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Short communication

Fatal diving accidents: Two case reports and an overview of the role of forensic examinations

Sybille Lüderwald *, Bettina Zinka

Department of Legal Medicine, University of Munich, Nussbaumstraße 26, 80336 München, Germany

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ABSTRACT

During the years 2004–2006, seven divers, who had deadly accidents, underwent post-mortem examination at the Institute of Legal Medicine of the University of Munich. The cause of death in all divers was drowning with typical pathomorphological findings. This should be regarded as separated to the triggering reason for drowning. The trigger for accident was established in four of seven cases by technical analysis and police investigation. High risk-taking, lack of technical service, and deficiency of dive equipment care were main reasons for death. We present two of these cases which showed several problems occurring concurrently. Autopsy always is necessary to look for indices for application of force or to exclude competitive reasons for death.

1. Introduction

Lethal diving accidents of scuba divers are rare in the daily routine of forensic doctors. Approximately 2–3 divers undergo post-mortem examination in Munich per year. Although other forensic departments with seaside proximity examine more diving accidents, they also only encounter a few cases annually. In 1993, Van Laak (National Director of the Divers Alert Network [DAN] of Europe) evaluated around 60 cases of diving-related deaths in Germany.

In 1994, Püschel and colleagues (Department of Forensic Medicine, Hamburg) compiled data on fatal diving accidents examined by forensic departments in Germany and Austria. Altogether, 45 cases were collected and analyzed in 20 years [4]. To date, no further analysis of divers' deaths has been published in Germany. To some extent, it is possible to acquiring data from diving accidents (e.g. http://www.dlrg.de), but so far, no reports have made use of these datasets.

The annual publications of the Divers Alert Network and the British Sub-Aqua Club (BSAC) feature statistics on diving accidents. Analysis of this data shows that an average of one per 2500 dives results in a decompression accident (DCI). One of approximately 40,000 dives results in the death of the diver; therefore one of 7500 divers dies [1,2]. In 2006, 88 divers died in the USA and Canada [2]; in Germany, exact numbers are unknown. Diving conditions in the USA and GB may represent confounding factors in the data, so they cannot be assumed to apply to Germany, although they may provide insight into problematic aspects of diving.

In 2006, BSAC reported that diving accidents increase during the summer. In most cases (112 of 379), DCI was the main cause of the accident; other causes were problematic ascents and accidents that happened during surfacing.

In 2003, Nakayama et al. published data from 3078 Japanese hobby divers and reported that 711 (23.1%) suffered an accident. The main complaints reported were barotraumas of the ears and sinuses (16.3%) and rapture of the deep (12.1%). Only 1.9% of them had a DCI. Between 1 in 2500 and 1 in 20,000 dives results in DCI [5].

Remarkably frequently, women with little diving experience and men with long-time diving experience sustain accidents. Typically the diving depth where incidents happen is between 21 and 30 m [3]. More than half of the divers who later had an accident were known to have had health problems such as diabetes mellitus or asthma. Three quarters of them were overweight [16].

Typical drowning signs are foam in the airways and lungs, missing retraction competence of lung tissue, distended lungs, dilute gastric content, fissures in the gastric mucous membranes, and (peri)pleural hemorrhage. The accidental component clearly

* Corresponding author. Tel.: +49 89 218073121; fax: +49 89 218073009.
E-mail address: Sybille.Luederwald@med.uni-muenchen.de (S. Lüderwald).

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Table 1
Data from the reported divers (D1–D7) with body mass index (BMI), sex, age, reason for death, and diving risk factors

	BMI	Sex	Age	Reason for death	Risk factors
D1	28.9	M	47	Drowning	Unknown
D2	25.6	M	56	Drowning	Unknown
D3	32.7	F	49	Drowning possible	Smoker, pain killers, coagulation problem
D4	25.1	M	31	Drowning	Smoker
D5	24.9	M	47	Drowning	Smoker
D6	31.3	M	24	Drowning	Anabolic abuse?
D7	26.5	M	49	Drowning	Unknown

seemed to be the triggering cause for drowning. In 1994, Birkholz stated that the diagnosis of "drowning" on a death certificate in the case of a diving accident has a similar value as "cardiac arrest" [15]. If a diver dies, it will usually be by drowning, because of the fact that he or she is diving. But first, the event of drowning may be the consequence of an event under water. What happened under water? What is the reason for the loss of consciousness? Why does a healthy person suddenly die?

First of all, the forensic post-mortem examination aims to exclude application of force and competing reasons for the diver's death, e.g. a heart attack that leads to drowning. The trigger event that leads to a diver's accident cannot be determined by autopsy alone. The final diagnosis must be discussed in conjunction with results of a police investigation, a technical report concerning the diving equipment, and reconstruction of the situation.

2. Methods

In the years 2004–2006, seven divers underwent post-mortem examination at the department of Legal Medicine of the University of Munich. Macroscopic findings were recorded, compared, and analyzed. Prosecution files were analyzed (including police investigations, witness statements, and technical reports) concerning the diving equipment. In addition, diving experts (Christian Krzywicki and co-workers, Beyond Diving, Feldkirchen) were consulted for their assessment. Two selected accidents are presented in detail.

3. Results

Seven divers underwent post-mortem examination at the Department of Legal Medicine of the University of Munich; six of them were recovered from a depth >10 m, one at the surface. Their mean age was 43 years (Table 1). None of them were diving beginners. All of them were overweight with a mean BMI of 28 (normal 18.5–24.9).

Post-mortem examination showed typical signs of drowning in all divers, although in some cases the autopsy was hampered by decomposition. Foam was found in the upper airways and lung tissue. The lungs showed decreased retraction of the tissue and mostly were massively distended. All autopsies showed an increase of brain weight with brain edema, obvious brain relief, and compression of the cerebellar tonsils [14].

Air embolism was seen in three cases. None of the cases had an open foramen ovale (Table 2). Only one case had diluted gastric content, but this finding should be taken with caution, as this diver was recovered no earlier than 2 weeks after death at a depth of 83 m, so dilution of gastric content could have been caused by passive permeation of water. No bleeding at the pleura and no fissure of the gastric mucous membrane were found. A competitive reason for death was not found in any of the cases.

4. Case reports

4.1. Diving accident A

The police were searching for a 50-year-old man who had been reported missing by his family. His car was found at a lakeshore, his diving equipment was missing, and his wife reported that he had been diving with an open-circuit system. Police divers searched for him, but the first search failed. Four weeks later, the corpse was found in the same lake at a depth of 83 m.

The man's documents contained a fake diving card, which authorized him to dive with a special breathing composite called "Trimix" (consisting of oxygen, nitrogen, and helium). Furthermore, bills for a purchase of helium and argon gas were found with his documents, obviously he intended to create a breathing-mixture by himself. He had logged 350 dives.

4.1.1. Autopsy

The body showed advanced decomposition. The lungs presented with massive distension. The stomach contained 500 ml content. An increased brain volume with signs of intense brain pressure was found. The death was caused by drowning.

4.1.2. Technical report

The diving regulator showed malfunction of some parts. The diving bottles were filled with improper breathing gas; for example, one bottle was filled with argon. Because of the presence of a tampered brevet with the title "Argon Decompression" it may be possible that he did not use the argon for his suit, but rather as a breathing gas. Four of five bottles were empty. Only the bottle containing the argon mixture was filled at 150 bars.

An analysis of the diving computer was performed. The diving profile (Fig. 1) showed that a depth of 95 m was reached after 12 min. A fast ascent (about 3–4 min) to a depth of 32 m followed, and, subsequently, there was a descent to 83 m in less than 2 min (free fall).

4.1.3. Discussion of case A

This diver died from use of the wrong breathing gas and defects in parts of his equipment. "Technical diving" begins starting at a

Table 2
Typical autopsy findings from the reported divers (D1–D7) and statement of positive (+) or negative (0) results

	Foam in airways/lungs	Missing retraction lung tissue	Lung distension	Dilute gastric content	Brain edema	Probe of air embolisms heart	Patent foramen ovale
D1	+	+	+	0	+	+	0
D2	+	0	+	0	+	0	0
D3	+	+	+	0	+	+	0
D4	0	+	+	+	+	0	0
D5	+	+	+	0	+	+	0
D6	+	0	+	0	+	0	0
D7	0	+	+	0	+	0	0
	28.6%	28.6%	100%	14.3%	100%	42.9%	0%

The percentages at the bottom are the total rates of positive cases of each special autopsy finding.