OBSERVATIONS ON "CAISSON DISEASE" AND
ITS PREVENTION.

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WHILE the number of men who suffered from caisson disease in the construction of the Greenwich Footway Tunnel was fortunately small, and the whole time occupied in tunnelling with compressed air was very short, namely, slightly under thirteen months, several points of interest to the medical profession were observed from time to time, and some have not, as far as can be ascertained, been mentioned in the literature upon the subject, and the close observation kept upon all the workmen, fit and otherwise, has prevented, so far as possible, the occurrence of caisson disease due to previous illness or physical unfitness.

SELECTION OF MEN.

It may be well to point out, in the first instance, that the position of medical officer to such an undertaking is one of great responsibility. It is twofold. First, in the selection of the men and the after-supervision when they have been passed as fit to work in compressed air; the inclusion of a man who has a defective heart, and especially defective powers of elimination, may mean a most painful illness, or even death, to that individual; and, secondly, the illness of the men reduces the working powers of the gangs to which they belong, and means pecuniary loss to the contractors and to the authorities, who make themselves liable for sick pay to those suffering from caisson disease. This responsibility was especially felt in this case, and the very greatest care was taken in the selection of the men. The inspections of the various gangs of workmen both going on and coming off duty were scrupulously carried out, as the following table will show. Thus the occurrence of the few cases of illness due to compressed air may be taken to be due to the effects of compressed air alone, in a healthy man working eight hours a day with a break after four hours. Altogether there were examined, from the start to the completion of the work, 122 men, of whom 17 were rejected, and of the remaining 105 men 6 were afterwards rejected thus:

No. of Men Examined.	Rejected at 1st Exam.	Rejected after having been at work	Percentage of Primary Rejections.	Percentage of After-Rejections.	Total Percentage of Rejections.
122	17	6	13.9	5.7	18.8

From this it is apparent that a considerable proportion of otherwise able-bodied men were not considered fit to work in compressed air. Among those rejected were several who had worked in compressed air for varying periods prior to examination—to these reference is made below.

MEANS TO REDUCE AMOUNT OF CO₂.

To make the work still safer various experiments were made to reduce the carbonic acid gas as far as possible. Such were: the introduction of screens of caustic soda into the volume of air pumped into the tunnel and the establishment of a blow-off tube from the shield where analysis of the air showed the carbonic acid was found in the greatest quantity. The effect of these expedients was tested by careful analysis of the air before and after their use. The results were decidedly favourable to the adoption of the blow-off tube, and as a considerable proportion of the caustic soda underwent transformation it might be deemed advisable to give it a fair trial by introducing it into the plant at the commencement of the work, which could not be done in this case as the machinery had already been laid down and could not be altered without entailing serious delay. The percentage of carbonic acid gas in the tunnel before the above experiments varied in different parts of the works, as did the temperature, as in the following table:

Date.	Air Pressure lb. per sq. inch.	Temperature at Face compared with Engine Room.	Free Air Supplied per Man per Hour.	Percentage CO ₂ in Engine Room.	Percentage CO ₂ in Tunnel.	Percentage CO ₂ in Shield.
Mar. 5	24	+ 10°	6,000	0.047	0.073	0.196
" 11	21	+ 19°	5,280	0.055	0.097	0.218
" 18	24	+ 15°	5,600	0.045	0.064	0.189*
" 25	23	+ 15°	5,280	0.047	0.058	0.125†

* After blow-out tube had been used, 0.124.

† End of shift blow-out tube used four times, 0.098.

Analyses of the air were taken 14 times from May 15th to June 14th. The averages before the caustic soda purifier was used were:

22.8 + 6.8 5.774 0.0474 0.0786

The average after the purifier was used were:

10 + 0° 5.330 0.0505 0.0688

In the last-named average it must be taken into account that the tunnel was longer, and therefore the carbonic acid gas more widely distributed.

HEALTH OF THE MEN.

There were 15 cases of sickness not due to compressed air, chiefly cases of chill (to which men engaged in this work are peculiarly liable), influenza, and rheumatism, and 1 case of malingering.

The health of the men generally was very good except one or two weeks during the completion of the concreting in the caisson on the south side of the river, when almost all of the men suffered from catarrh of the naso-pharyngeal and bronchial tubes, and during that time there were 3 slight cases of caisson disease, as compared with 6 cases for the whole of the rest of the time. In strict accordance with the rules laid down by the medical officers and enforced by the Resident Engineer to the London County Council, men suffering from colds should not have been allowed to go into the tunnel, but in the prevailing inclement weather, and in consideration of the heavy nature of the work in a confined space, at the time it would have been impossible to obtain a full gang of properly healthy men, and as the air pressure was not high, 8 to 12 lb., the risk was comparatively small.

The exemption from serious caisson disease was considered to be due to the ample supply of fresh air, for though the air pressure at no time exceeded 28 lb. and averaged 22 lb., the occurrence of one-third of the cases at the comparatively low pressure of 12 lb. in less favourable circumstances than in the case of those working under the higher pressures must place mere air pressure among the predisposing causes to the disease rather than the immediate cause. Similarly, the small number of such cases is to be attributed to the purity of the air, the uniform temperature, and the good health of the workmen. In the course of examination of the men, it was discovered that a large proportion of those who had previously worked in compressed air had a much lower pulse rate than the newer hands, and they did not perspire nearly so freely while at work; of 12 men, 7 had worked in compressed air for periods of over 12 months and 5 for only a few months. The pulse-rate of the former was much slower than that of the latter, averaging about 80 per minute to the latter's 104 immediately after work. They also showed a deviation from the normal in the sounds of the heart, usually in the pulmonary area, but often in the aortic; considering that these men must have come under examination frequently in the course of their previous work it might be puzzling how their condition did not attract attention on the part of the medical examiner, were it not for the very curious phenomenon observed in 3 or 4 of these who exhibited the deviations from normal alluded to, but to a much less extent, and who were allowed to go to work in the tunnel on condition that they presented themselves for re-examination after each shift until further notice. After each of these men had been at work in compressed air two or three days it was discovered that the heart sounds became absolutely normal in every respect; that this was actually so was placed beyond doubt (and here the advantage of having two medical officers was opportune) by the writer, after the first case came under his notice, taking care to ascertain his colleague's opinion (besides his own) of the conditions of the hearts of

2 men prior to allowing them to go to work; of 6 men who had previously worked in the Blackwall Tunnel or in the Waterloo and City Tunnel, 4 were summarily rejected for pronounced systolic murmurs, or reduplication of the second sound with diastolic murmurs; of the remaining 2, 1 had a diastolic murmur in the aortic area, the other had reduplication of the second sound. My colleague, Dr. Murray Leslie, confirmed these conditions, and also saw the men again with me the following Saturday, six days afterwards, when the heart sounds could not be said to differ from those of the other men, though examined immediately after work, and while still showing the effect of the exertion entailed by climbing the long ladder from the air lock to the top of the caisson. This, of course, only bears out the already well-known fact that often the best and most speedy remedy for a person suffering from caisson disease is his subjection to compressed air by putting him back again into it; and for this reason the medical lock is an absolute necessity in such work. But I have never before heard of an abnormal condition of the heart being so got rid of, and it must not be for a moment supposed that such a proceeding is safe, or to be followed in the case of former compressed air workmen who exhibit such symptoms, very much the reverse: as in the writer's opinion workmen with a history of previous work in compressed air should be more carefully examined than others, since as large a proportion as 27 per cent. will be found to have deviations from the normal in the sounds of the heart. Only the three or four who were exceptionally good workmen were permitted to go to work provisionally, for a few shifts, and were kept under very careful observation all the time.

Of the cases of caisson disease, 3 were serious, the others slight, all of them had giddiness as a symptom, only 1 had pain in the joints, 2 had the pain in the thighs and back, 3 complained of the pain being in the shoulders or arms, 1 had recurrent epistaxis with pain in the nape of the neck and forehead, shortness of breath and abeyance of certain functions. One became deaf. The most serious of all had a peculiar and instructive history.

CASE I.—H. T., aged 27, had worked in compressed air for varying periods for two years, and never had caisson disease before; he commenced work on the day he was seized, at 2.30 p.m., and went off at 10.30 p.m. He missed the 10.30 boat across the river, and after having a cup of coffee, which was supplied to each man after work, he went to a public house to wait till the next boat was due; he had three glasses of beer but no food. Half an hour afterwards, while on the ferryboat, he was seized with giddiness, which made the ascent of the steps on the other side of the river a matter of difficulty. After proceeding about fifty yards further he fell down, and was removed to Greenwich Hospital, where he was detained seventeen days. He was unable to sit up for ten days, as he immediately became faint, he never had any pain, but there was marked continued failure of the heart's action, especially on assuming an erect posture. On coming out of hospital the following interesting fact was elicited from him. His duty was to open and shut the door leading from the tunnel into the air-lock; when neither trucks nor passengers were passing he had nothing to do; to pass the time he rolled a cigarette and began to smoke, inhaling as he was in the habit of doing. After inhaling a portion of the smoke twice, he became so giddy that he fell down, and could not rise for about five minutes, but he remained on duty till the end of the shift.

CASE II.—J. J., aged 35, a well-developed muscular man of rather full habit of body, twelve months' previous work in compressed air. No former attack, had been suffering from a cold, finished work at half-past two, and at half-past six was seized with severe pain in the left hip and thigh, and then in the right thigh and the whole length of the spine, he went to bed and after vigorous rubbing the pain passed away, but on trying to get up in the morning it returned and did so at intervals for six days, after which he complained of weakness in the legs, loss of appetite, and restlessness; he continued on the sick list for three weeks. This man also told me that there had been entire abeyance of the sexual functions during the entire period of his illness, but thought nothing of that, as he was frequently in that condition before he was laid up, and further, that other men in the construction of Blackwall tunnel complained of the same thing.

CASE III.—J. D., aged 50 years, a stout, plethoric man with a long history of compressed air work, complained of complete deafness, noises in the head and giddiness, and was taken off work for six weeks, during which time he was put under treatment for liver complaint and gouty dyspepsia. He recovered completely, and was allowed to return to work in the tunnel, where he continued to follow his occupation for two months; he then caught a chill and was not allowed to go into compressed air, a week afterwards he returned to work without permission and remained three days, after which he became quite deaf again; the hearing partially recovered, but after his discharge the case was lost sight of.

PATHOLOGY.

Considering the paucity of the cases and the comparatively short period there was for making observations it may appear presumptuous to offer any conclusions as to the causation of caisson disease, nevertheless, such as they are, the cases have

borne out a theory that has been advanced by other writers, who, however, have put it down to causes which were inaccurate or non-existent. I will only mention one of these. Osler in the earlier editions of his *Practice of Medicine* attributes the disease to the disturbance of the ratio of nitrogen to oxygen in the compressed air inhaled into the lungs. This, we know now, is not so. Similarly, we must put out of consideration the accidental presence of other gases of a poisonous nature, such as carbonic oxide and marsh gas; these are not likely to have been present in sufficient quantity in all cases where caisson disease occurred, without their having been detected. What has been established conclusively is that the presence of carbonic acid gas in undue proportions in compressed air causes an increase in the number of cases of caisson disease, but the manner in which CO₂ so acts has been a matter of speculation. Now, I believe that workmen whose eliminatory functions are impaired or sluggish are more liable to the disease, hence the rejection of a certain proportion who showed signs of alcoholism and obesity, and that the attention of the medical officer to the functions of liver, kidneys, and stomach as evinced by pulse and tongue, etc., is of as great or greater primary importance as attention to the heart conditions and age of the candidate, as the increase of the proportion of CO₂ in the air must tell more powerfully on such men than on others whose powers of elimination are equally good. Thus, if a modification of Osler's theory be adopted—namely, that interchange of gases in the lungs is interfered with in such a way that, though the ratio between the oxygen and nitrogen is not upset, the pressure of the air breathed into the lungs diminishes the elimination of CO₂ from the body, and that the elimination of other waste products are similarly impeded, the cause of caisson disease is not far to seek. Added to that I believe in the hyperaemia of the deeper tissues. It is quite reasonable to suppose that a pressure of twenty odd pounds to the square inch compresses, however slightly, capillary and peripheral blood vessels, and that proportionately the circulation is retarded in the deeper tissues throughout the body; pathologists agree as to the effects of such hyperaemia on the nerve centres, especially the vasomotor and sympathetic. Interference with the functions of one or other or both of these systems will alone account for the symptoms in several recorded cases of caisson disease; and in the case No. 1 above, the sustained syncopal condition can only be accounted for by interference with the heart through the nervous system—that is, the sympathetic and vasomotor centres in the medulla. The man had no other symptoms except the giddiness when first seized; he also gave a history which discloses a valuable fact—namely, that the effects of inhalation of the smoke of a cigarette in compressed air were not got rid of for a much longer period than would have been the case in ordinary circumstances; in other words, by-products from the lungs are impeded in their discharge by the compression of the air.

I am aware that the theory of hyperaemia is not generally believed by observers of the disease, but I think it is put on one side without sufficient grounds for doing so; for instance, it is argued that there is not likely to be hyperaemia, because there is no constant effect on the pulse observable in the workmen; further, that pressure on capillary or peripheral vessels is not likely to act because in many instances after coming out of compressed air workmen have a slow, full beat in the radial artery. Now that condition of the circulation would be precisely what would be expected if the blood from the capillaries was kept in the deeper and larger vessels. It is certainly what happens when there is a larger amount of CO₂ in the air inhaled over a prolonged period. If we combine the two, hyperaemia of the nerve centres and accumulated impurities in the blood because of imperfect interchange of gases in the lungs, there is a double effect on the sympathetic and vasomotor systems, the consequences of which are not manifest till varying periods after the cause has been removed. When the affected centres resume their activity there is (quite in accordance with established physiological theories) a reaction and a reflex action manifested in the sensory and sympathetic nerves throughout the body. In this way the peculiar conditions described in cases Nos. 2 and 3 can be accounted for consistently; in the former the sexual functions were impaired for long periods at a time, and in the latter complete deafness from action on the labyrinth, but in

these instances the stage of irritation of the centres had passed farther into that of paralysis. Similarly the temporary restoration to normal when at work of disturbed heart functions from prolonged work in compressed air must be due to hyperaemia of the deeper vessels together with inhibition of the vasomotor centres and through the sympathetic nerve on the heart itself.

Concerning the treatment, I found that nerve sedatives such as bromides, especially ammonium bromide, were better than opiates, and in a severe case of pain cannabis indica gave great relief. Potassium nitrate, potassium acetate, and ammonium acetate are good in the convalescent stage, or when the pain diminishes, but may be given from the first with good results. By far the best treatment is the medical lock, into which, however, a purified air should be pumped till the pain goes, and then the pressure very gradually reduced. To effect this there should be attached to the medical lock an apparatus containing caustic soda in screens over which the air in passing would give up most of its CO₂. Similarly the prevention of the worst form of caisson disease would be effected by getting rid of the CO₂, where it collects in largest quantity, namely, in the shield where the men are working. This was done in the Greenwich Tunnel by running a blow-off tube down to the shield and blowing off the air every hour or oftener if necessary, if the analysis of the air in the tunnel and in the shield given above is examined it will be seen that the carbonic acid was reduced almost a half in volume by this expedient alone.

Finally, all workmen about to be employed in compressed air should be subjected to a most searching medical examination, all new hands should be examined after work each day for a week, and the gang going off and that going on twice each week, and those who are indisposed kept above ground till well; should the pulse have a high tension the man should be kept under observation every day, and should there be a booming sound in the heart or reduplication of the second sound he should be suspended altogether. This entails great labour on the part of the medical officer, but the responsibility of allowing men to work when unfit is infinitely greater, and the freedom of those under his care from a disease of such a distressing nature is a sufficient recompense.

COCAINE INTOXICATION AND ITS DEMORALIZING EFFECTS.

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BESIDES the use of cocaine hydrochlorate as a therapeutic agent its consumption as a drug for intoxication is so great in Calcutta that unless stringent measures be adopted to control its sale, I have reason to fear that its demoralizing effects will soon spread amongst the juvenile members of respectable families, and that at no distant date special asylums will be required for the safety and treatment of cocaine inebriates.

Fortunately, however, the cocaine habit is at present confined to people who are more or less addicted to opium, ganja, or alcohol, but we occasionally come across cases where the victims have contracted the habit *de novo*. We do not know how the people of Calcutta have obtained their knowledge of the intoxicating property of a costly drug which has hitherto been only handled by medical men, but facts tend to show that they have got it from Bhagalpore, where cocaine has become a social necessity amongst the less thoughtful. Inebriates say that the hilarity it produces is almost instantaneous, and is followed by no deleterious results. Novices as a rule take it quite secretly during the early hours of the night, whilst confirmed and veteran eaters consume it during all hours of the day. It is generally taken in the form of tablets or powder and chewed with betel leaves (*Pan*, piper betel) and slaked lime.

Unlike ganja or bhang it requires no special preparation. The habit once acquired cannot be easily given up. The first symptom experienced by the victim after he has taken a dose of cocaine is loss of sensation in the tongue and lips, followed by dryness of the mouth and fauces. A thermometer placed under the tongue does not indicate any rise of temperature.

The approach of the so-called hilarity is announced by a feeling of heaviness of the head, throbbing of the arteries of the neck, and palpitation of the heart. The pulse becomes slightly full and quick, but never exceeds 110. At this stage the inebriate likes to be left alone; he firmly closes his lips and avoids talking, lest, in his attempt to do so, the saliva flows out of his mouth. His ears become hot and red, whilst his cheeks become pale; the tip of the nose becomes cold, perspiration soon breaks out on the forehead and neck, and the height of intoxication is marked by coldness of the finger ends and dilatation of the pupils. This stage lasts from 30 to 45 minutes, after which the victim longs for a fresh dose, and unless he gets it he feels lifeless and dejected. This depression of spirits is more imaginary than real, for I have not noticed any fall of temperature or slowness of the pulse, but the respiration becomes slightly hurried. The tongue and lips now become moist again, and perspiration on the forehead ceases altogether, but the pupils remain dilated. The physiological effects of cocaine are most marked upon novices. The teeth and tongue of confirmed cocaine eaters turn jet black, and this is probably due to the chemical change produced by the action of lime and saliva upon cocaine.

The craving for an increase of the dose becomes irresistibly great, and in one case the dose was raised from 1 gr. to 12 gr. within the short space of a month. Unlike opium, it brings on insomnia and anorexia, soon followed by dyspepsia and diarrhoea. The dyspepsia of a cocaine inebriate is very obstinate and does not readily yield to treatment. Its prolonged use brings on some deafness. The quantity of urine is diminished, but in none of my cases was albumen detected. Delusions and hallucinations often occur, and cause dejection and dread. In some cases cocaine brings on acute mania, which is not amenable to treatment. Amongst numerous other cases I select the following in which the deleterious effects of cocaine upon the system were most marked.

CASE I: *Cocainism following the Use of Opium and Bhang: Gradual Increase of Dose: Diarrhoea: Convulsions: Death.*—L. B. M., a promising boy, aged 20, very respectably connected, fell into bad company and contracted the habit of taking opium and bhang in their various forms. His friends remonstrated with him, and he gave up the opium habit altogether and took a fancy to try the effects of cocaine. A friend of his offered him 1 gr., and its effect, as the young man said, was simply pleasant. He continued to take 1 gr. daily for some time with apparent benefit to his physical health. He then began to take 2 gr. twice daily, and he went on increasing the dose until it was raised to 30 gr. a day. The demoralizing effect of the drug was soon marked upon him: he now avoided society and became solitary. He was honest and truthful before, but now he became a liar and a pilferer. He was fair and strong, but he soon became weak and dark. He suffered very badly from insomnia, and hypnotics failed to give him rest and sleep. He would take nothing for his food except milk in very small quantities. His heart beat was strong, but his hands and feet were cold and clammy. His pupils were dilated, and the conjunctivae looked pale and bloodless; his tongue and teeth were black. Obstinate diarrhoea supervened and carried him off. He had convulsions before death.

CASE II: *Confirmed Cocainism: Plus Sulphonal: Ruined Life.*—S. B., aged 45, a Sanscrit scholar, and versed in Hindu philosophy, consulted me for insomnia, the result of the cocaine habit. As a priest he said he had fast at least three days in a week. About a year ago he had occasion to go to Bhagalpore, where he met a learned Pundit, who advised him to take cocaine, which possessed remarkable power of sustaining vigour and life without food, and enduring fatigue of all kinds. This induced him to take cocaine. At the commencement he derived benefit from its use. Thinking he might further improve his health he raised the dose from 1 gr. to 3 gr. He felt weak and giddy, and consulted another cocaine eater, who advised him to take it twice daily and in pretty large doses. He raised the dose to 5 gr., which he took regularly for three months, when unpleasant symptoms began to make their appearance one after another. He soon felt himself dispirited and miserable; he suffered from anorexia and obstinate insomnia; he lost his memory, and