The salvage of the *Wahine*: an exercise in occupational medicine

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Abstract

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In 1968, the inter-island ferry *Wahine* sank in the entrance to Wellington Harbour in a wild storm with the loss of 51 lives. Following a further storm, attempts to refloat the vessel were abandoned. This report, written over 30 years ago by Tony Slark as the diving medical consultant to the salvage operation, describes some of the medical aspects involved in the cutting up and clearing of the wreck between 1968 and 1973. It includes two detailed case descriptions of decompression sickness. From April 1970, Dr Slark introduced the SOS decompression meter to control all diving operations, with over 10,800 hours of diving time being completed without any further incidents of decompression sickness.

Introduction

The inter-island ferry *Wahine* sank in Wellington Harbour in a wild storm in April 1968 with [the] loss of 51 lives. It was initially hoped that the salvage of the vessel could be performed by refloating the whole hull with foam and compressed air. However, a further storm in May 1969 shifted the vessel breaking it up to such a degree that the original concept of salvage had to be abandoned in favour of raising the individual broken sections. However, further deterioration of the hull occurred and eventually the system of salvage necessary has been the piecemeal cutting of the hulk into sections capable of being lifted from the bottom by the support vessel *Holm Park* anchored beside the wreck. This has required the formation of a team of professional divers working constantly on the wreck to cut it into manageable sections.

During the initial period when the wreck remained in one piece lying on the sea-bed, the diving work consisted primarily of the removal of vehicles and cargo, and the cutting down of the superstructure. Twelve divers were employed for a period of approximately 3,000 hours underwater. [During] this time there was no organised system of decompression, but no bends resulted. It can be assumed that much of the diving took place at depths less than necessary for the production of a sufficient degree of nitrogen supersaturation to make decompression sickness possible. The average working depth was in the region of 40–50 feet of sea water (fsw).

When work was begun after the wreck had broken up, the maximum working depth increased to 70 fsw. Again, no organised system of decompression was used. During this time two divers suffered attacks of decompression sickness. Four divers only constituted the team during this time, which extended from October 1969 to March 1970, and they put in about 1,400 hours of work underwater.

Case report one

On 2 March 1970, the senior diver of the team, a man aged 52 years, a professional of many years' experience working underwater, surfaced about 4 pm after a total of 4 hours at 60 fsw. He did not perform any decompression time. The American Naval Tables would have suggested a total ascent time of some 82 minutes and the Royal Naval Tables [a] total decompression time of 90 minutes. Even with such a decompression time the tables are reckoned to have a possible 10% bends rate for such prolonged exposures.

The diver first noticed a pain in his left biceps, forearm and wrist with some pain in his left groin. The pain started some three hours after surfacing and he felt it became really unbearable in the early hours of the morning. He recognised that he was suffering from decompression sickness having had similar bouts before, and arrangements were made by the Salvage Master for him to be flown direct to Auckland first thing in the morning so that recompression could be offered him if necessary. He came by ordinary commercial flight which meant that he suffered further decompression stress during the flight for the cabin is only pressurised to an equivalent level of 5,000 ft. However, he did not remark upon any exacerbation of his symptoms.

On arrival he was able to walk into the consulting room and give a good account of the circumstances. He described his pain as being more severe than he had felt on any previous occasion, but did not admit to any neurological symptoms. His bladder function was normal. General medical examination revealed no abnormal signs, apart from brisk tendon reflexes throughout, and bilateral upgoing plantar responses. Since he described one major previous bend as having a considerable neurological content this finding was ascribed to the earlier incident, for which incidentally he had not received treatment with recompression.

He was asked whether he felt able to put up with the pain while a further medical examination took place – he said he would rather not. I would have wished to have done a chest X-ray, electrocardiogram and full blood screening, but he was quite blunt in his lack of enthusiasm for any delay. Since analgesia would have confused the decision-making process whilst under recompression treatment, I decided to recompress him forthwith. He was put under pressure at approximately 10.30 that morning and we tried initially the 'minimal-pressure oxygen recompression' schedule,[1] which involved initial compression to a depth of 60 fsw on pure oxygen for 20 minutes with breaks in air after each 20 minutes for 5 minutes. This latter is designed to prevent oxygen poisoning. Towards the end of the first oxygen period it became obvious that he was receiving little benefit, and it was therefore decided to proceed with the longer air table. He was therefore compressed further to a level of 165 fsw on Table 5B of the Royal Naval Diving Manual.[2] After a short spell at this depth he noted a very great relief in the pain and following this, decompression on the schedule proceeded uneventfully. He left the chamber at 10.30 that evening complaining only of a very slight tenderness of the left upper arm and with virtually no other abnormalities apart from the minor neurological signs noted previously. He was kept under observation at the Naval Hospital for the following day, during which time routine medical examinations were performed, including chest X-ray and electrocardiogram and blood screening. Apart from an ESR of 40 [sec] and a haemoglobin of 13 [g.100ml^{-1}] there were no abnormalities detected. He did not have a platelet examination or blood lipid screening as would now be my practice.

It was noted that he had a marked limp. And examination of his legs revealed shortening of the left leg of approximately three quarters of an inch. There were no symptoms relevant to this and he had what seemed a fairly full range of painless movement. It was decided to perform a full X-ray screening of him for the possibility of aseptic [bone] necrosis. This was confirmed by the X-rays, which showed a very widespread involvement with virtual complete destruction of his left hip and widespread necrosis throughout the long bones and many infarcts involving joint surfaces in other parts.

Because of this he was advised most strongly that in future his diving should be confined to supervision. It is interesting that his pattern of diving i.e., that of doing long periods at relatively shallow depths was similar to the pressure changes experienced by tunnel and caisson workers in whom aseptic [bone] necrosis is a far more common finding. He was, however, the sort of older worker who always wishes to show the younger generation that he can do more and do it better. He did not in fact follow my advice and continued his diving for a further fairly extensive period. The Salvage Master said he had had the limp for 15 years. He would often actively refuse to undergo decompression and cut it short if he could. Many of the old school divers regarded bends as some lack of courage. This attitude, of course, influenced the younger divers.[3] I understand, however, that his arthritis has still not caused him much pain though he has now retired from diving completely.

Case report two

The following week another diver of the team, a man aged 25 years, was sent to us with similar symptoms. He had been diving at a depth of 65 feet for 3.5 hours without decompression. This exposure according to the Royal Naval Tables should have required a total decompression time of 115 minutes, and on the US Naval Tables for exceptional exposures a time of ascent of 179 minutes. He stated that 15 minutes after surfacing severe pain had begun in his left shoulder, a less severe pain in the left elbow and some slight numbness of the fingers of his left hand. There were no other significant signs on examination and the central nervous system seemed quite normal in all respects. He was accordingly recompressed again. Initially an attempt was made to treat him on the minimal-pressure oxygen table but with no relief. Once more we recompressed further on the much longer deep air table and he stated fairly soon after being at 165 ft [sw pressure]. that he had considerable relief of his symptoms. Decompression according to Table 5B continued uneventfully and he was removed from the chamber the next day complaining only of some slight ache in the left shoulder. Further examination was performed at the Naval Hospital including electrocardiogram, blood investigation and a full series of X-ray examinations. None of these revealed any significant abnormalities and he was therefore returned to Wellington and has since continued to dive, and is now their second in charge.

Management of diving operations from April 1970

It was obvious that with two cases occurring in such a short space of time, both illustrating a complete absence of proper precautions for decompression following prolonged time underwater, some review of the safety precautions offered the workers on the salvage operation was required.

It was obvious that the senior diver's long personal apparent immunity to decompression sickness had allowed a rather casual approach to develop in the team, and I think that it was very much a matter of familiarity breeds contempt. The Salvage Master himself had faith in his chief diver with whom he had worked for many years, and had had no reason hitherto to concern himself much with the detail of the safety aspects of the diving side to the work. He also wished to avoid undermining his authority which he thought was precariously maintained. However, the complete disruption of the operation of a small team which was occurring because of the neglect of the standard of diving patterns could only result in a great deal of further trouble. There was therefore a considerable tightening up of all safety procedures, and all further diving in the next period between March and [April 1970] was worked strictly under the United States Navy Standard Air-Decompression Tables with surface interval credit tables and repetitive dive time-tables.

Each diver was provided with a depth gauge and complete records of dive times and depths were recorded in a log book. This system prevailed for a month during which time 278 hours of time were recorded.

This system of diving in salvage circumstances has grave disadvantages. Firstly on a salvage operation it is extremely difficult for any diver to perform one long dive at one consistent depth. He must move around varying his depth and position, he may have to return to the surface for different articles of equipment, and therefore may involve himself in a pattern of repetitive dives which complicate his decompression schedule to a considerable degree. Maximum depths and maximum times are routinely used for the calculation of decompression schedules as they should be and very often from a commercial point of view the divers have 'run out' of diving time before the end of the working day. Furthermore calculations with repetitive dive sheets, three different diving tables, the calculations of surface interval credits, even the simple difficulty of pencil and paper work and minor arithmetic on a wet and windy diving platform are very prone to errors. It seemed to me that this would inevitably lead to a further crop of "bends" as well as having disadvantages from the commercial point of view to the operators. I therefore recommended

1 the use of decompression meters for each individual diver suggesting that, together with their use, log books be maintained as accurately as possible
2 that repetitive dives be kept to the absolute minimum and of the briefest duration possible
3 that as far as possible, the decompression meters be used to indicate when the dive should be completed without the need for decompression stops.

From the institution of this pattern of diving operation in April 1970 until the end of July of 1973 something over 10,800 hours of diving time had been completed without any incident involving decompression sickness. One diver was killed by an underwater explosion on 25 October 1972, but apart from this accident the pattern of operations has been one of very considerable safety which bears very good comparison with any other similar pressure work. For instance in most pressure works involving caisson or tunnels an incidence of 2% bends rate is considered quite acceptable, and in many instances the number of cases has been considerably greater.

I would not, however, wish to recommend the uncritical use of decompression meters for commercial diving, nor indeed for any other sort of diving. They are but one method of monitoring a dive pattern and should in general be used with a full knowledge of other systems in addition. Certain points regarding the decompression meter have to be borne in mind.

1 It seems to be rather safer for shallower dives. The tables are safer for deeper dives. The crossover safety point seems to be in the region of about 90 fsw.
2 The meter is definitely less safe than tables when surface intervals occur over a period of longer than 6 hours.
3 Short, deep repetitive dives on the meter are likely to be dangerous.
4 There is a proven instrument variation.
5 The supposed 6 hour 'memory period' of the decompression meter is much less than the real excess nitrogen elimination period of the body – which is probably greater than 24 hours.

Decompression meters should only be used with a full understanding of their limitations. Nevertheless, the value of a simple instrument eliminating the need for calculation on a wet and windy surface with pencil and paper give it practical advantages which may in many cases outweigh its potential disadvantages. This is of particular significance in salvage work where in most cases the diving is likely to take place in depths less than 100 fsw.

I paid a visit to *MV Holmpark* myself in September and October of 1971 with a view to instructing the diving team in various safety procedures including the safe use of the decompression meter. I examined the site of work underwater and made continuing arrangements for the safety and medical supervision of the diving team, in addition to the provisions required by the Department of Labour code of practice for underwater operations. All divers were subsequently issued with a plastic card indicating vehicle management if decompression sickness might be suspected, and a list of telephone numbers relevant for assistance. A designated Medical Officer was appointed to conduct all routine pre-employment examinations and regular assessments on continuing fitness for diving. A high standard of fitness and safety has been maintained subsequently, apart from the one accident already mentioned. In addition even though a great deal of time has been spent by the divers in water possibly suffering from considerable contamination, they have been remarkably free of otitis externa.

Discussion

There are several points of interest in these two cases and the subsequent safety procedures adopted after their occurrence. Both cases were simple bends, classified currently as Type 1, without neurological or other involvement. Recently it has been our unfortunate lot to have to deal with a large number of very much more seriously injured divers, though in almost all cases these have been the result of much deeper dives for much briefer periods. Although both these divers exceeded the safe diving times for surfacing without decompression by a very great degree they did not receive the severe neurological involvement that has often occurred with other divers, even though in both cases there was a delay in treatment and an air evacuation involving some considerable additional decompression stress. Neither case responded adequately to the minimal-pressure oxygen recompression tables, and [both] required the older high-pressure air tables for their

adequate treatment. I personally ascribe this to the delay in the institution of treatment, and although I have in all cases tried to use the shorter tables initially, I have only found them of benefit when instituted very rapidly after the onset of symptoms. I think this displays some inadequacy in the assessment of the tables when they were originally introduced. It is obvious that, in testing therapeutic tables, patients cannot be subjected to a delay in treatment. I think it relevant that the diving pattern and pressure-time changes involved were similar to those for caisson and tunnel workers and that this case of aseptic necrosis should have occurred in a diver performing such work. Finally although during the past years the decompression meter has come in for a great deal of criticism by professional and amateur divers alike, this safety programme, when the instrument was used with a fairly full knowledge of its limitations, shows how valuable it can be. The salvage firm is intending to use the same system for the diving on the salvage operation on the *Seawise University* in Hong Kong.

References

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