

Technical reports

Forensic analysis of an unwitnessed fatal diving accident using in-water investigative reconstruction

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Abstract

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Unwitnessed diving fatalities present significant challenges for forensic investigation. We describe a fatal diving accident involving a 32-year-old experienced female diver during a deep night dive in freshwater. The diver became separated from her buddy and was recovered at depth in a head-down position, with evidence of entanglement of the central manifold valve of the twin-tank open-circuit breathing apparatus by a thin guideline. Autopsy findings were consistent with drowning. Technical examination of the diving equipment revealed no mechanical malfunction. Given the absence of eyewitnesses and inconclusive assessment of the accident circumstances, an underwater reconstruction was conducted in collaboration with a police diving unit. Using the original breathing apparatus and controlled underwater conditions, the reconstruction evaluated the technical feasibility of various accident scenarios, including entanglement, buoyancy redistribution, and loss of equipment control. The reconstruction demonstrated that unintentional formation of a simple guideline loop around the central manifold valve could occur during attempts at disentanglement. Partial inflation of the buoyancy control device and drysuit, combined with mechanical constraint of the breathing apparatus due to entanglement, resulted in inversion into a head-down position and displacement of the breathing apparatus following release of the waist strap. These configurations substantially impaired the diver's self-rescue capability and were consistent with objective findings documented at recovery. This case underscores the forensic value of controlled underwater reconstruction as a complementary investigative tool in unwitnessed technical diving fatalities and highlights its potential contribution to accident analysis and prevention.

Introduction

Most diving fatalities occur in situations without direct witnesses, leaving investigators with limited information about the diver's final minutes of life. In such cases, the body is typically recovered, examined at the scene, and subsequently subjected to autopsy; however, the immediate circumstances preceding death often remain unverifiable. This uncertainty creates considerable scope for divergent interpretations of the accident sequence and underlying mechanism.

Previous studies have shown that post-mortem findings and equipment inspection alone rarely allow reliable differentiation between incapacitation, entrapment, loss of buoyancy control, or behavioural factors during the terminal phase of a dive.^{1–5} Consequently, unwitnessed diving

fatalities remain among the most challenging scenarios in aquatic death investigation. Methods capable of integrating scene documentation, equipment analysis, and controlled underwater investigative reconstruction may therefore represent a valuable adjunct for improving the interpretative framework in such cases.^{6,7}

Underwater reconstructions have been proposed as a valuable – although still infrequently implemented – approach to reducing interpretative uncertainty. When logistically feasible, such reconstructions allow investigators to reproduce critical mechanical factors, assess equipment behaviour under realistic conditions, and evaluate the plausibility of competing accident hypotheses.

The concept of re-enactment as an investigative tool in diving accidents was first reported in 1967 and was originally

designed for internal expert use within the Royal Australian Navy.⁸ Edmonds and Caruso have described the use of controlled re-enactments in the investigation of unexplained diving fatalities, particularly in cases where conventional post-mortem examination and equipment testing failed to provide a convincing explanation for the fatal event. Such re-enactments aim to replicate selected aspects of the fatal dive under controlled conditions in order to identify potential adverse mechanisms, rather than to establish a definitive sequence of events.^{9,10}

In contrast, the present report applies a deliberately restricted underwater investigative reconstruction focused on evaluation of technical configurations and physical constraints, without attempting full replication of the fatal dive. The authors encountered a case involving the fatality of an experienced female diver during a deep night dive in which the diver became separated from her buddy. The body was discovered at depth in a pronounced head-down position, entrapped by a thin line, with no direct evidence explaining how the incident unfolded.

Given the uncertainties surrounding the terminal events, forensic specialists, in collaboration with the Police divers of the Czech Republic, initiated an underwater investigative reconstruction of the presumed crisis scenario. The reconstruction aimed to reproduce the mechanical constraints under which the diver became entrapped and to assess the functionality and configuration of her breathing apparatus under comparable conditions, while also exploring feasible self-rescue options. This article presents the case circumstances, recovery findings, autopsy and technical examination results, and the outcomes of the underwater reconstruction, and discusses the forensic value of reconstruction-based analysis in the investigation of unwitnessed technical diving fatalities.

Case report

A 32-year-old female diver (XX) participated in a night dive with four other experienced divers to a depth of approximately 45 metres of freshwater (mfw). The divers began their descent at approximately the same time; one diver conducted the dive solo, while the remaining divers dived in pairs. Upon reaching the bottom at a depth of approximately 45 mfw, diver XX and her buddy initiated a joint ascent toward the surface, following the bottom profile. Due to disturbance of bottom sediment, visibility deteriorated markedly despite the use of torches, leading to separation of the dive pair. After switching off his light, the buddy did not observe any light signal from diver XX and therefore initiated a solo ascent to the surface while adhering to the planned decompression schedule. The remaining divers in the group also surfaced without complications. The police were informed of the disappearance of diver XX approximately two hours later.

According to statements from the other members of the diving group, diver XX did not report any problems prior to the last dive. She appeared relaxed, in a good mood, and was joking during dive preparation. She informed her buddy that she was not carrying her personal diving knife on this dive, as it was reportedly damaged. Diver XX did, however, carry a hook-shaped cutting tool with a sharp blade suitable for cutting thin cords and fishing lines. The tool was stored in the side pocket of the right leg of her drysuit and secured with a lanyard and a bolt-snap. The diver also wore relatively oversized dry gloves, which partially limited manual dexterity. The twin-set open-circuit scuba cylinders (2×10 L) were relatively short. In an attempt to lower the centre of gravity, diver XX had made a modification by attaching a standard 50-mm weight belt, screwed to the lower tank band. Two standard lead blocks (3 kg each) were threaded onto this belt, forming a freely hanging auxiliary ballast 'tail' suspended from the twin-set when the diver was in an upright position.

Recovery and scene findings

The body of diver XX was located at a depth of 28 mfw and recovered by police divers. At the scene, the body was maintained in a pronounced head-down position, oriented vertically with the feet upwards, and held in place by a taut 5-mm guideline secured by a simple loop around the central manifold valve between the cylinders, without knot formation (Figure 1).

Both legs and boots of the drysuit were inflated. The breathing apparatus had slipped over the diver's head; the waist strap was unfastened, and the shoulder straps were

Figure 1

Configuration of the breathing apparatus as recovered, showing a simple loop formed around the central manifold valve between the cylinders, without knot formation



loosened and displaced onto the diver's forearms. The auxiliary ballast 'tail' described above was suspended downward on the external side of the cylinders.

The primary and back-up second-stage regulators were hanging freely alongside the diver's body. The buoyancy control device (BCD) was partially inflated, approximately to half of its volume. The low-pressure hose for drysuit inflation was disconnected from the drysuit inflator valve. The diver's mask contained greenish water mixed with blood and whitish foam.

Autopsy and technical expertise findings

Autopsy findings were consistent with drowning, without any remarkable pathological changes. No traumatic injuries or significant natural disease processes were identified that could have independently explained death.

Technical examination of the diving equipment did not reveal any mechanical malfunction. All components of the breathing apparatus were found to be functional and appropriate for use. The breathing gas used was compressed air; however, at the time of expert examination, the cylinders were empty.

Data from the personal dive computer were extracted and analysed; the recorded dive profile documented a critical phase consistent with a crisis event.

Investigative experiment (reconstruction)

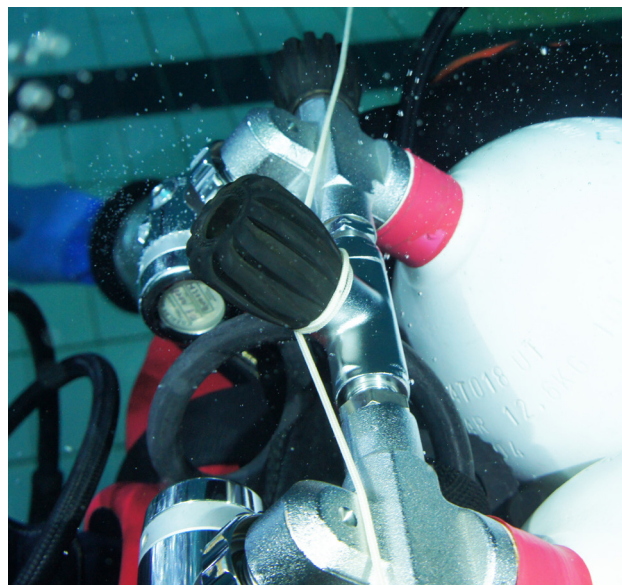
An investigative reconstruction was conducted by divers of the Department of Special Diving Operations and Training of the Police of the Czech Republic in an indoor swimming pool with a maximum depth of 5.5 mfw. The reconstruction was performed in the presence of a forensic expert witness in the investigation of diving fatalities (Slovak Republic); photographic documentation was performed by the expert witness, while video recording was carried out by the police divers.

The objective of the reconstruction was to situationally reconstruct plausible scenarios involving entanglement of a guideline around the central manifold valve of the breathing apparatus and to assess the practical ability of a diver to self-extricate from such entanglement using their own means. Prior to commencement, an identical guideline was positioned by police divers approximately 1 m above the pool bottom.

The test subject was a police diver equipped with a drysuit identical to that used by diver XX. The test diver used the original breathing apparatus of diver XX, including the buoyancy control device (BCD) and the auxiliary ballast tail. Underwater, the test diver was deliberately positioned in predefined configurations in accordance with the reconstruction protocol.

Figure 2

Simple, non-knotted loop of the guideline formed around the central manifold valve of the breathing apparatus during the reconstruction



Subsequent actions, including attempts at self-release from the guideline, were continuously documented using photographic and video recording. The expert witness and police divers guided the test diver underwater into configurations considered most consistent with the probable real-world circumstances of the diving accident.

This investigative reconstruction was designed to evaluate technical feasibility and physical constraints only; no conclusions regarding intent, precise sequence of events, or causality were derived from the experiment alone.

Principal findings of the reconstruction

During the reconstruction, the test diver was able to create a simple, non-knotted loop of the guideline around the central manifold valve of the breathing apparatus using one hand while manipulating the line in an attempt to remove it. This occurred despite the use of oversized dry gloves, which limited manual dexterity (Figure 2).

In an attempt to free from the guideline, partial inflation of the BCD and the drysuit, in combination with firm fixation of the breathing apparatus by the guideline, resulted in rotation into a vertical inverted (head-down) position. Redistribution of gas into the lower parts of the drysuit further contributed to this inversion (Figure 3).

Following disconnection of the drysuit inflator hose and unfastening of the waist strap of the breathing apparatus while already in a vertical inverted position, the breathing apparatus immediately slipped over the diver's head. This resulted in immobilisation and was assessed as a critical situation requiring immediate intervention by the surrounding police divers (Figure 4).

Figure 3

Inversion into a vertical head-down position caused by partial inflation of the buoyancy control device and drysuit, with gas redistribution within the drysuit during fixation of the breathing apparatus by the guideline

**Figure 4**

Breathing apparatus displacement over the diver's head in a vertical head-down position following release of the waist strap and disconnection of the drysuit inflator hose



In no tested body position was self-extrication from the simple loop of the guideline around the central manifold valve of the breathing apparatus achievable using manual efforts alone.

Interpretation of the diving accident based on reconstruction

The following interpretation is based on integration of recovery scene findings, autopsy results, technical examination of the diving equipment, and outcomes of the underwater investigative reconstruction. It does not claim to establish the exact sequence of events or the diver's intent.

During a night dive at a depth of approximately 30 mfw in green-brown water with markedly reduced visibility (approximately 0.8 m), diver XX likely experienced accidental entanglement of the central manifold valve of the twin-cylinder breathing apparatus with a thin guideline (diameter 5 mm) secured underwater between fixed structures. Such entanglement would have abruptly arrested the diver's forward movement.

In response, diver XX plausibly attempted to remove the guideline manually. Under conditions of darkness, near-zero visibility, and reliance on tactile perception alone – further compromised by oversized dry gloves – it is technically plausible that a simple, non-knotted loop of the guideline could have been unintentionally formed around the central manifold valve during manipulation of the line. This manoeuvre would have occurred in a confined and difficult-to-access area behind the diver's head, at depth, and under conditions conducive to acute stress and panic.

Following unsuccessful attempts at manual release, partial inflation of the BCD and the drysuit may have been initiated in an attempt to relieve tension or regain mobility. Redistribution of gas into the lower portions of the drysuit plausibly resulted in inversion into a vertical head-down position. In this configuration, the guideline would have been subjected to upward tension towards the surface, forming a configuration resembling an inverted V relative to the diver's body position.

At no stage was the cutting tool carried in the right thigh pocket of the drysuit used. This omission may have been related to difficulty accessing the pocket, interference from oversized dry gloves, or cognitive narrowing associated with panic.

In the final phase of the event, diver XX appears to have attempted to abandon the entire breathing apparatus and initiate an ascent without it. This likely involved disconnection of the drysuit inflator hose followed by unfastening of the waist strap of the breathing apparatus. In the inverted position, the unsecured breathing apparatus – additionally burdened by freely suspended auxiliary ballast – would have immediately slipped over the diver's head, resulting in loss of the regulator from the mouth. This sequence plausibly led to uncontrolled water aspiration and subsequent drowning.

Discussion

This case illustrates the interpretative challenges inherent in unwitnessed diving fatalities. Although sometimes used by experienced police investigators in some jurisdictions, published contemporary case-based reports integrating recovery findings, systematic equipment examination, and controlled underwater reconstruction in unwitnessed diving fatalities remain limited.^{8–10} Despite comprehensive recovery documentation, autopsy findings consistent with drowning, absence of detectable mechanical malfunction of the diving equipment, and no evidence of alternative natural or traumatic causes of death, the immediate sequence of events leading to death could not be reliably established on the basis of post-mortem findings alone.

As in many diving incidents, particularly during night dives, the critical phase of the accident occurred underwater, outside direct observation, and under environmental conditions that severely limited situational awareness and self-rescue options. Reduced visibility, depth-related physiological stressors, and task loading likely contributed to rapid escalation of the incident once entanglement occurred. The underwater investigative reconstruction demonstrated that a simple, non-knotted loop of a guideline around the central manifold valve of the breathing apparatus could be formed unintentionally during manual attempts at line removal. When combined with partial inflation of the BCD and drysuit, and with the breathing apparatus remaining fixed by the guideline, this configuration resulted in inversion into a vertical head-down position. Under these conditions, disconnection of the drysuit inflator hose and unfastening of the waist strap led to immediate displacement of the breathing apparatus over the diver's head, resulting in loss of effective mobility.

The configurations observed during reconstruction were consistent with objective recovery findings, including the inverted body position, inflation of the lower portions of

the drysuit, partial BCD inflation, displacement of the breathing apparatus, and disconnection of the drysuit inflator hose. Although reconstruction cannot determine intent, precise timing, or the exact sequence of actions, it provides important insight into the technical plausibility of the observed configuration and the rapid deterioration of self-rescue capability. Underwater investigative reconstructions must be conducted exclusively by appropriately trained and experienced divers under strict safety protocols. While such reconstructions cannot replicate the physiological or psychological state of a diver during a real emergency, they offer a valuable adjunct to scene documentation, equipment examination, dive profile analysis, and witness statements.

Conclusions

This case demonstrates the limitations of post-mortem findings and equipment inspection alone in the investigation of unwitnessed diving fatalities. Integration of recovery scene documentation with controlled underwater investigative reconstruction allowed evaluation of the technical plausibility of alternative accident scenarios and provided a coherent explanatory framework consistent with objective findings.

Although reconstruction cannot establish the exact sequence of events or the diver's intent, it represents a valuable complementary approach for reducing interpretative uncertainty in complex diving incidents. When applied cautiously and under strict safety conditions, underwater reconstruction may enhance forensic analysis of diving fatalities and contribute to improved understanding of accident mechanisms and preventive considerations.

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