ikeda, K. Umetsu, and S. Kashimura

Dept. of Forensic Medicine, Yamagata University School of Medicine, Yamagata 990-23, Japan

Summary. Under certain circumstances, even a good swimmer may drown during swimming exercise. Two cases of drowning, a survivor and a dead, during swimming exercise in swimming-pool are described. These cases and experimental researches with dogs indicate that the initial aspiration of water may cause extremely low heart rate and low blood pressure by reflex vagal inhibition, which deprive a good swimmer of his consciousness and make him drown.

Key words: Loss of consciousness – Drowning, sudden death

Zusammenfassung. Unter bestimmten Umständen kann auch ein guter Schwimmer beim Schwimmen ertrinken. Zwei Ertrinkungsfälle, ein Überlebender und ein Toter, beim Schwimmen im Schwimmbad werden beschrieben. Diese Fälle und die tierexperimentellen Versuche mit Ertrinken bei Hunden zeigen, daß die initiale Aspiration des Wassers eine exzessive hypotonische Krise mit deutlich unter das Ausgangsniveau gesunkener Herzfrequenz durch Reflex-Vagusinhibition hervorrufen kann, die einen Schwimmer ganz plötzlich und kampflos durch Bewußtlosigkeit untergehen läßt.

Schlüsselwörter: Bewußtlosigkeit – Ertrinken, plötzlicher Tod

Drowning is usually associated with the non-swimmer or the inexperienced swimmer. It has been emphasized that many people who were either good or very good swimmers died in the cold water [1]. Keatinge and Hayward [8] suggested that the cooling of the trunk, particularly if the head is cooled as well, can occasionally induce sudden death from ventricular fibrillation in susceptible individuals. Alcohol seems to increase the risk of this type of sudden death, possibly by flushing the skin and increasing the shock on immersion [2, 3, 9]. In 1961, Craig [5, 6] reported that under certain circumstances, a person swimming under water may lose consciousness and drown. He suggested that hyperventi-

Offprint requests to: T. Suzuki, MD (address see above)

lation preceding breath-holding and exercise may delay the sensation of the urge to breathe and the O_2 may decrease to a degree incompatible with high-level cerebral function before the partial pressure of CO_2 increases significantly.

Recently, we examined a boy who was known to be a good swimmer and drowned in a swimming-pool during school swimming exercise without any underlying illness. The drowning occurred under conditions that suggest that the victim may have lost consciousness before he died. Furthermore, we have been able to obtain valuable information about a good swimmer who survived after loss of consciousness during swimming exercise in a swimming-pool. It was difficult for us to understand how these victims lost consciousness during swimming without any such possible conditions that are described above. In connection with these two cases, we simulated the drowning in a series of laboratory experiments and were hence able to offer a reasonable explanation of the pathophysiology of loss of consciousness during swimming.

Case Report

Death Case

The evidence reported about this case is only circumstantial. This case of drowning may be said to have occurred under conditions that show that the victim may have lost consciousness before he drowned.

A 11-year-old boy, who was known to be a good swimmer and to be in good condition, was swimming in a swimming-pool containing water with a temperature of approximately 27° C. He was known to intend to swim two lengths of the pool after a certain period of rest. He had swum in this pool without difficulty earlier that day. There were many classmates in the pool during this period. A classmate noticed suddenly that the boy lay prone on the bottom of the pool. He was pulled out almost immediately. The maximum time he could have been there was no more than several minutes. He was clinically dead and his skin was ashy, his pupils fixed and dilated, and there was no sign of a pulse or breathing. External cardiac massage and artificial respiration were immediately started by some trained people standing by the swimming-pool and were continued according to normal practice for about 1 h without effect.

Postmortem examination revealed nothing but lungs which were "full of water". There were no contents of stomach in the airway.

Survivor Case

This case was witnessed thoroughly. The survivor and the eye-witnesses were interviewed by us, and details were readily obtained.

A swimmer, a 10-year-old boy, set as his goal swimming on the surface over a 50-m distance in a swimming-pool. A person watching his swimming reported that nothing seemed to be amiss until he reached the goal, namely one side of the swimming-pool. However, at the moment when he touched the side of the swimming-pool, he floundered suddenly and sank. His actions in the water were said to be wild and ineffective until he submerged. However, the person watching the boy's swimming could not understand what had become of him. Another person who had been standing near the boy's goal in the swimming-pool noticed suddenly that the boy was lying still on the bottom of the pool and wondered why the boy was lying under water. Immediately, after being sure that the boy was drowning, he pulled the boy out of the water. The boy was unconscious and flaccid when taken out of the swimming-pool. At that moment, the boy coughed out a small amount of water and began to respirate spontaneously. No artificial resuscitation was necessary. The coughing out of an amount of water was a hint that he had aspirated water. Several seconds after the beginning of respiration, the boy regained consciousness. The last event which the boy could remember was intending to touch the side of the pool.

Material und Methods

Experiments were carried out on 30 healthy mongrel dogs. The animals were anesthetized by slow i.v. administration of 25.9 mg sodium pentobarbital/kg b.wt.. They were placed in supine position on the table with their legs fastened to it. The trachea was intubated with an endotracheal tube, and the animals were allowed to breathe spontaneously. The endotracheal tube was connected to a reservoir containing a measured quantity of fresh water to allow aspiration of water. To avoid variable results obtained with the use of general anesthesia during the experimental drowning, aspiration of water was allowed for 3–12 h after the administration of sodium pentobarbital, when the anesthetized animals recovered fully from the effects of the anesthetics. The blood pressure was recorded through a polyethylene catheter threated into the femoral artery. A continuous record of respiration was obtained by means of another polyethylene catheter introduced into the esophagus to register the intrathoracic pressure. Electrocardiogram and electroencephalogram were also registered.

Results

In the series of experiments on the process of drowning, it was found that there were two types of drowning.

In *type I drowning* which was observed in most of the experimental animals, the sequence of events was as follows. When fluid was introduced through an endotracheal tube into the trachea, one or several inspiratory and expiratory movements occurred, and aspirate of some volume of water was followed by cessation of the respiratory movement. This period of initial apnea was replaced by gasping of 1–2 min and then followed by another cessation of respiratory

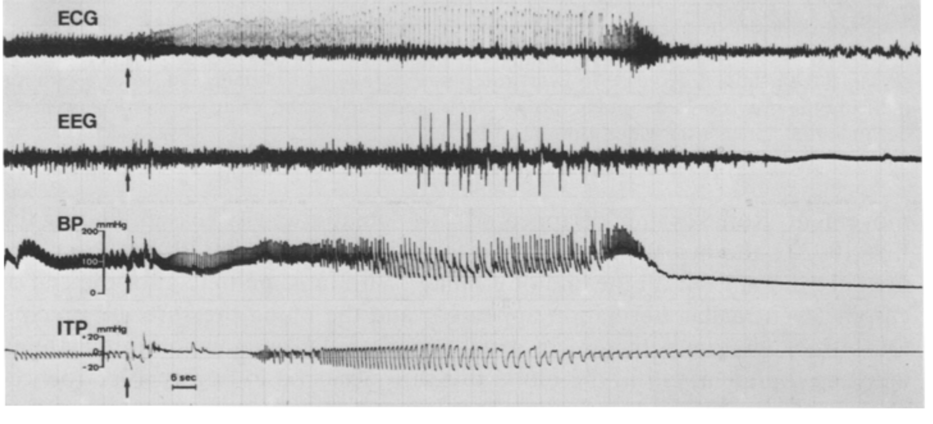

Fig. 1. Typical record obtained during type I drowning. No fall in blood pressure occurred immediately after initiation of water aspiration. It occurred with ventricular fibrillation at the end of gasping, which was followed by disappearance of electroencephalogram. *ECG* electrocardiogram; *EEG* electroencephalogram; *BP* blood pressure; *ITP* intrathoracic pressure; *Arrow* (↑) the starting point of water aspiration

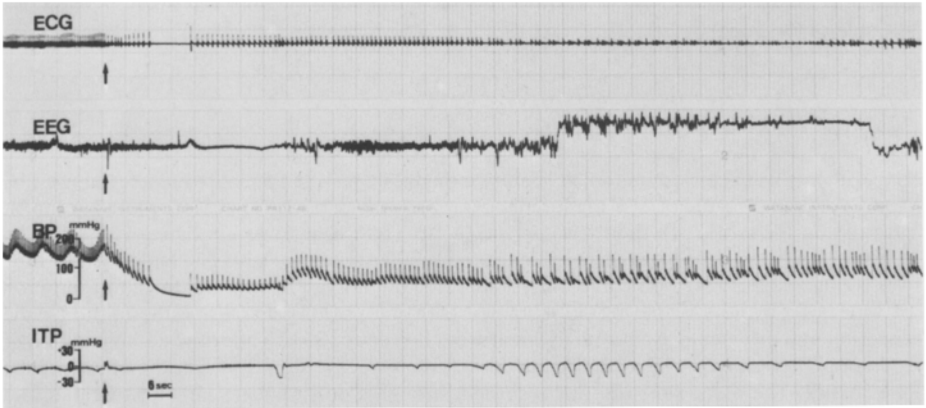

Fig. 2. Typical record obtained during type II drowning, showing a precipitous fall in blood pressure with sudden decrease in heart rate and transient asystole immediately after initiation of water aspiration, which was followed by provisional disappearance of electroencephalogram

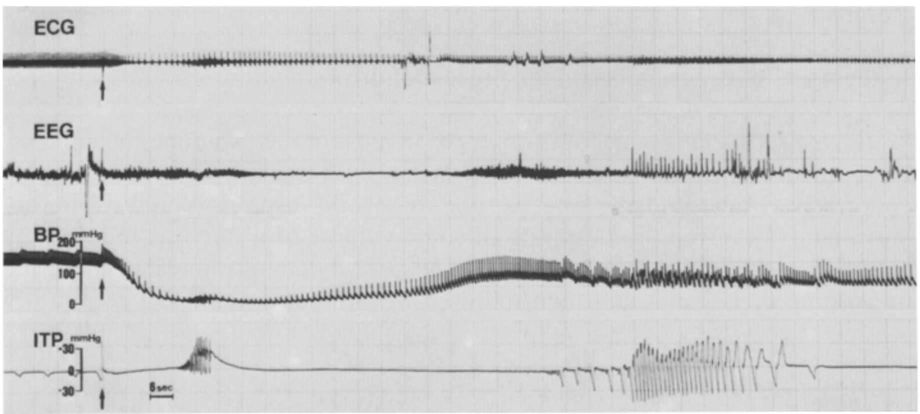

Fig. 3. Typical record obtained during type II drowning, showing a precipitous fall in blood pressure with sudden decrease in heart rate immediately after initiation of water aspiration inducing the provisional disappearance of electroencephalogram. Transient gasping occurred during initial apnea after water aspiration

movement. Reflexes then disappeared, and somatic activity ceased. During the first 10–20 s the heart rate decreased from 200–230 to 150–130, but the blood pressure did not fall till the end of gasping. With or some time after the end of gasping, ventricular fibrillation appeared, and the blood pressure fell precipitously to approximately zero in some experimental animals, and arrhythmia inducing a gradual fall in the blood pressure occurred in others. Electroencephalogram disappeared immediately or some time after the stage of gasping (Fig. 1).

In *type II drowning*, which was observed in some of the dogs placed on the table for more than 6 h before introduction of water, the sequence of events in the respiratory movement was practically the same as in type I, except for transient gasping during the initial apnea, which was observed in a dog, but it was not in other parameters. Marked bradycardia, 40–50 beats/min with or without transient asystole appeared as soon as the water was introduced through an endothracheal tube into the trachea. The blood pressure fell suddenly to approximately zero. The period of extremely low blood pressure lasted 30–60 s, and then the blood pressure increased gradually to 50–130 mmHg with a slight increase in the heart rate some time before or with the stage of gasping. Electroencephalogram disappeared approximately 20–30 s after the initial aspiration of water and appeared again with a gradual increase in the blood pressure. The period of initial disappearence of electroencephalogram continued for 25–60 s (Figs. 2, 3). After cessation of the gasping, the blood pressure fell gradually to zero and electroencephalogram disappeared again.

The autopsy findings in both types of drowning revealed edema fluid and froth throughout the bronchial tree and the cut surface of the lung.

Discussion

It would be difficult to explain that a good swimmer, who was known to be in good condition and had not any underlying illness, drowned suddenly while swimming exercise in a swimming-pool of which the depth was 1.2 m or so.

Several mechanisms, such as reflex vagal arrest of the heart in cold water [3, 8], loss of consciousness due to hyperventilation before breath-holding, and exercise during swimming under water [5], have been suggested to be a cause of sudden death on immersion. Prokop [10] suggested various reflexes triggered by the effect of cold water on the ear and on the skin of the face or on the mucous membranes of the nose and the larynx, presumably inducing a cardiac arrest. It is said that alcohol intoxication may lead to a state of hypersensitivity [7].

These explanations of drowning of a good swimmer are not appropriate to the present cases where the victims were swimming on the surface in a swimming-pool in summer.

We investigated this event in experiments designed to explain how a person might lose consciousness while swimming on the surface. In the series of experiments on the process of drowning, we found that in a few experimental animals, immediately after fluid was introduced through an endotracheal tube into the trachea, the heart rate decreased, and the blood pressure fell suddenly to approximately zero. The precipitous fall in blood pressure was followed by disappearance of the electroencephalogram. This finding suggested that under certain circumstances, the entry of water into the trachea may be another possible trigger for vagal inhibition of heart. This may cause an extremely slow heart rate and hypotension presumably inducing loss of consciousness. During loss of consciousness drowning may ensue.

Generally speaking, when water enters the mouth, it is usually first swallowed in copious amount by the person whose reflexes remain active, and the entry of water into the lungs is prevented by laryngeal spasm until cerebral hypoxia produces unconsciousness and paralysis of the respiratory center [4]. However, under certain conditions, for instance, when the swimmer has some goal in mind or is in competition with others, it is possible that he notes the extreme urge to breathe and aspirates water. If a person is unusually sensible, the extreme low heart rate and hypotension, presumably inducing loss of consciousness and drowning, may occur at the initial aspiration of water. A few experimental animals that showed the sequence of events of type II drowning belonged to those of which legs were fastened to the table for more than 6 h before aspirating water. Fastening of an experimental animal for many hours may make it exhausted. From the point of view, this observation suggested that such condition as exhaustion may play a role for unusually high sensibility of the trachea, and it may be a trigger for vagal inhibition of heart, which causes a sudden decrease of the heart rate at the initial aspiration of water.

From the two incidents described here and the experimental research, it is indicated that, under certain circumstances, a person swimming on the surface of a swimming-pool may lose consciousness from aspiration of water and be unable to make an action appropriate to the situation so that drowning may ensue.

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