# X-RAY SURVEY FOR BONE CHANGES IN LOW-PRESSURE CHAMBER OPERATORS

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Presented at Aerospace Medical Association Meeting

Miami, Florida

May 9 - 11, 1960

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The literature on decompression sickness contains many accounts of bone lesions developing in caisson workers. Aseptic necrosis of the head of the femur has been the most frequently reported lesion, though other sites in long bones have been involved. It had been suggested by some that high altitude pilots, and persons exposed in low pressure chambers, would not develop these lesions. This was based on the smaller reduction of pressure, always less than 1 atmosphere, and the finding that the intramedullary pressure in live bone decreased with increases in altitude.[5] Others felt that bone lesions might be observed in persons exposed to altitude, and, in 1956, Coburn[3] reported a study of forty low pressure chamber operators in the U. S. Navy. In surveys of the long bones he recorded a 17.5% incidence of bone lesions. Most of these were areas of increased density, but in one case there was flattening and asymmetry of the femoral head (aseptic necrosis) and, in another, bone proliferation into the medullary cavity. The distribution of these lesions was similar to that reported in caisson disease. Four lesions were observed in the femur, two in the humerus, three in the tibia, one in the ulna and one in the fibula.

The problem was discussed with the Aerospace Medicine Division, Headquarters USAF, and it was agreed that this incidence was not only interesting but also of great significance to the USAF for it has some 600 physiological training technicians who are engaged in daily work in and about low pressure chambers. In view of this, a study of the USAF chamber operators was initiated.

Method:

A letter explaining the purpose and operation of the project was sent to 52 physiological training units. A sufficient number of questionnaires for all chamber operators in each unit was included. See Figure 1. A sample x-ray request and details of x-ray technique were also included. These were as follows:

> Tube Film Distance: 40 inches
>
> Film size: 14 x 17 inches, exposing more than one extremity on each film if possible, with least number of exposures practical.
>
> Bucky diaphragm where indicated for part thickness.
>
> Lead-apron shielding for all parts except area being recorded.
>
> Coding for easy identification and location.

Films taken were anterior-posterior (AP) views of humeri, radii, ulnae, femorae, tibiae and fibulae. The completed films and questionnaires were returned to the Department of Flight Medicine, School of Aviation Medicine, for review and compilation. After review the x-rays were filed as baselines for future comparison. Phase II of this study envisions a repeat of the x-rays in two to five years and comparison with the baseline films. This would be a health monitoring service also.

A few base surgeons questioned the necessity of the survey on the grounds that excessive radiation exposure would result. This was carefully considered prior to preparation of instructions for obtaining the films and it was felt no undue risk of radiation effects was involved. Subsequent calculations and measurements show the original estimate to be correct.

Results:

Six of the original 52 units queried reported they had no chamber personnel assigned. The remaining 46 bases returned 579 questionnaires and sets of long bone x-ray surveys. The films in general were of excellent quality and the assistance of Directors of Base Medical Services and x-ray personnel is appreciated.

Dysbarism episodes were reported by 283 of the 579 chamber operators. Thus the group was almost evenly split, for 296 reported no episodes of dysbarism. There were 341 separate dysbarism episodes reported. (See Table I) Bends was the most frequently reported symptom and the various vascular skin changes were the most common sign reported.

In view of the widely reported relationship between age and dysbarism and obesity and dysbarism, it was felt that these factors should be compared for the two groups. Figure 2 shows the rather marked shift to greater age in the dysbarism group. Unfortunately the data did not allow conclusions to be drawn for these ages are those at the time of the survey and not necessarily those at the time of the dysbarism event.

The age, height and weight were used to check against an ideal weight chart where the maximum weight allowed is the present Air Force Manual 160-1 standard, plus 15%. When compared with this standard, 57 of the dysbarism group and 59 of the non-dysbarism group were considered to be significantly overweight.

In an attempt to have some gauge-of-risk of bone lesions or exposure, the hours over 20,000 feet in chamber and aircraft were tabulated for both groups (dysbarism and non-dysbarism). The results are shown in Table II. It can be seen that the dysbarism group had a greater exposure in both altitude chamber and aircraft. It is planned that further evaluations will elaborate on exposure.

There were a surprising number of fractures reported--see Table III, 104 in the dysbarism group and 99 in the non-dysbarism group. There were also 21 and 8 dislocations in the respective groups. Thus the incidence of bends was apparently not affected by the fractures. The data do not allow determination of the relationship of bends to the fracture sites.

A variety of "serious" illnesses were reported, including rheumatic fever, pneumonia, poliomyelitis, etc. See Table IV.

X-Ray Findings:

Not one of the 579 bone surveys had lesions which could be attributed to pressure change. Plans had been made to survey a matched control group but in view of the totally negative findings there was no need to carry out this plan.

Discussion:

A great deal has been written about bone lesions in caisson workers.[5,6,7] The majority of the lesions have involved the femora and reasons given include the yellow marrow content (nitrogen highly soluble in fat) and the peculiar blood distribution in the femoral heads. The lesions have been described as infarcts in the shafts of long bones with or without intra articular bone necrosis. These appear as irregular areas of altered or decreased density, sometimes but not always surrounded by a thin linear area of increased density representing a partial re-ossification. The cortex is not involved. In the ends of the bones the articular surface may present an irregularity and although relatively rare there may be aseptic necrosis or sequestration. The bone marrow cavity has been shown to function physiologically as a semiclosed cavity. Vasoconstriction may play a role in producing the pressure changes and any bone lesions found after exposure to altitude.[5]

The time element between exposure to pressure change and the finding of bone lesions has been rather long in the caisson cases. In fact the New York compensation commission waived the statute of limitations for this condition due to the late development of symptoms. Most of these lesions are asymptomatic for years and many are discovered without specific symptomatic referral.

The question of permanent sequelae from altitude exposure has been quite controversial. There are many documented cases in divers and caisson workers and this is said to be due to the greater range of pressure change, more prolonged exposure, etc. The Germans in World War II decided that the easy reversibility of decompression symptoms was evidence on which they could base a policy of no pensions for occupational disease (rheumatic and arthritic disorders) as sequelae of decompression sickness while on flying status.[4] They later stated however that the question of permanent sequelae was unanswered and, though not yet seen, bone lesions should be watched for and any cases of recurrent bends should be studied by serial x-rays.

Several cases with chamber and inflight altitude exposures have now been reported to have at least long term sequelae of dysbarism, usually of a neurological nature.[1,2] Coburn's[3] report of the lesions shown in Table V was the first evidence of bone lesions developing in personnel exposed to altitude except for a questionable case having typical bone lesions and a history of numerous parachute jumps. Coburn found no relationship between the number of exposures and the appearance of bone changes. The age of his operators ranged from 17-39 and ours ranged from 18-40, but had no apparent related significance.

The absence of any bone lesions attributable to altitude exposure in 579 persons is of some importance. This study leaves some doubt as to whether low pressure chamber and aircraft altitude exposure will produce these typical bone changes. Theoretically it should be possible to produce bone lesions as a manifestation of low pressure exposure or dysbarism. Our subjects had had many hours of exposure to lowered barometric pressure and approximately fifty percent had had manifestations of dysbarism. It may be that the exposures have not been long enough and severe enough to produce such lesions. Though if so, those engaged in altitude work, either chamber or aircraft, are most fortunate. This study would seem to indicate that factors as yet undetermined must work to produce the described pathology. Further follow-up of the chamber operator population should add valuable information to our present ignorance of this baffling condition.

<u>Summary</u>:

While bone infarcts and aseptic necrosis have long been described as sequelae of decompression sickness in caisson workers, Coburn first described it in altitude chamber workers. In an effort to check these results in USAF low pressure chamber operators, 579 such personnel were asked to complete a questionnaire and submit to an x-ray survey of the long bones. Approximately fifty percent (283) of the operators reported 341 previous dysbarism episodes. The dysbarism group and the non-dysbarism group had an almost equal number of persons considered to be obese. The dysbarism group had more hours of exposure in both altitude chamber and in aircraft. A large number of previous bone

injuries was reported by both dysbarism and non-dysbarism groups. No bone lesions attributable to pressure change were found in the 579 chamber operators. The reasons for these negative findings are discussed, and the need for continued follow-up is stressed.

TABLE I

TYPE OF DYSBARI[illegible] BY 2[illegible]3 OF THE [illegible]

| | |
|---|---|
| Aerosinusitis | 1 |
| Bends | 268 |
| Chokes | 13 |
| Skin Lesions | 50 |
| Neurological | 8 |
| Neurocirculatory Collapse | 1 |
| TOTALS | 341 |

TABLE II

EXPOSURE OF CHAMBER OPERATORS TO ALTITUDE

| Hours Over 20,000 Feet | Chamber | | Aircraft | |
|---|---|---|---|---|
| | Dysbarism | No Dysbarism | Dysbarism | No Dysbarism |
| 0-24 | 90 | 167 | 257 | 284 |
| 25-49 | 76 | 71 | 11 | 5 |
| 50-99 | 71 | 39 | 5 | 1 |
| 100-149 | 22 | 10 | 3 | 0 |
| 150-199 | 9 | 6 | 2 | 1 |
| 200-249 | 6 | 0 | 2 | 3 |
| 250-299 | 1 | 0 | 1 | 1 |
| 300-349 | 1 | 2 | 0 | 0 |
| 350-399 | 1 | 0 | 0 | 1 |
| 400-449 | 1 | 0 | 0 | 0 |
| 450-499 | 0 | 1 | 0 | 0 |
| 500-999 | 4 | 0 | 0 | 0 |
| 1000-1999 | 0 | 0 | 2 | 0 |
| 2000 & up | 1 | 0 | 0 | 0 |
| TOTALS | 283 | 296 | 283 | 296 |

## TABLE III

### BONE INJURIES REPORTED BY CHAMBER OPERATORS

| | Fractures | | Dislocations | |
|---|---|---|---|---|
| Fractures of | Dysbarism | No Dysbarism | Dysbarism | No Dysbarism |
| Skull | 1 | 4 | | |
| Nose | 5 | 5 | | |
| Mandible | 1 | | | |
| Clavicle | 11 | 8 | | |
| Scapula | 0 | 1 | | |
| Shoulder | | | 12 | 3 |
| Rib | 4 | 2 | | |
| Arm | 24 | 26 | 3 | 3 |
| Hand | 21 | 18 | 2 | 1 |
| Wrist | 7 | 9 | | |
| Leg | 13 | 9 | | |
| Knee | 1 | 2 | 1 | 1 |
| Ankle | 7 | 9 | 3 | |
| Foot | 6 | 6 | | |
| Vertebrae | 3 | | | |
| TOTALS | 104 | 99 | 21 | 8 |

TABLE IV

"SERIOUS" DISEASES REPORTED BY CHAMBER OPERATORS

| | Dysbarism | No Dysbarism |
|---|---|---|
| Pnemonia | 4 | 11 |
| Appendicitis | 0 | 2 |
| Rheumatic Fever | 1 | 2 |
| Bronchiectasis | 0 | 1 |
| Asthma | 1 | 1 |
| Nephritis | 0 | 1 |
| Infectious Mononucleosis | 0 | 1 |
| Jaundice | 0 | 1 |
| Coccidioidomycosis | 1 | 0 |
| Meningitis | 1 | 0 |
| Smallpox | 1 | 0 |
| Gout | 1 | 0 |
| Poliomyelitis | 3 | 0 |
| TOTALS | 13 | 20 |

TABLE V

DISTRIBUTION OF BONE LESIONS IN 40 LOW PRESSURE CHAMBER WORKERS (COBURN)

Lesion Distribution

| Bones Involved | No. of Lesions | Percentage |
|---|---|---|
| Femur | | |
| Left | 1 | 9+ |
| Right | 3 | 27.0 |
| Humerus | | |
| Left | 0 | 0.0 |
| Right | 2 | 18.0 |
| Tibia | | |
| Left | 3 | 27.0 |
| Right | 0 | 0.0 |
| Ulna | | |
| Left | 0 | 0.0 |
| Right | 1 | 9+ |
| Fibula | | |
| Left | 1 | 9+ |
| Right | 0 | 0.0 |

## REFERENCES


1. BERRY, C. A.: Severe Dysbarism in Air Force Operations and Training. U. S. Armed Forces Med. J., 9:937, 1958.

2. BERRY, C. A. & KING, A.H.: Severe Dysbarism in Actual and Simulated Flight. U. S. Armed Forces Med. J., 10:1, 1959.

3. COBURN, K. R.: Preliminary Investigation of Bone Change as a Result of Exposure to Reduced Atmospheric Pressure (unpublished report). Abstract, J. Aviation Med., 27:163, Apr. 1956.

4. HORNBERGER, W.: Decompression Sickness. Chapt. IV-L, Vol. 1, German Aviation Med., WW II, Dept. A.F., U.S. Govt. Printing Office, Wash 25 DC.

5. KALSER, M. H., et al: Changes in Bone Marrow Pressure During Exposure to Simulated Altitude. J. Aviation Med., 22:286-294, Aug 1951.

6. TAYLOR, H. K.: Aseptic Necrosis in Adults--Caisson Workers and Others. Radiology, 42:550-569, 1944.

7. THORNE, I. J.: Caisson Disease. J Am. Med. Assoc., 117:585-588, Aug. 1941.