OSTEONECROSIS IN TUNNEL AND CAISSON WORKERS

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The occurrence of bone necrosis in compressed-air workers in the United Kingdom became generally known in the construction industry and to the general public about 1967. However, the Decompression Sickness Panel (DSP) of the Medical Research Council (MRC) in England has been actively concerned with the problem since about 1959. Sporadic cases of painful and disabling bone necrosis in tunnelers and caisson workers have been described for over 60 years. But only comparatively recently has it been recognized that the disease is a fairly widespread condition in compressed-air workers and that the majority of lesions occur without clinical symptoms or signs other than radiological changes.

Data on aseptic necrosis of bone resulting from compressed-air work in the U.K. have been sought mainly through the study of tunnel-construction operations, in several of which large numbers of miners have been employed. For example, during the contracts at the Dartford (1957–1959), Clyde (1958–1963), and Blackpool (1960–1964) tunnels, over 1000 men worked for some time in compressed air (McCallum, 1968).

The first British radiographic survey of the joints of men during the course of their employment in compressed air, at the Dartford Tunnel, was a rather limited one (Golding *et al.*, 1960). At this contract the primary interest of the DSP was to evaluate what was at that time a new decompression table (Work in Compressed Air Special Regulations, 1958), a table that is in fact still the official one in Great Britain. Symptomless bone necrosis was found in 10 out of 83 men with a long history of exposure to compressed air, all of whom had suffered from bends at one time or another; and in 3 out of 20 men who had never sought treatment for decompression sickness. It was thus established that a history of bends severe enough to demand treatment is not necessarily associated with bone necrosis.

It became clear that for practical purposes radiography of the bones of compressed-air workers should be concentrated on the areas around the shoulder, hip, and knee joints. These sites, particularly the hips and shoulders, are the clinically important ones. Radiation exposure in routine examinations had to be limited; and the time involved in these examinations, which were and are still voluntary in the U.K., further restricted the number of radiographs taken.

It also seemed desirable in a study of men employed at a particular contract to distinguish between those who had previously worked in compressed air and those who had not, so that the circumstances in which bone lesions had occurred might possibly be defined more clearly. These considerations were applied in a study of men employed in compressed air during the construction of two tunnels under the River Clyde in Glasgow (Decompression Sickness Panel, 1966). Work on these tunnels was spread over five years, during which time 1362 men were so employed. In this survey 47 (19%) of the 241 men radiographed were found to have one or more bone lesions. Subsequently 11 other men not included in the original survey were found to have bone lesions. Out of 58 men known to have developed bone necrosis during this contract, 12 have become seriously disabled by lesions in the femoral or humeral heads.

Some of the serious problems associated with the epidemiological study of bone necrosis were revealed by this investigation. The survey was conducted toward the end of the compressed-air work, so that it was not possible to examine radiographically more than 18% of all those at risk. Furthermore, there were two or three major tunnel projects in the U.K. that overlapped one another in time. Marginal differences in pay rates among these contracts led to rapid movement of men from one contract to another. At times an entire shift of men might disappear from one site, shortly to reappear at another.

On the basis of our experience with the River Clyde and Dartford tunnel workers, a classification of the radiological abnormalities of bone necrosis was drawn up (Decompression Sickness Panel, 1966) that has since proved useful in practice.

Further observations were made on men employed in constructing a large road tunnel under the River Tyne near Newcastle between 1963 and 1966 (Decompression Sickness Panel, 1971). Although 641 men worked in compressed air, it was possible to take radiographs of the joints of only 171 (27%). Of the 171 men, 124 were new to compressed-air work. Bone necrosis was found in 44 men altogether; and of the 15 (12%) new to work in compressed air who had developed bone necrosis, 4 are now disabled.

One of the difficulties in making accurate estimates of the prevalence of bone necrosis is that it may not be detected in men who have worked at a particular contract until months or even years after the contract has ended. Unless the initial examination and follow-up rates are very good, the true prevalence of bone lesions is likely to be underestimated.

The most recent contract studied by the Decompression Sickness Panel is one concerned with cooling-water tunnels for a nuclear power station on the seacoast at Dungeness in southeast England. This is the first major contract in which newly calculated decompression tables (Blackpool Trial Decompression Tables, 1966), prepared for and sponsored by the DSP, have been used. At present we of the DSP are examining data from the Dungeness contract for comparison with the Tyne tunnel data. So far, we have found four or five cases of bone necrosis in men whose exposure to compressed air has been only at the Dungeness contract, but none of them has a disabling or potentially disabling lesion.

Bone lesions found in a group of compressed-air workers were distributed rather unevenly in different anatomical sites. In a series of 629 lesions in 281 men (Table I), about 40% were in the lower end of the femur (Walder, 1969), where they are typically symptomless and nondisabling; and 16% were in the femoral head, where they are potentially the most disabling. The longer men continue in compressed-air work the more likely they are to have bone lesions (Table II).

Table I. DISTRIBUTION OF BONE LESIONS IN 281 COMPRESSED-AIR WORKERS*

	Number of lesions	% total lesions
Humeral head	182	29
Femoral head	101	16
Lower end of femur	252	40
Upper end of tibia	94	15
Totals	629	100

*Walder, 1969

Table II. PERCENTAGE OF COMPRESSED-AIR WORKERS WITH BONE LESIONS WHEN RADIOGRAPHED 1 TO 5 YEARS (OR MORE) AFTER FIRST EXPOSURE TO PRESSURE*

Years after first exposure	% with bone lesions
1	6
2	20
3	39
4	44
5	40
>5	66

*Walder, 1969

Our general experience in tunnel contracts is that about half the seasoned compressed-air workers of some years' experience have radiographic evidence of symptomless bone lesions.

In attempting to determine the cause of bone necrosis, one must try to take into account a number of variables — *e.g.*, maximum pressure experienced, shift length, overall period of exposure, acclimatization factors arising from experience, a rise in working pressure, or breaks in pressure due to holidays, strikes, etc. The overall exposure period (total number of shifts worked) and maximum pressure experienced are difficult to separate. We have tried to compare men with bone lesions and those without, according to maximum pressure experienced and number of shifts worked (number of compressions–decompressions) (Fig. 1). Unfortunately, most men have worked at pressures greater than 18 or 25 psig, so that the picture is at present incomplete. As more data are collected, it is hoped to add the missing information.

One striking feature of compressed-air work is the gross difference between decompression procedures in different parts of the world or even within the same country (Table III). These

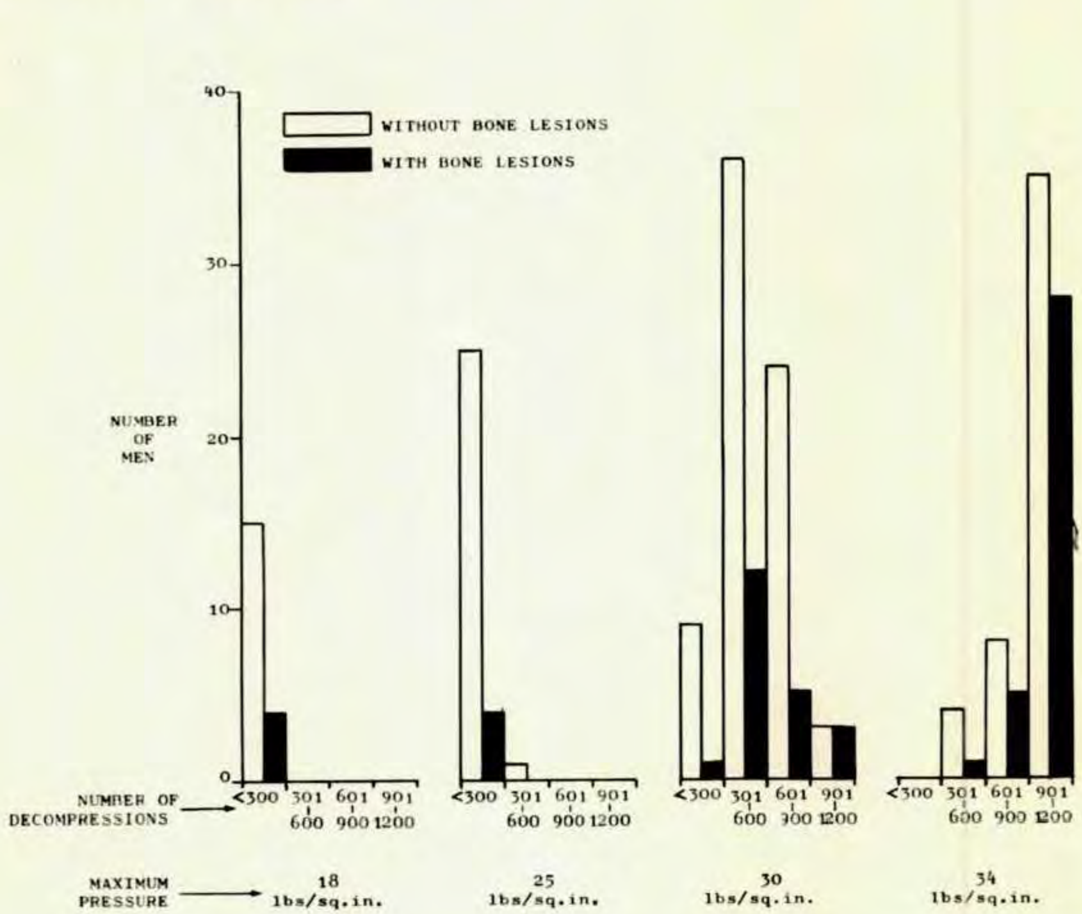

FIG. 1. Comparison of men with and without bone lesions according to maximum pressure experienced at a tunnel contract and number of shifts worked.

Table III. COMPARISON OF U.S. AND U.K. DECOMPRESSION PROCEDURES USED IN CIVIL ENGINEERING

	Pressure (psig)	Shift length (hr)	Total decompression time (min)
Great Britain			
1958 Regulations	24	5	37
Blackpool Trial Tables	24	5	94
United States of America			
Washington, D.C., Tables, 1966	24	5	117
Seattle, Washington, Tables	25	6	125

differences underline the need for reliable indices by which the success or inadequacies of decompression tables can be judged. As part of our response to this situation we have established, with Medical Research Council help, a Registry in Newcastle upon Tyne. This Registry contains information on the health and compressed-air experience of almost 10,000 workers, including some 1700 bone radiographs. The Registry will be described in more detail later. More information is still required on the very large number of men who have at some time or other worked in compressed air and on whom we have no data. It appears that the more one looks for bone lesions the more one finds. We hope to go on looking.

REFERENCES

Decompression Sickness Panel, Medical Research Council. (1966). Bone lesions in compressed-air workers, with special reference to men who worked on the Clyde Tunnels, 1958-1963. J. Bone Joint Surg. 48-B, 207-235.

Decompression Sickness Panel, Medical Research Council. (1971). Decompression sickness and aseptic necrosis of bone. Brit. J. Ind. Med. 28, 1-21.

Golding, F. C., Griffiths, P., Hempleman, H. V., Paton, W. D. M., and Walder, D. N. (1960). Decompression sickness during the construction of the Dartford Tunnel. Brit. J. Ind. Med. 17, 167-180.

McCallum, R. I. (1968). Decompression sickness: A review. Brit. J. Ind. Med. 25, 4-21.

Walder, D. N. (1969). Work in compressed air, including diving. Institution of Civil Engineers' Safety on Construction Sites Conference, 1969. Paper 6. pp. 49-55.