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EARLY DIVING PROBLEMS AND FATALITIES

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Abstract

Diving accidents and incidents contribute to a steep learning curve. Over the centuries, divers of all descriptions have provided us with a wealth of useful data to help us learn and understand the physics and physiology of diving through their self-sacrifice, though perhaps not necessarily intentionally. This paper traces a variety of such events which befell divers in bells, semi-atmospheric systems and helmets as they adventurously pioneered their downward quest.

Early accidents

The early history of diving medicine has already been well-documented and it is not my intention to duplicate this effort. My aim is to relate some of the lesser-known examples of early diving incidents and accidents which have provided the subject material for aspiring diving medics.

Since the earliest form of diving would have been breath-hold diving, there is little of interest that can be said about related accidents. However, the the first recorded underwater war casualty was the Arab diver, Issa, who in 1190 served with the fleet of Saladin during the Third Crusade. He carried money and letters between the fleet and the shore. Eventually he was shot and killed by a Crusader archer. Figure 1 is a rather fanciful illustration showing him swimming in helmet, with a built in snorkel, and wearing weights round his waist. Above him Crusaders are dumping the dead and below him two large Morays are tidying up the mess.

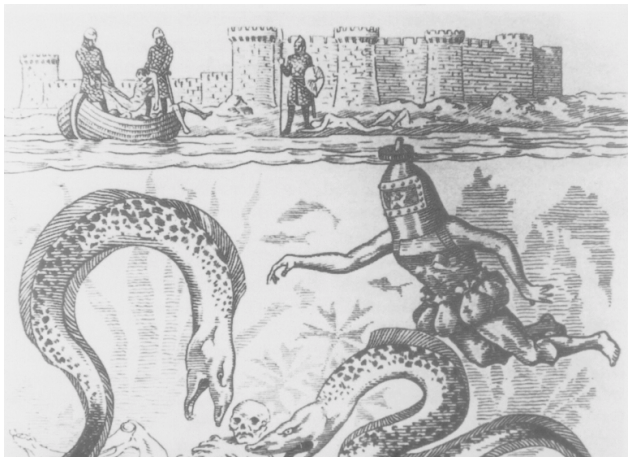

Figure 1. The Arab diver, Issa, who in 1190 served with the fleet of Saladin during the Third Crusade, carried money and letters between the fleet and the shore. He was the first recorded underwater war casualty.

The first genuine diving accidents would have arisen with the use of diving bells where there is every opportunity to generate a plethora of diving illnesses.

It is not surprising, therefore, to find that as early as 1535 in the very first reliable account of any bell diving operation, the first reference to the problem of ear-clearing is also recorded.[1] On 15 July 1535 the Italian bell diver Francesco da Marchi dived in the bell designed by Gulielmo di Lorena when he was able to survey the Roman galleys sunk in Lake Nemi, near Rome, and explained: *If you can swim you can undo the buckle of the harness, leave the vessel, and rise to the surface as I did the second time I entered the apparatus and went to the bottom. Be warned, that for 20 days afterwards, with every step I took, my ears tingled.*

After carrying out the first recorded free ascent from a diving bell, Marchi is lucky that it was only his ears that suffered from barotrauma! Marchi had more to say about pressure equalisation problems; *... when I was going under water I felt such a pain in my ears that it seemed that a steel dagger had been put into me, which transfixed me from ear to ear, and I felt very great pain. I tell you that it was so great that a vein in my head broke, so that the blood came out of my mouth and nose ...*

We probably have here the first recorded example of a sinus squeeze and underwater nose bleed as well as the ear clearing problem. Marchi also recorded for the first time the dangers of being eaten alive whilst diving: *I tell you that the fish called* laterini, *which are in this lake and which are not bigger than your little finger, appear below as thick as a man's arm and three palms long. If I had not been told about these fish, I would have been frightened by the great multitude that swam in my direction, especially as I was carrying four ounces of bread and one of cheese with me to eat, and because the bread was hard and black it fell to pieces and a huge number of fish came round and surrounded me, and as I had no breeches on, they came to bite me in that part which a man can think of ... I was not wearing breeches, because in Tuscany at the time of Duke Alessandro de Medici, who was my patron, when some fishermen once went to fish along the Arno, there was one of them who dived under the water to catch some fish by hand (and there are a lot of people in that province who*

catch fish under water), and he got caught by his breeches on the root of a tree, and they could not dislodge him, and he stayed there dead ... which was the reason why I did not put any on, and so the fish freely bit me in that part more than in any other.

There has to be a whole string of firsts in this account. The first record of an underwater meal break, the first animal attack on a bell diver, the first case of injury to a diver in "that place which a man can think of" and perhaps the first bell diving practical joke if Lorena had had his tongue in his cheek when he suggested to Marchi to take his trousers off and take a piece of dry bread down with him!

The 17th century

Perhaps it was excessive use of a diving bell or pulmonary barotrauma from a bell dive that caused the earliest diving accidents. As early as the 17th century, perhaps the first diving medic made his appearance and proposed a special treatment for divers with "falling sickness".[2] This was Nicholas Culpepper (1616-1654) and apart from allegedly curing decompression illness the treatment had a beneficial side effect of curing the diver's scabby head at the same time: *FOX GLOVE - (Digitalis purpura) ... the herb bruised and applied, or an ointment made with the juice thereof ... and a decoction of two handfulls thereof with four ounces of polypody in ale, has been found by late experience to cure divers of falling sickness, that have been troubled with it about twenty years. I am confident that an ointment thereof is one of the best remedies for a scabby head.*

But before anyone re-introduces this alternative medical treatment in place of therapeutic recompression it should be pointed out that the word "divers" in those days was commonly used to denote "various people", and that "falling sickness" normally referred to epileptic fits. On the other hand, the administration of the medicine with a pint of beer would certainly fit a diving context.

Asphyxia would have been a perfectly reasonable problem to encounter in bell diving. Indeed, as early as 1663, a Scotsman named James Maule recorded that at depths below 16 fathoms (96 ft, 29 m) bell divers were liable to faint.[3] Maule's diving bell was made of lead. It was two and half feet (0.75 m) deep and as wide at the base. This was a very small bell and it is hardly surprising that, with claims that they could dive to 24 fathoms (144 ft, 43.6 m) for half an hour, the poor diver would faint. In fact he would probably have been dead for the last 20 minutes of the dive!

The dangers of breath-holding during an ascent either in or from a diving bell would have been an early experience for the underwater adventurers. The first allusion to this problem has been traced, by fellow historian Nigel Phillips, to a letter from Thomas Bartholin the Younger of Copenhagen, Denmark, to his colleague Dr Johann Ludwig Hannemann, a professor at Kiel, in Germany written on 20 September 1676.[4] Bartholin refers to Wynmann who had stated: *... that divers use a suitable glass vessel, very large and capacious, into which they give off the breath of their nostrils or mouth.*

Bartholin also referred to a previous letter received from Hannemann saying: *But those who braved the seas held their breath with a greater danger. I shall not add a word about respiration, as you will have demonstrated it lucidly in your letter, from the medical point of view.*

Is Bartholin talking about breath-holding here? The letter he refers to from Hannemann has been traced, but, being in Latin, a translation is awaited and unfortunately is not yet available.

Not long after, Sir Edmond Halley (1656-1742), while pursuing his day job as a salvage diver, was exploring the frontiers of diving physiology. In July of 1691 he tested his new diving bell at Pagham harbour on the south coast of England and in October that year took out a patent for his revolutionary life support technique entitled an "Engine for Conveying Air into a Diving Vessel".[5,6] His intention was to demonstrate how he could remain in the submerged bell for as long as he wished thanks to his invention. The experiment was an outstanding success and he remained one and a quarter hours at a depth of 60 ft (18 m). Unbeknown to Halley, he had been the first person to exceed the no-stop dive duration recommended by the Royal Navy nearly 300 years later. Halley also claimed that there was no limit to the depth he could reach with his bell. It is clear that his new technology would have introduced him, and those who followed his example, to hyperbaric exposures easily capable of producing decompression sickness.

One of Halley's less well known records of a bell diving problem was that of the cut finger incident. Though perhaps not life-threatening or likely to have made the front page of the Phil Trans Roy Soc, Halley's observation that blood was green when viewed underwater was perhaps the first time this curious fact had been brought to the attention of the public.

The 18th century

Halley clearly carried out quite a few dives with his bell because he took a special interest in the problems of ear-clearing. So much so that, on 22 February 1722, he read a paper to the Royal Society on the subject entitled "Of protecting the drum of the ear under water" which had to wait over 200 years before it was published.[7] In it he described, perhaps for the first time, the mechanics of ear

clearing: *... I related a constant effect of the pressure of the condensed Air upon the outward passage of the Ear, which was felt by all persons that went down in the diving engine, not without pain; till such time as a valve (as I conceive) that is placed near the Drumm of the Ear being forced by the great pressure of the external medium, gave way and slippd up; whereby the Air in the Cavity within the bony caverns of ye Ear immediately became of the same density & elasticity with the external, whence present Ease ensued ... The constancy of this effect made me conclude that there was a valve obstructing the entrance of any thing into a cavity of ye Ear from without ... which if I mistake not they call the Eustachian Tube ...*

The well-known Swedish "urinator", Martin Treiwald, who had developed an improvement to the life support system in his campana urinatoria, provided a useful insight into some of the life-threatening problems associated with his profession in 1736.[8] He described how divers in semi-atmospheric diving suits were risking instantaneous drowning if the atmospheric compartment of their diving dress lost its watertight integrity and how a bell diver once saved his own life by stopping a leak in his bell by simply placing his hand over the leak: *I will not for brevity sake, mention the many impediments that attend other inventions, only that of a water armour, in which the man is drowned in an instant, when such a machine receives the least leak. Whereas experience has shewn, that when such an accident has happened to the diving bell, as to my knowledge it did once, when the diver was 12 fathom* (72 ft, 22 m) *underwater, and a pretty large hole happened to be struck in the bell, by a boult of the wreck he went upon, at which time the air rushed out of the same with such violence as astonished the beholders by the excessive boiling on the surface of the water, fearing, not without reason, that the man in the bell was drowned; but he clapped his hand to the hole or leak, and gave a sign to be hauled up, which was done with all the ease and safety as if no accident had happened to him, the water having only risen about half a foot into the bell by this leak.*

The very same diver that was then in the bell is 63 years of age, and has used the business of diving ever since he was 20, in a common diving bell, till of late, and is as yet a pretty strong and healthy man.

The increasing use of semi-atmospheric diving systems led to an inevitable increase in accidents. In 1763 J T Desaguliers produced a comprehensive list of important observations in his Course of Experimental Philosophy,[9] including one concerning a semi-atmospheric suit: *... though this diving engine be better than a great many, yet it has the same inconveniency of not being fit for great depth of 11 fathom* (66 ft, 18 m) *he felt a strong stricture about his arms by the pressure of the water; and that venturing two fathoms* (12 ft, 3.6 m)*lower to take up a lump of earth with pieces of eight sticking together; the circulation of his blood was so far stopped, and he suffered so much, that he was forced to keep his bed six weeks. And I have heard of another that died in three days, for having ventured to go down 14 fathom* (84 ft, 25.5 m).

Desaguliers then gave the first clear description of the potential dangers of pulmonary barotrauma in bell divers.[10] *Care must be taken not to take up the bell too fast, because the condensed air in the bodies of the divers must expand itself by degrees, and be breathed out; otherwise, if they were too suddenly delivered of the outward additional pressure, the air within them would burst them outwards.*

Desaguliers could not exclude the well-documented ear-clearing problem from his review but added a bonus in his record of the danger of the use of ear plugs when diving and perhaps the first intervention of a diving surgeon.[11] *At first they felt a small pain in their ears, as if the end of a tobacco pipe was thrust in their ears; but after a little time, there was a small puff of air with a little noise, and they were easy. ... One of the men, to prevent this pressure, stopped his ear with a pellet of chewed paper; but that pellet was pushed in so far, that the surgeon had much ado to get it out.*

Diving bells were the safest way to dive during this period and much attention was given to improving their design further. Charles Spalding of Edinburgh, Scotland, made several such improvements but continued to use Halley's life support system. One account of Spalding's successful bell diving operations stated *Mr Spalding, impelled by curiosity and intrepidity of spirit, and a genius for mechanics, made several attempts to remain for a considerable time in deep water under the bell which was always crowned with success. He at length became such a proficient in the aquatic art, that he could remain if necessary for a whole day in water of 12 or 14 fathoms deep* (72 to 84 ft, 22 to 25.5 m!).

Not only are we looking here at the first saturation dives but the ringing in the minds of diving medics with an interest in decompression procedures must by now be reaching a deafening level.

Sadly, on 2 June 1783, Charles Spalding became a fatal diving accident statistic whilst diving with his bell on the recently sunk wreck of an East Indiaman outside Dublin harbour, Ireland. A newspaper account[12] gave the following description of the accident: *They had been down three times the preceding day, and in the last fatal attempt, had remained an hour and a quarter; during the first hour, the signals had been properly attended to, and three supplies of fresh air conveyed down, but unhappily, as is supposed, the last barrel had not reached them, which must immediately have brought on a speedy suffocation, so as to have prevented them from adopting the mode of preservation invented by Mr Spalding, of cutting the weight that hung from the center of the bell, by which means it must have immediately reached the surface of the water ...*

Upon drawing up the bell, Mr Spalding was found reclining on his breast, and Mr Watson sitting erect.

It does seem very strange that Spalding did not initiate an emergency ascent as his bell was specially designed to do. Perhaps there was a different reason for the accident. The same newspaper proposed an alternative and very interesting explanation for the fatal accident in the following day's edition: *From the authority of several skilful investigators into the ill-fated cause of Mr Spalding's death, it appears evident, that it was undoubtedly owing to a highly noxious effluvia, either arising from the putrid bodies in the Indiaman, or the great quantity of medical plant called Ginseng, part of the cargo; his death must have been instantaneous, from the highly active and exalted state of the putrid air ...*

This appears to be a very likely cause of the deaths of the two bell divers. As such, the sad event provides the first recorded death of a diver due to breathing a contaminated air supply.

The same year, 1783, William Tracey (b 1735), a ship broker at Portsmouth, attempted a dive on the wreck of the ROYAL GEORGE at Spithead, Portsmouth.[13] He used a semi-atmospheric diving suit which included a copper section which covered his head and chest. He appears to have tried to go too deep and suffered a very serious neurological problem as a result. In his own words:[14] *I returned to London in Nov 1782, where I lived ... at heavy expense, much increased by procuring diving machines, pipes, and other necessary apparatus, in order the more effectually to discover the state of the ROYAL GEORGE lay in etc, in which undertaking of going down under water, the first time, the pressure of the water occasioned my great injury, as it was from that pressure I am now a cripple.*

A friend added further information: *... when inspecting the ROYAL GEORGE in his first imperfect machine, received a material hurt, by pressure of water, which brought on lameness for many years, with two bad ruptures, and has been for the last two years an entire cripple on crutches.*

The chronicle of the use of semi-atmospheric suits must be riddled with such disaster stories.

On the other hand, the good news is that in 1799 a medic named Dr Thornton, Physician to the General Dispensary, Guy's Hospital, London, began promoting oxygen treatment as a cure for a variety of ailments. He published a series of papers including "A Remarkable Case of Scrophula cured by Vital Air, A Remarkable Case of Internal Pain in the Heel, and an Incipient Mortification, cured by Inhalation of Vital Air, A Case of Melancholia, A Case of St Antony's Fire cured by Vital Air".[15]

The 19th century

Another good word is put in for oxygen by a Mr J Elliott in a letter to the Mechanics Magazine in 1832.[16] Elliott related his observation concerning a bell dive in the river Thames over the site of the digging of the Thames Tunnel by Sir Mark Brunel and the young Isambard Kingdom Brunel, where the river bed had collapsed into the tunnel and caused it to flood, in 1827. The great scientist Michael Faraday carried out a bell dive and first discovered the beneficial effect of hyperbaric oxygen on breath-hold times: *At the time of the first irruption of water into the Tunnel, Mr Faraday descended in the bell with Mr Brunel, Jun; and in a lecture at the Royal Institution, Mr F stated a remarkable fact, that Mr Brunel, when he dived under water from the bell into the Tunnel, was able to remain full two minutes under water without experiencing any great inconvenience. He accounted for the fact in this way: when the bell was lowered to the greatest depth (about 30 feet* [9 m]*) the air inside was necessarily much compressed; the persons in it, therefore, though they inhaled the same bulk of air which they would under other circumstances, yet as two atmospheres were compressed into one, inhaled twice the quantity, and of course a much larger supply of oxygen was furnished to the lungs.*

Staying with this subject, a Dr Foley made some enlightening remarks about the positive effects of hyperbaric oxygen treatment in 1864,[17] when he quoted from a sitting of the Societe Medicale d'Emulation: *... if a patient be in want of more oxygen than he can get under the ordinary pressure, let him be exposed to an atmosphere rendered artificially denser. This can be done by constructing a small chamber, communicating with a forcing-pump, and provided with an air-gauge and a safety valve. A patient confined in such a chamber may be subjected without inconvenience to the pressure of about two atmospheres and a half. By this treatment catarrh, asthma, and other complaints of the respiratory organs may be removed. In croup the compressed air will flatten down the adventitious membranes; and in disorders arising from weakness compressed air will arterialise the blood and increase the vital power of the patient.*

Finally, on the subject of hyperbaric oxygen, Alphonse Esquiros mentioned in passing in his book on English Seamen and Divers dated 1868.[18] "The workmen also quote an instance of a consumptive person who was entirely cured by using the diving bell."

Returning again to the 1830s we pick up our next diving-related incident which is one of asphyxia. The danger which threatens when inexperienced people experiment with equipment they do not understand was well demonstrated in 1836 when a second-hand shop dealer decided to try on one of Charles Deane's old diving helmets with its attached jacket:[19] *A tradesman in Blackman Street named Caston, carrying on the occupation of a 'general*

dealer' had a narrow escape from suffocation a few days ago, under singular circumstances. Amongst some articles he had purchased at a sale was a diving apparatus. Never having before seen a machine of similar construction, Mr Caston determined to try it in the first instance on terra firma, and for this purpose drew the helmet or cap over his head, and then adjusted that part of it which fitted the lower extremities. He however omitted the most essential part of the apparatus - namely, the valve which admitted the air onto that portion which fitted over his head and face. The neglect nearly cost him his life; for when one of his servants entered the warehouse, Mr Caston was discovered rolling in great agony. The servant entered just in time to extricate his master.

Not very far away, a little down river on the Thames, a brig had sunk in the middle of the fairway and was a major obstruction to the shipping traffic. The Lord Mayor of London commissioned Colonel Pasley of the Royal Engineers to clear the wreck using gunpowder. Pasley originally considered using a diving bell but eventually decided to try to employ his own Sappers and Miners who could use the new diving helmet and dress. Corporal Henry Mitchell, one of his best men was sent down in a Fraser design of diving dress. Figure 2 shows how the work was carried out. Unfortunately, because he was untrained and completely inexperienced in diving, he became foul of the wreck and died. Mitchell was the first military fatal diving accident. Pasley was so grieved about the accident that he personally commissioned and paid for Mitchell's grave stone.[20]

Between the years 1839 and 1843, the biggest diving operation to date was carried out at Spithead, Portsmouth, when Colonel Charles Pasley in charge of a team of Royal Engineers, Royal Sappers and Miners and Sappers from the East India Company, completely cleared the wreck of the 108-gun ROYAL GEORGE from the prime naval anchorage. It was an enormous feat of engineering and helmet diving. To Pasley's credit, not one fatality occurred to a diver under water during the entire operation, though there were some interesting incidents.

One of the most insidious of these was the emergence of serious cases of "rheumatism". Pasley became quite concerned about it because it was affecting the efficiency of his operations. On 25 May 1841 he noted in his personal journal,[21] that Corporal Harris "has rheumatism" and Corporal Jones is "excellent. He remains 1 1/2 hours under water" in 13 fathoms (78 ft, 23.6 m) and in August Williams stayed down 2 hours" and again on 29 June and 14 July Corporal Harris "is ill". George Hall, the noted civilian diver who introduced helmet diving to the Royal Engineers did not escape this strange "illness" either. The local newspaper reported on 31 August 1841[22] that: *Mr George Hall, who has distinguished himself so much under Colonel Pasley at Spithead, having been obliged to give up his employment on the 8th instant, and having soon after quitted Portsmouth on account of an illness, which though not serious, rendered him unfit for the laborious duty for some time ...*

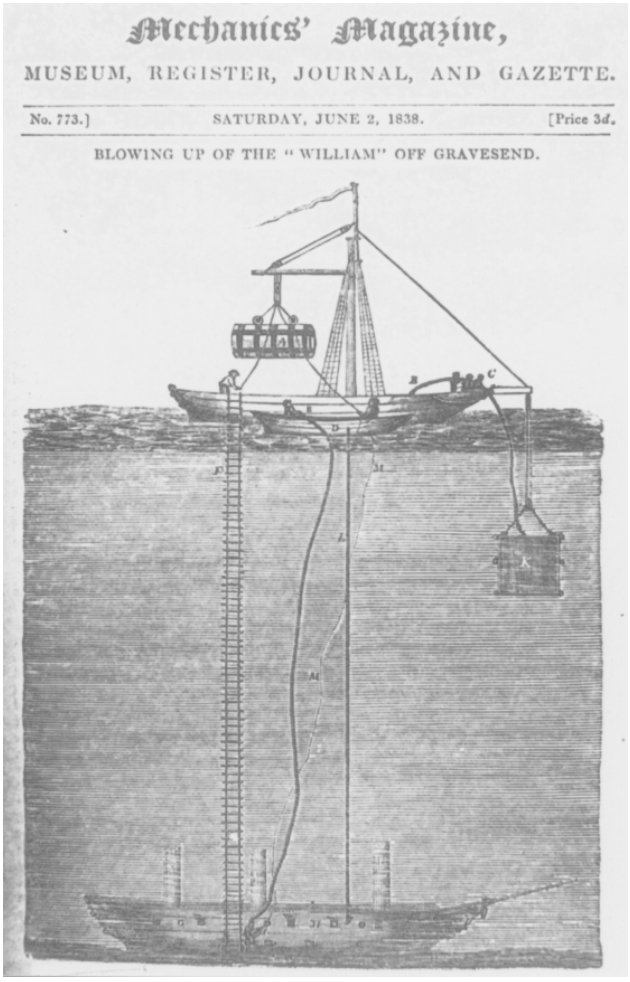
Mechanics' Magazine,
MUSEUM, REGISTER, JOURNAL, AND GAZETTE.
No. 773.] SATURDAY, JUNE 2, 1838. [Price 3d.
BLOWING UP OF THE "WILLIAM" OFF GRAVESEND.

Figure 2. On 21 May 1838 Cpl Henry Mitchell became fouled on the wreck of the *William*. He died from either hypothermia or drowning. This was the first British military diving fatality.

The "rheumatism", and even "violent attacks of rheumatism" became such a major problem that in 1846, the Royal Engineers published an Aide-Memoire[23] to establish the best way to avoid the condition developing: *To guard against the effects of damp and cold striking through the dress, the diver must be well clothed in flannel or woollen dresses: he generally puts on two suits, each consisting of a pair of drawers, stockings, and a Guernsey frok; these must be well dried, and aired on being taken off: constant change is necessary so that every diver should have about six suits in wear. At Spithead the regulations as to drying were strictly enforced; a cabin was set apart in the vessel on board of which the men were quartered, as a drying room, with a stove in the centre and rails all round for hanging the dresses on; the divers' attendants received them as they were taken off, took them to the drying room, and supplied fresh ones before the ensuing tide: in this way*

the divers were always provided with warm comfortable garments, but notwithstanding these precautions many were subject to violent attacks of rheumatism.

In the years ahead, "rheumatism" reared its ugly head many more times. One Whitstable diver who had been diving since the early 1830s, named William Wood, attracted the following comment from the author of an article about him in 1875:[24] *I am sorry to say that since the above was written, poor Mr Wood has died. He suffered terribly for many years with rheumatism, the result of spending so much of his time under water.*

Returning to Pasley and the ROYAL GEORGE, even more insidious were his references to divers who became "over-fatigued". On 22 June 1842 he wrote a letter to the Admiralty[25] to let them know his policy on recruiting new divers when his own divers became unfit to continue their work: *... as the number of volunteers far exceeds the number actually required I have given orders that only the best of the whole shall be employed, and in case of their being attacked by rheumatism or over-fatigued, which occasionally happens, that they should be replaced by the next best.*

Pasley was a little more explicit in his letter to the Admiralty on 7 December 1843 when he used the actual word "paralysis": *I now write to request through you, that their Lordships will be pleased to extend this exemption to the case of Philip Trevail of the Royal Sappers and Miners, who was sent as a patient to Haslar Hospital on 20th of October and remained there 36 days, in consequence of his having been severely injured whilst diving, not by any accident, but from his extraordinary zeal, which induced him to over-exert himself and remain too long under water, which caused him a sort of paralysis of one side, as the Surgeons informed me, when I visited him in hospital. Before this period he was one of the strongest and most active men in his corps ...*

These notes penned by Pasley in 1842 and 1843 represent the first reliable references to "type II" decompression sickness cases.

The Canadian diver J B Green has provided one of the earliest and most descriptive accounts of a serious case of decompression sickness following a series of deep dives he carried out in 1854: *I removed the face of the armour, and sat down to await for the implements. I had sat but a moment, when a sharp pain shot like lightning through my lower extremities, and the next instant it went through my whole system, so prostrating me that I could not move a limb, or even a muscle ... The best physicians pronounced me incurable ... it was five tedious months before I could step; and in the spring I was only so far recovered as to walk a very little with crutches.*

As soon as Green felt well enough to dive again, he repeated the exercise and was immediately struck down once more, in which state he remained for the rest of his life.[26]

Paul Bert (1833-1886), the great French physiologist pointed out very serious problems suffered by sponge divers using the English diving apparatus whilst those using the diving equipment produced by Rouquayrol and Denayrouze had no problems whatsoever. He quoted the unpublished memoire of M Aublé, the agent for the Society for Sponge Fishing. A certain amount of national bias may be detected in the account: *During the 1867 cruise, no serious accidents occurred among the men who were equipped with this apparatus for fishing. But in the same season, out of 24 men who used 12 suits of English manufacture, 10 died ... three of them died suddenly as they were leaving their submarine work and ... others had languished from one to three months, paralysed in the lower limbs and bladders.*

This is the earliest record of death in divers by decompression sickness so far found.

The temptation to go too deep and stay too long was greatest where gold bullion lay waiting to be recovered. This was certainly the case when the SS *Alphonso* sank in 160 feet (48.5 m) of water. Two of the best divers from Siebe Gorman, Alexander Lambert and David Tester, recovered £20,000 in 1885 but "their urinary organs were affected for the rest of their lives".[27]

The phenomenon of a suit squeeze became possible once the "tight" diving dress had been introduced (as early as 1835) by John Bethell. If the diver's air pipe burst at or near the water surface, the pressure would immediately fall to atmospheric pressure within the air pipe. Since the pipes were made to be incompressible by the inclusion of a spiral wire in the wall of the pipe, it did not collapse and the pressure in the diver's helmet would fall quickly to atmospheric pressure. In effect, the diver would become a semi-atmospheric diver with only his head protected from the ambient pressure! The result was inevitably catastrophic for the diver. The first time this happened was to the unfortunate Private Roderick Cameron on 4 October 1841. Dr John Richardson of Haslar Hospital described the effect in a paper to the British Association in 1842: *On the 4th October 1841, Roderick Cameron, a private in the Royal Engineers a well-made, tall, active and intelligent man, who had been trained for some time as a diver, descended to the bottom in 13 fathoms (78 ft* [23.6 m]*) and in a few minutes afterwards the air-pipe burst close to the pump. The air escaping with a loud rushing noise ... instantly made the accident known, and the workmen commenced immediately to haul the man to the surface by the safety line, the air pump being kept in action all the time. Cameron himself imagines that he became aware of the accident sooner than those up on the deck, and he had time to make the signal of danger before he felt that they were pulling him up. His first sensation was that of suffocation, from want of air, and*

he felt that the collar of the helmet, the leads on the back and breast and the dress on the body generally pressing upon him, as if he was about to be crushed, after which he lost all perception. It is supposed that he was brought up to the surface in less than one minute, and air was immediately admitted into the helmet by unscrewing the eye-piece. No water had entered the caoutchouc dress. In less than quarter of an hour he recovered his consciousness and was soon afterwards able to speak. He was immediately removed to Haslar Hospital, three miles distant from the scene of the accident. When first examined at Spithead, the face, head and neck and breast were discoloured, and the tint became darker before he reached the hospital. When he arrived there, his face was considerably swollen, his neck more so; both had a dark purple hue, and large patches of extravasated blood separated the conjunctiva from the sclerotica of both eyes ... Leeches were applied to the throat, and he was placed in a warm hip-bath ... he was anxious to return to his duty as a diver, but was not permitted to do so again that season ...

The same thing happened to Private John Williams on 11 July the following year. This time Dr John Liddell of Haslar Hospital gave the gory details:[28] *.. he was conveyed to the hospital, where he arrived one hour after the accident. His face was then one mass of lividity; his neck was excessively swollen, bloated, and suffused with livid coloured blood. Dark patches of ecchymosis that did not coalesce existed over his clavicle and shoulders ... He vomited some blood before he reached the hospital, and afterwards he made occasional efforts to vomit ... The haemorrhage had ceased from the nose and ears, which were still covered with clotted blood ... On admission, warmth was applied to his extremities; some warm tea was given him, which he swallowed with the greatest difficulty; he had a turpentine enema; and in the course of the day, twenty ounces of blood were taken from the arm ...*

The divers are employed four hours at a time, during the slack of low water, and in that space they usually descend four times. On their ascent after an hour's submersion, they appeared to me, while they were leaning against the hulk's side to be pale, languid and exhausted, though they did not admit that they were fatigued.

The severity of the decompression insult the divers were experiencing is also clearly stated here and it is comforting to note that diving medicine has moved on from leeches and turpentine enemas. Private Williams was back diving within 25 days and Pasley also decided to put non-return valves in the diver's helmet where the air supply hose was connected.

A more serious case of suit squeeze was enacted in the USA in 1854 when an English diver named Tope using a tight diving dress was lowered down a mere 40 ft (15 m). The account speaks for itself. *The signal line was at once worked to ascertain if anything was wrong; but receiving no answer, they at once drew him to the surface, and on opening the armour, to their horror, found him quite dead; although he had been down but one minute. The corpse presented such a dreadful spectacle; blood was oozing from the eyes nose and mouth ... we found the head very badly swollen, the face and neck so filled with blood as to resemble liver, while the remainder of the body was as white as unclouded marble.*

Within just ten years or so of the Royal Engineers adopting diving as a *bona fide* military activity, they had the opportunity to apply it in a military conflict when Britain, in an unusual alliance with France and Turkey, declared war on Russia in 1854. The principal theatre of the conflict was the Crimea. This is where the first fatalities of helmet divers occurred during an armed conflict. Sadly, as they might have preferred, the divers did not die "with their boots on" but were the casualties in a devastating storm which dashed their ship, the PRINCE, to pieces on the rocks at Balaclava with the loss of over 140 souls on board.[29] The diving casualties were Sgt William Carns and four privates of the Royal Sappers and Miners under the leadership of two civilian divers from Guernsey, Mr John Gordon and Mr Orchard.[30]

A further civilian diving casualty of the Crimean War was that of John Deane's partner, William Edwards of Whitstable, Kent, who died of dysentery and "fatigue" during diving operations at Kertch.[31]

The diving career of Frank Davis (1844-1885) was one of the most successful and well respected until one day in November 1879. His account explains what happened next: *Got a few days work to examine the bottom of a well at Short Heath for Birmingham water works company in one hundred and twenty feet* (36 m) *of water. Did this satisfactory although owing to the great depth and severe cold it was very distressing. I must mention that I caught a severe cold which partly paralysed me and brought on severe rheumatism through sleeping in a damp bed while at this job and I had to return to London where for months I was laid up not able to work and under medical treatment.*

Three years later, he records: *Unemployed until early in January during the whole of which time I was under medical treatment for rheumatism ... Still under medical treatment and this is now November.*

Frank Davis died two year later while working in India. His sad experience must have been repeated many times by his colleagues who, tragically, were working in complete ignorance of the cause of their "rheumatism" and paralysis.

It has become clear that the international diving profession was plagued with a very high incidence of all forms of decompression illnesses well into the early 1900s. The work of the Admiralty Committee on Deep Water Diving (1905-6), and Professor J S Haldane's

decompression tables (1908) that were generated as a result, provided the desperately needed turning point in this disaster-ridden profession.

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OXYGEN TOXICITY
A BRIEF HISTORY OF OXYGEN IN DIVING

Chris Acott

Key Words

History, hyperbaric research, incidents, injuries, oxygen, medical conditions and problems, unconscious.

Introduction

The Earth was probably formed about 4,600 million years ago by the gravitational coalescence of cold material. Initially there was a tenuous atmosphere of hydrogen and helium which was lost because of a weak gravitational field. The secondary atmosphere was created by the thermal and radioactive decay of various Earth's constituents. Ammonia dissociated into nitrogen and hydrogen and water vapour into hydrogen and oxygen. However, by far the greatest source of oxygen was, and still is, from photosynthesis. There is some evidence to suggest that the atmospheric concentration of oxygen cannot have changed for the past 345 million years.[1]

Discovery of oxygen

Oxygen was not discovered until the 18th century, although its presence in air, as a gas which supported combustion, was postulated by Boyle and Hooke (1666), Lower (1669), Mayow (1673) and demonstrated by Joseph Black (1728-1799) in 1754. He showed that when a