CARBON MONOXIDE POISONING IN THE SENGHENYDD EXPLOSION.

[WITH SPECIAL PLATE.]

By IVOR J. DAVIES, M.D., B.S., M.R.C.P. LOND.,
HONORARY ASSISTANT PHYSICIAN, KING EDWARD HOSPITAL,
CARDIFF.

THE Senghenydd explosion happened about 8.10 a.m. on October 14th, 1913, and is the worst disaster in the history of British mining. The number of men killed was 440. The whole of the men working on the eastern side of the mine were brought up safely, almost immediately after the explosion occurred; 18 men only were rescued from the western side, after an exposure to the noxious fumes for twenty hours, and survived. Five died from the effects of burns and injuries sustained whilst following their occupation in close proximity to the shaft, and one man lost his life on the day following the explosion whilst assisting in work at the fire which was raging in the west main level, being killed by a fall of stone. The whole of the remaining men working on the west side were asphyxiated by carbon monoxide gas, many were also burnt and sustained multiple injuries, either as a direct consequence of the explosive blast or from being buried under falls of roof.

AN ACCOUNT OF THE RESCUE OF EIGHTEEN MEN FROM THE BOTTANIC DISTRICT OF THE SENGHENYDD MINE.

The rescue party consisted of representatives from the various colliery companies, the Miners' Federation, the Home Office, and a few of the Senghenydd Colliery officials, with the Rhymney Valley Rescue Brigade in charge of Superintendent Kitto, together with Dr. Dan Thomas, of Bargoed.

The circumstances under which rescue operations into the Bottanic District were rendered possible will be fully explained in a later paragraph. The party entered the No. 1 North Road from the east side of the pit, taking fresh air with them, and found but slight evidences of force and fire along this road.

Four bodies were passed; one, a man of exceptionally fine physique, was found in the middle of the road lying on his back with his hands clasped behind the head, indicating that he assumed a position of repose when first affected by the fumes of afterdamp. There were superficial burns upon the face and hands, and well-marked signs of carbon monoxide poisoning were present. The noxious fumes in this instance must have produced a narcotic effect, for the position was one of ease, and must have been assumed before consciousness was lost.

Two other bodies were found close by, lying in a semi-prone position against a box, and leaning against each other; these also showed typical signs of asphyxia from carbon monoxide. It is interesting to note that a live horse was found on the road.

The narrow entrance to the Bottanic District was now reached, and a dead haulier was found lying doubled up over the back of a tram with his head inwards. There was an extensive scalp wound over the back of the head, and death was due to carbon monoxide poisoning. The position of the body and wound on the head suggest that he was hurled backwards against the side, struck his head, and fell forwards into the tram, and was asphyxiated whilst lying stunned in this position. A little further in, close to the mouth of the narrow airway, was the body of the district fireman, lying in a semi-reclining position with the legs crossed, and head resting on the left hand; the body showed no marks of violence nor of burning, and presented well-marked signs of poisoning by carbon monoxide. The man's lamp was found some yards nearer the pit bottom, in the middle of the road, indicating that after leaving his district, and finding the air insupportable in the No. 1 North Road, he attempted to get back to inform his men, and, when affected by the fumes, dropped his lamp, and tried to crawl back. As will be described later, one of the earliest signs of poisoning by carbon monoxide is that anything carried becomes too heavy, and has to be dropped. The state of this body proves conclusively that comparatively little force entered the district, and also points to

the complete absence of fire. The importance of these observations will be fully understood later in connexion with the description of the erythematous lesions found on the bodies of the survivors.

The narrow airway was now reached, and the party proceeded in single file, but it was agreed that a line of communications should be kept from a fixed base, where some of the rescue men remained with their apparatus. The working places were now thoroughly explored in turn, and most of the survivors were found along the main road. The air was fresh up to this point.

Rescue brigades from Porth and Crumlin, in charge of Superintendents Thorne and Wimborne respectively, also rendered valuable assistance in the treatment and transport of the survivors.

The following cases are illustrative of the series of 18, a clinical abstract of which is given below.

CASE I.

(22) He first experienced a sensation of choking, which he attributed to smoke which entered the district, and says that ten minutes later his legs gave way and he lost the use of his feet, and was obliged to crawl on his knees to reach the main road, but before getting there "he felt his head going," and became unconscious, and recollects nothing further until the evening of the following day, after admission to the temporary hospital. When rescued his condition was as follows: Unconscious, foaming at the mouth and nostrils, lying in a reclining position, with his back against the coal face and head dropped forwards. Respiration was greatly laboured and frequent; the pulse was feeble, frequent, and irregular, and there was evidence that he had vomited. The condition of the man was extremely grave, but he gradually revived by the treatment, which will be fully described in another paragraph. He again collapsed into a similar state after being brought to the surface and carried to the temporary hospital, which had been prepared and equipped at short notice for the reception of the survivors under my care.

This patient was almost in *extremis* for twenty-four hours, and his condition constantly varied from that already described to periods of improvement which were only transient. He was conscious at times, but again, as in the case of the pulse and respiration, the state of consciousness varied a good deal, and with the remissions he would doze and become quieter. Throughout the forty-eight hours following the rescue his condition was very critical, and both cardiac and respiratory failure occurred almost hourly. His temperature varied from 99° to 100°.

Owing to marked restlessness his position in bed had to be continually changed. He expectorated frequently an abundant frothy blood-stained material, and there were numerous râles present, indicating acute oedema of the lungs. There was retention of urine, which was drawn off some hours after he was brought into hospital. The urine was dark in colour but contained no blood pigment, but unfortunately a sample was not kept for further examination. The urine afterwards was normal. Oxygen was administered regularly every hour, and at intervals the lower ribs were forcibly compressed bimanually according to the Howard method of artificial respiration. He responded well to stimulation with strychnine and digitalin hypodermically, the former in doses of $\frac{1}{10}$ grain hourly for twelve hours, and with each alternate dose digitalin gr. $\frac{1}{160}$ was combined. The same dose of strychnine was repeated at times when cardiac failure threatened to supervene.

His condition improved in the course of twenty-four hours, but on the following day he relapsed, the temperature became raised and respirations increased, and physical signs of pneumonia appeared. For several weeks afterwards there was irregular pyrexia, varying from 99° to 101°, and the physical signs were those of bronchopneumonia, successive portions of the lungs becoming involved in turn. He ultimately got quite well, but the areas of skin affected by erythema remained anaesthetic for several months, and sensation is still somewhat impaired in those situations.

Erythematous Lesions.—Over the left lower ribs posteriorly were two areas of acute erythema, almost contiguous, one circular and the other oval in shape, involving an area of skin several square inches in extent. These were acutely painful and tender. These areas of erythema were raised and of a cherry-red colour, the hair follicles standing out prominently, as is well shown in the photograph. Complete anaesthesia was present over these areas, and hyperaesthesia as already noted. The colour gradually faded, but was evident for several weeks, and some desquamation resulted, but anaesthesia persisted for months.

CASE II.

J. J. (19), brother to the foregoing. His first symptoms were consequent upon the smoke coming into his working place, and he felt "choked" and giddy, and some minutes later a feeling of weakness came over him, which was felt in the feet, and a sensation as if something was lifting the hair of the scalp. He says that he has no recollection of anything further until the fourth day after the explosion, when he realized what had happened. He was found some distance from his working place, and close to the main haulage road.

He was unconscious and lying in a semi-recumbent position

against the side of the road. He was badly affected by the fumes of after-damp, but to a lesser extent than his brother.

He was revived and conveyed to the temporary hospital, where his condition was found to be as follows: Semi-conscious and extremely restless and irritable, his mental state closely resembling that of cerebral irritation. He constantly shifted from one position to another, but this was partly due to extensive erythematous lesions, which made lying in almost any position uncomfortable.

The erythematous lesions were confined to his back in the following situations:

1. An almost quadrilateral patch of acute erythema in the left infrascapular region and involving an area of skin of about 2 in. in extent.

2. Another on the left buttock triangular in shape with its base over the tuberosity of ischium, and sides extending upwards and forwards to the iliac crest, as shown in the accompanying photograph.

3. Smaller patches in the right infrascapular and lower dorsal regions.

The whole of these erythematous areas possessed characters similar to those already described, and these lesions were evidently very painful, for he groaned repeatedly, and on examination exquisite tenderness was elicited, particularly over the affected buttock.

These areas of skin remained congested for several weeks and anaesthetic for several months.

His general condition is now good, but he still suffers from neurasthenia.

CASE IV.

T. M., aged 18. He was working on the face of the coal at the time, close to the airway, with his father and two brothers, who were afterwards found dead. He accompanied the others in their endeavour to escape along the return road, and remembers distinctly that his father and two brothers were with him when the double parting was reached on the way back. All were now feeling the effects of the after-damp and fell. He attributes the onset of symptoms to the exertion of walking quickly uphill along the incline road, for three-quarters of an hour had now elapsed from the time of the explosion.

When rescued he was seen to be badly affected, and more in a state of collapse than asphyxia. He was revived with difficulty, and conveyed to hospital, where he recovered sufficiently some hours later to be conveyed home. He has no recollection of the rescue party coming to his aid, and only vaguely remembers being conveyed and detained in hospital.

His condition was as follows: There was some degree of collapse, but this had greatly improved on reaching fresh air.

Peripheral Neuritis.—This involved the dorsiflexors of the right foot, giving rise to foot-drop as shown in the photograph. There was also some pain, swelling, and redness of the foot and leg for several days. Anaesthesia of the lower third of the outer side of the right leg and of the whole of the foot and heel was present. This afterwards cleared up upon the sole, but anaesthesia still persists in the other situations, and paralysis remains almost unaltered. Some slight improvement has resulted from massage and electrical treatment of the affected muscles. There is paresis and atrophy of the whole of the right lower limb; the calf measures 2 in. less and the thigh 1 in. less respectively than the corresponding parts of the sound side. Complete reaction of degeneration is present in all the muscles of the right leg, except the gastrocnemius, which gives a partial R.D. The thigh muscles react normally. Loss of tactile sense and anaesthesia persist on the lower half of the outer aspect of the leg, the inner side of the dorsum of the foot in a line with the great toe, and also on the ball of the foot. The foot is usually cold and red, and there is also some vasomotor instability elsewhere. He has complained at times of pain along the sciatic nerve as far as the knee, and occasional shooting pains in the foot and ankle. The knee-jerks are exaggerated, but the plantar response is flexor in type.

Erythematous Lesions.—(1) A well-defined area of acute erythema, quadrilateral in shape, on the right buttock, 5 in. long by 3 in. wide, and extending almost transversely from the tuberosity of the ischium to the great trochanter. The characters were identical with those described in previous cases, and in his case the lesion closely resembled an extensive wheal produced by local injury and attended by considerable pain, swelling, and induration of the part. (2) There was also an oval patch of acute erythema over the right lower ribs in the anterior axillary line. (3) There was another small patch of erythema above the external malleolus.

These lesions progressed in the same manner as in the cases already described.

CLINICAL ABSTRACT OF THE SERIES.

Symptomatology.

General.—Languor, weakness, and an almost irresistible desire to lie down.

Cerebral.—Drowsiness, mental confusion, giddiness, headache (in one case only).

Muscular weakness of the legs was complained of by all, and was in most instances the earliest symptom felt, particularly in the knees. Probably this was but a part of a general asthenia, which first manifested itself in the legs, and was brought out by exertion. In one case the patient says that his head became too heavy for his body, and he was obliged to lie down.

Cardiac symptoms were not complained of in the early stages of poisoning, although subsequently several were in a state of collapse from cardiac enfeeblement.

Respiratory.—Cough was present in some of the cases, but this was probably due to smoke. One complained of a feeling of constriction in the chest, another of suffocation.

Physical Signs.

General.—Some but slightly affected, others suffered from various degrees of collapse.

Cerebral.—Stupor, restlessness, irritability, depression, coma.

Cardiac.—Marked enfeeblement of cardiac action in many and repeated attacks of cardiac failure in one case. The occurrences of remissions and relapses so frequently in this case, made the question of prognosis very difficult. His case (No. 1) was considered as hopeless by most of the medical men present, but he responded well to timely stimulation and inhalation of oxygen, which was given almost continually. The condition and progress of this case have convinced the writer that no case of carbon monoxide poisoning should be regarded as hopeless, for he was almost in *extremis* when brought out of the mine, and after some improvement following the restorative measures applied at the time of rescue, he again collapsed on reaching fresh air and during transport to the temporary hospital a quarter of a mile or so distant from the colliery.

Respiratory.—Acute oedema of the lungs occurred in one case (No. 1). There were three cases of bronchitis and two cases of bronchopneumonia. One of these (No. 1) was prolonged, and attended by considerable constitutional disturbance, whilst the other (No. 3) was of short duration. In both cases the course was subacute for the major part of the illness.

Nervous System.

Ataxy occurred in several patients antecedent to loss of consciousness.

Peripheral neuritis occurred in five cases. In four cases paralysis in the distribution of the external popliteal nerve resulted in foot-drop, and anaesthesia in the area supplied by this nerve. The lesion was on the right side in all; but in one (No. 5) foot-drop was also present on the left side, but cleared up quickly. There was some paresis of the dorsiflexors of the feet in several, but of short duration. In one case (No. 7) the extensor muscles of the forearm were affected, resulting in wrist-drop, but this was also of short duration. The hand on this side was also in a condition of acute erythema with vesiculation, with absolute anaesthesia. This has now resulted in an atrophic condition of the whole hand with ankylosis of the carpometacarpal joint of the thumb in a position of adduction, some atrophy of the thenar eminence and first dorsal interosseous muscle, and the fingers are cold, glossy, and tender. There is anaesthesia of the ball of the thumb and of the four fingers, and also incurving and furrowing of the nails. There is loss of movement in the thumb and index finger. The lesion in this case must have involved many of the terminal twigs of the ulnar and median nerves. The ordinary methods of treatment for cases of peripheral neuritis were adopted.

CUTANEOUS LESIONS.

Acute erythema occurred in nine of the cases. In one case (No. 7) oedema, vesicles, and bullae were associated with the erythema. In several oedema of the part was present, with erythema. In five erythema affected the right buttock only. In three erythema affected the left buttock. In one both buttocks were affected. In several of these cases other parts were also involved. In only one case did the buttock escape.

In seven cases erythema affected the skin over the scapula or immediately below its lower angle, and most commonly over the spine and vertebral borders. In six cases erythematous lesions involved the skin of the chest wall, and in five of these on its posterior aspect inferiorly, whilst in one instance the skin over the pectoral muscles was involved and in another a large area on the front of the thigh was affected. In two cases the skin above the malleoli was affected. In three of the cases a patch of skin below the head of the fibula was affected, and in two paralysis of the dorsiflexors of the foot on that side was associated.

Thus the lesions most commonly involved the buttock, and generally the skin over the tuberosity of the ischium was affected. In other situations the skin over bony prominences was most commonly affected.

Thus pressure must have played a part in the determination of the site of these areas of acute erythema, for most of the survivors were found in a sitting or reclining position. However, the occurrence of acute erythema in situations other than over bony points indicates that pressure was not the cause of these lesions, and the presence of hyperaesthesia with anaesthesia, too, affords strong evidence of the existence of some other factor in the causation of the cutaneous lesions.

Characters.

The patches were raised and of a brilliant cherry red colour, and the hair follicles stood out prominently, and the erythematous condition was attended with considerable pain, which made lying on the affected part impossible.

The affected areas were hot to the touch and very tender, and faded a little on pressure, but, owing to extreme tenderness, only slight pressure could be applied without causing much discomfort. Absolute anaesthesia was present to painful impression. This was strictly confined to these areas for the most part, but in some instances it extended a short distance beyond, but not more than to the extent of an inch in a single instance, in others it was less than this.

Progress.

The colour gradually faded over a period of several weeks, and it did not go through the stages of a bruise. In two cases the areas of erythema are still evident, and the colour can be restored to some extent by rubbing the part. In one case, when this is done, the patch becomes red, and the margins are of a purplish colour.

Many show generalized vasomotor instability, and in some factitious urticaria or dermatographism can easily be elicited. In one (No. 7) there is passive congestion of the fingers, which are generally cold. In some desquamation and crusting resulted.

In one (No. 7) definite scarring has taken place, and this involves the subjacent muscles of the thumb. Probably septic infection was responsible for this result. In two others probably scarring will ensue. There is evidence of atrophy in two cases, for the area of skin previously occupied by acute erythema is now depressed below the surrounding parts. In one (No. 7) the acutely erythematous condition of the fingers has been definitely succeeded by atrophic changes as already described.

Hyperaesthesia lasted for several weeks. Anaesthesia was absolute for several months, and in many is still evident.

PATHOLOGY.

The considerations detailed above point to some resemblance between the cutaneous lesions of carbon monoxide poisoning and those belonging to the group of toxic erythemata. In both there is capillary dilatation, serous exudation, and cellular infiltration.

The presence of hyperaesthesia and anaesthesia, so striking in the cases now under consideration, constitute an important difference between the two affections, for they are absent in toxic erythemata.

The scarring and atrophic changes in carbon monoxide poisoning afford a marked difference between the two affections.

The association of anaesthesia with erythema indicates that the cutaneous lesions of carbon monoxide poisoning are of the nature of an angioneurosis, and brought about either directly by anoxaemia, or indirectly through the circulation of toxins produced by faulty metabolism.

The persistence of the lesions and their results favours the former view, and point to a marked interference with the nutrition of the skin. If the lesions were due to the circulation of toxins, one would expect this to subside soon after the patient recovered from the immediate effects of the gas, and on this supposition the cutaneous lesions should be of brief duration, and clear up completely.

The association of peripheral neuritis with several of the cases favours the view that an angioneurosis is responsible for the condition of carbon monoxide erythema, and it is rather remarkable that in two cases of external popliteal paralysis erythematous patches were present just below the head of the fibula, and almost

exactly over the situation of the nerve. The influence of pressure has already been discussed.

The cutaneous lesions of carbon monoxide poisoning were first described by the writer in a communication to the BRITISH MEDICAL JOURNAL of November 1st, 1913. There is no record of any previous observation of these lesions, which, in the writer's opinion, are now fully established as true manifestations of carbon monoxide poisoning. There was no evidence of burns or of any fire having reached the part of the mine where the survivors were found.

TREATMENT OF CARBON MONOXIDE ERYTHEMA.

Lotio calaminae was of some value locally, but relieving pressure such as by a ring pad or cushion enabled the patient to lie down with some degree of comfort.

SYMPTOMS SHOWN BY RESCUERS.

The symptomatology of carbon monoxide poisoning as shown by those engaged in the work of exploration, etc., will now be considered.

General.

A marked feeling of languor and an irresistible desire to rest quite regardless of immediate danger. Those affected wanted to be left alone, and would resent interference, even if directed to their advantage.

Fatigue becomes so acute that almost any muscular action cannot be sustained. One man was obliged to relieve himself of a pocketful of nails, another a hammer, another his cap, for even this seemed too heavy. A colliery manager leading one of the parties, and carrying the canary, when affected by the gas felt his grip upon the wooden cage weaken, and imagined his fingers were swollen. Others complained of faintness, others of exhaustion.

These symptoms were usually brought on by exertion, and were far more evident in those doing hard manual work than in the officials superintending such work. Some relief would ensue from rest, but this would be of a brief duration, and recur immediately work or walking were resumed.

Cerebral.

Tinnitus aurium was one of the earliest symptoms. Headache was general, and first felt at the back of the head, and described by some as amounting to a severe pain. Some complained of a feeling of constriction as if the head were encircled by a band which could be tightened by a screw.

Others said they had a feeling as if the crown of the head was being lifted off, or a sensation of expansion of the head; or a feeling of the head splitting in two. One said that "his head felt double the size." A marked feeling of "throbbing in the temples" was present in many. Headache was delayed in some, and absent in a few. A feeling of contentment or complacency was general even in those suffering from the various subjective sensations described above. Many were fully aware of their dangerous position, but strangely there was no mental distress, and they would lie still, and make no effort to move on to a place of safety. In some the mental state was one of exhilaration, even when prostrated and conscious of extreme danger. Such cases would desire to rest, and would not actively assist any one desirous to help them. All precaution would be abandoned, and one leader of a party carried the canary mechanically, and ceased to take any further notice of its movements. Many said that their sense of humour was increased as in the early stages of alcoholic intoxication, and jokes and pleasantries would be exchanged between the mine officials and the working men.

Many responsible officials who ordinarily possess a keen sense of authority and duty would joke with their subordinates, although fully conscious of doing so, and, indeed, they would mentally reprove themselves for being "childish."

Some were greatly amused at the gasping appearance of others, although fully aware that their own condition was very similar.

Others, again, would exhibit hysterical symptoms, such as immoderate laughter, shouting, or singing, and in this respect one said that the effect in his case was very similar to that produced by nitrous oxide. A mild degree of delirium was produced in some instances, and one of the mine officials when affected became excited on reaching

fresh air, and raised his lower limbs in walking in a manner resembling the "turkey trot."

Some were happy and depressed in turns, others were irresponsible and indifferent as to their language to their superiors. One man in this respect behaved similarly when "gassed" as on another occasion when observed by the writer to be under the influence of alcohol. Giddiness was complained of by many, and several were observed to be ataxic on endeavouring to walk.

Cardiac.

Palpitation was a common and early symptom, and accompanied in many by a very tumultuous action of the heart. Cardiac action would become so forcible that some were obliged to keep the elbow firmly pressed against the left side. The members of one party exploring the mine within a few days of the disaster, and when it was possible that some of the workmen were still living, believed that they could hear knockings, which they attributed to the presence of entombed men, but which were really due to tumultuous heart's action, and which became audible to others.

Another party which suffered in the same way said that they could plainly hear one another's hearts when all were silent in a remote part of the mine. Some stated that palpitation was so acute that they felt compelled to fall, for the heart's action was strained "almost to bursting point." Others described their symptoms as a severe throbbing of the heart.

Respiratory.

Breathlessness was common, and was probably in many cases partly cardiac in origin. Some described this as being asthmatic in character, others as "heavy and deep breathing"; others, again, said their breath was "heavy and gasping."

Muscular.

Weakness of the lower limbs was general, and described by some as a giving-way of the knees; others as a sagging of the knees; others stated that their legs became tremulous and weak; another said that his legs failed to support him and "felt like rubber"; another said "his legs were like whips"; others that their feet became too heavy. One—the official already mentioned, whose gait and behaviour excited some amusement—said that his lower limbs seemed very pliable, and he felt capable of performing almost any acrobatic movement. This was partly due to his mental state of exaltation, but which was maintained by a condition of flaccidity in the lower limbs.

Gastro-intestinal.

Vomiting occurred in some instances and gave relief. This happened in a few cases on reaching fresh air, and was attributed by one to the administration of oxygen.

Sequelae.

Malaise and lassitude were present for days in most cases, and some complained of failure of memory for some time. Those who continually inhaled small quantities of carbon monoxide gas—as, for example, those at work on the bashings—were subject to a cumulative effect, and general failure in health was the result and neurasthenia. It is the opinion, too, of many of the leading mining experts that respiration is permanently affected after such work.

The writer hopes to verify this by further observations of those affected at Senghenydd.

TREATMENT OF AFTER-DAMP POISON.

Preventive.

Miners in each district of the colliery should be subject to discipline and in charge of the district fireman.

When an explosion occurs the fireman should warn all the men to this effect by a recognized signal, such as ringing of an electric bell.

Some districts of the mine may escape the immediate full effects of the explosion, as did the Bottanic district in the Senghenydd disaster. The men should assume comfortable reclining positions on either side of the road, in a place selected by the fireman as being the best situated to obtain the purest air available. The fireman then inspects the roads leading from the district, and ascertains if escape be possible.

We have evidence from the survivors that the fireman in charge of the Bottanic district of the Senghenydd Mine made an attempt to collect his men, and cautioned them not to move until his return. His body was found just inside the narrow airway leading to the district. He was probably overwhelmed by the after-damp ascending No. 1 North Road.

The efforts of the men to escape have been already described, and the onset of symptoms in almost every case followed the exertion of walking quickly up the inclined road. Some also were considerably more excited than others. The party of men was almost wholly overcome by the time the double parting of the district was reached, and most of the bodies were found in groups close to this spot.

It is difficult to explain why eighteen men survived and why eighteen men died, for there were no marked differences of age, general health, and habits. Their respective positions also were somewhat similar, for almost all were found reclining against the side, and in some places the dead and living were mixed together.

The air close to the Mafeking return must have been heavily charged with the deadly fumes of after-damp, for a canary died suddenly here on the following day. Many of the men in endeavouring to escape traversed the road leading to the Mafeking return, and it is possible that some went further than others, and so were worse affected by the vitiated air of this part of the mine. Moreover, the concentration of the men at the double parting of the district must have lessened their ultimate chances to escape.

There is, of course, the question of varying susceptibility to the effects of after-damp poisoning, and this must have been partly responsible for the result.

When escape by the comparatively short route along the No. 1 North Road was impossible, the men would have done wisely to remain in the district rather than to traverse the long and difficult road heavily charged with the fumes round to the main level of the mine.

A supply of oxygen kept in the district would probably have saved the lives of many, for some of the survivors were hardly affected and only in a drowsy state. Inhalation of oxygen would have revived these men, and they could then assist the others. A knowledge of the administration of oxygen could be included in the instruction given to miners in first aid classes which are so well attended in the principality.

Large cylinders of oxygen could be kept in each district, and fitted with several gas bags, which could be filled, and used to resuscitate those affected by the after-damp. Unfortunately the effects of an explosion in many parts of the mine are so immediate and overwhelming that no escape is possible, but districts like the Bottanic in the Senghenydd Mine may escape the full blast and the noxious fumes may only diffuse in slowly, and thus with the aid of oxygen and the precautions already noted many lives may be saved.

Again, miners under such circumstances should drink the cold tea which is their favourite beverage when at work, and unless they have taken food recently they should partake of that in their boxes. The "jacks" and "boxes" found in the Bottanic district in the Senghenydd Mine at the time of the rescue were for the most part full.

Thermos flasks containing hot tea and milk, or hot coffee and milk, would be better than "jacks" containing cold tea.

Summary of Recommendations.

1. The district fireman to be responsible for the safety of the men, and the strictest discipline should be maintained at all times.

2. No man is to leave the district until permitted by the fireman in charge.

3. The fireman with another, or failing him two or three experienced men, are to undertake examination of the air along the roads leading to the district, and they should be careful to avoid over-exertion when carrying out such an inspection.

4. The men in the meantime should assume a position of rest, preferably in a semi-recumbent posture, and should drink their beverages and partake of food if necessary.

5. They should endeavour to keep awake, and those less affected should encourage the others.

6. A supply of oxygen, if available, should be used to restore those already affected by the after-damp. Inhalation of ammonia, too, would be useful.

Curative.

In the treatment of a person suffering from after-damp poisoning, unless removal to fresh air can be carried out immediately, treatment should first be applied on the spot.

The oxygen cylinders attached to the breathing apparatus of the rescue brigade can be utilized, and the air around the patient fortified by an ample supply of the gas. Artificial respiration can be performed at the same time. Inasmuch as most of the survivors in the Senghenydd Mine were found in a sitting position, this was maintained, and artificial respiration performed by the Howard method.

These measures proved to be effective, even in the worst cases suffering from collapse.

Massage and brisk friction of the limbs, too, was useful, and strychnine hypodermically. In less affected cases in which stupor is a feature, vigorous shaking and flipping measures were adopted.

The application of lotio calaminae seemed to relieve the pain of the erythematous lesions after the patients were removed to hospital.

In many of the explorers who were "gassed" artificial respiration by the Schäfer method was best. Oxygen was administered whilst the movements were being performed.

Owing to spasm of the upper limbs (Case 1), erythema, and oedema of the hands (Case 7), burns on the limbs in many others, the Sylvester method of artificial respiration was inapplicable, and this, too, would have hindered the simultaneous administration of oxygen.

As regards transport various means were adopted at Senghenydd. In slightly affected cases they were shouldered out by a helper upon either side, and the boys were carried pick-a-back. In badly affected cases a stretcher was used, but owing to the turns and obstructing timbers in the narrow entrance of the Bottanic district leading to the No. 1 North Road a blanket had to be used.

Ambulance trams for conveying injured or "gassed" miners should be devised for use in collieries. A wheeled support across which a stretcher or blanket could be suspended would be useful as a means of transport from distant parts of the mine. Commonly in ordinary cases of injury occurring in the mine the coal trams are used as a means of transport, but this for obvious reasons is unsatisfactory, and may seriously aggravate such injuries.

The patients should be covered up warmly with blankets or rugs, for on removal from the hot air of the mine to the relatively cold outer air serious collapse is apt to take place, as happened in some of the Senghenydd cases.

A small hospital should be permanently established as near as possible to the colliery.

All men suffering from the effects of after-damp poisoning should be carried, and under no circumstances should be allowed to walk home, for symptoms may be delayed and come on suddenly.

It is important that restorative measures should be carried out as far as possible in the mine itself, for the difference of temperature and pressure at the surface may lead to a relapse, as happened in some of our cases. This is probably due to the sudden liberation of small bubbles of the gas, which might form emboli in the brain and elsewhere.

RESCUE BRIGADE WORK.

The rescue brigades equipped with special self-contained apparatus rendered fine service in the work of rescue of exploration.

The first rescue party to arrive was the Rhymney Valley rescue car, with eleven men in charge of Superintendent Kitto, at 10.30 a.m. The nearest rescue station was Porth, ten miles distant, but this brigade did not reach the mine until half an hour later than the first named, owing to trouble with tyres, and to the fact that they were not summoned to the scene of the disaster until 10 a.m., nearly two hours after the explosion; thus valuable time was lost, inasmuch as before their arrival it was impossible to repair the damage done to the water pipes owing to fumes and smoke.

Had a rescue brigade been on the spot the water pipes could have been repaired immediately, and efforts directed

against quenching the fire raging in the main west level would have been far more likely to be attended with success than three hours later. Whilst immediate measures were being taken to combat the fire, probably others of the rescue brigade with breathing apparatus might have been able to reach the West York district, and possibly also the Bottanic district, and thus many more lives would have been saved. This view is supported by the following considerations. The districts already mentioned were far more favourably placed for the purposes of rescue than the others.

One man employed in the West York district actually escaped from a point about twenty or thirty yards below the engine on the incline. He was blown down, but uninjured; and as he expressed it, he made a bolt for the shaft, and groped his way out, and fell unconscious close to the bottom of the upcast shaft.

The West York district was explored on the day following the explosion and the air found to be tolerable. Several men had made their way to within twenty yards of safety, and their bodies were recovered on the next day. Most of the others working on the coal face had traversed several hundred yards before being overcome. The positions of these bodies will be fully described in a later paragraph.

One of the bodies found in a group close to the Mafeking return was brought up on the next morning and bore the appearance of not having been long dead. The body was examined by several medical men, and each one formed this opinion independently.

Again, with regard to the Bottanic district, where the eighteen men were eventually rescued, the committee of experts determined that after an examination of No. 1 North Road at 9 a.m. and at 1 p.m. on the day of the explosion, rescue operations in this direction were impossible, owing to the fire having reached the Cross Cut, and dense volumes of smoke were travelling with the air into the road. The road subsequently became impassable, owing to falls, consequent to the burning of timbers supporting the roof.

The falls of the roof just described must have almost completely blocked the road, and thus the amount of smoke travelling up the No. 1 North Road was greatly diminished. Probably this was responsible for the reversal of the air, which maintained life in the Bottanic district and made rescue operations possible. Probably, too, before the falls occurred a large amount of this smoke was diverted into the stables, for the doors here were destroyed as a direct result of the explosion.

The rescue brigades early in the day were desirous of making an effort to reach the men in the Bottanic and West York districts, but permission was not granted, inasmuch as the mining experts believed that such efforts would be attended with certain calamity. The reason stated against making an endeavour to reach the Bottanic district from the east side of the mine was that it was impossible owing to the smoke in the No. 1 North Road.

The Rhymney Valley Rescue Brigade had worked at a fire two years previously, where the smoke was said to be even denser than that at Senghenydd, and the gauges of the apparatus could not be read even by a lamp of a hundred candle power, and a line of communications had to be kept by each man touching the one in front. After this experience this brigade at Senghenydd was prepared to enter the districts already mentioned.

Upon the arrival of Professor Redmayne, His Majesty's Chief Inspector of Mines, and Dr. Atkinson, the Chief Inspector of Mines for Wales, it was decided to examine the east roads leading to the west side, and this was done at 9 p.m. on the same day, with the result that they found the air to be now travelling down the No. 1 North Road, and not in the reverse direction as is normally the case. When this fact was reported it was decided to explore the Bottanic district from the east side of the pit, and the party started at 10 p.m. Their further progress has been elsewhere described.

The matter has been referred to in detail, inasmuch as it is highly probable that had the mine a permanent rescue brigade of its own, equipped with the breathing apparatus, an attempt would have been made much earlier to reach the Bottanic district.

The rescue brigades which came from other places were not acquainted with the mine, and proceeded almost

immediately to attack the fire and repair the water pipes. They were informed that no lives could have possibly escaped the immediate effects of the explosion.

The considerations strongly support the view that each mine should have its own rescue brigade, consisting preferably of men drawn from the ranks of the officials who possess an intimate acquaintance with the workings, which are varied and often complex, as the plan of the Senghenydd Colliery shows.

Rescue brigades for mines should consist of very carefully selected men. They should be in charge of a brigade superintendent qualified by long experience, and capable of instructing the men and maintaining thorough discipline.

It may seem almost unnecessary to suggest that the men should be of good physique, and that medical examination should be done at intervals, and immediately before undertaking any rescue work. However, at Senghenydd a brigade man collapsed whilst taking part in the exploration of No. 1 North stables. The heat was intense and the fumes dense, with the result that one of the men was overcome, and had to be carried out by the others. On subsequent examination it was found that the man suffered from heart disease, and had been unable to work for three weeks, and on the day of the explosion was actually under orders to attend the Cardiff Hospital for special examination. The apparatus was confiscated, but afterwards found by Professor Haldane to be in thorough working order. As a result of this the other brigade men were medically examined, and two more men certified unfit for the work.

The question of temperament, too, is of great importance in the selection of men for rescue brigades in mines. It transpired that whilst the brigades were removing the bodies from the York West district one of the men took fright and ran back. With this single exception the men constituting the various brigades were fearless, and were of great service in the work of rescue and exploration.

If, as already suggested, each mine had a rescue brigade trained and always ready for any emergency, the superintendent in charge would have ample opportunity of knowing his men and rejecting those unfit by temperament as for any other reason. In such a permanently instituted brigade, too, much advantage would be gained from the men becoming well acquainted with one another, which is so necessary for the purpose of discipline and co-ordinated work.

The brigade should have a medical officer to examine the men at intervals and to instruct them in principles of first aid, and it would be a great advantage if he could attend the practices and accustom himself to the use of the apparatus.

The training of rescue brigades should be carried out under conditions which resemble the actual as closely as possible. Arrangements should be made for filling the galleries of rescue stations with a certain percentage of irrespirable gases, such as carbon monoxide and sulphur fumes, and smoke.

The brigades, too, should have frequent practice in the mine itself, and operations could be carried out in the various districts with obstacles here and there to simulate falls of roof. Moreover, all the men should possess a good knowledge of first aid, together with that of the chemistry relating to gases and the administration of oxygen.

Whenever an accident happens in the mine the brigade should be summoned to attend the injured and convey them to the surface.

One of the brigade men at Senghenydd whilst assisting to carry a body slipped and was momentarily stunned. Instead of transferring the wounded man to the stretcher and removing with all speed to fresh air, some of the others ran for help to the base 50 yards away. Had these men possessed an intimate knowledge of first-aid principles, and been accustomed to put this to practice, their first consideration would have been to convey their injured colleague as quickly as possible to fresh air.

In actual operations the men should be thoroughly fresh, and have had a good meal before descending the mine, and should not take alcoholic liquors in any form.

The various brigades should work in shifts, for it is of vital importance that the men should not be exhausted by overwork, as they are then much more prone to be affected by the after-damp and to suffer acutely. One

man at Senghenydd collapsed after being at work continuously for twenty-one hours. This was the result of physical exhaustion and not of a defect in the apparatus, which was afterwards found to be in good working order.

Immediately symptoms of poisoning are experienced or observed by others, the man should desist and return to the surface, and afterwards should not resume work until he is pronounced fit by the medical officer of the brigade.

As far as possible a close watch should be kept by all members of the party upon each other for signs of after-damp poisoning, and no one should be allowed to proceed alone to any part of the mine. Should the conditions prevent the brigade working together, then a line of communications should be maintained from a fixed base.

The rescue party should never go without a canary previously noted to be chirpy and lively. The bird, in a cage fitted with a small oxygen cylinder, should be carried by the leader of the party, and kept by the left hand on the corresponding shoulder, where its movements could be constantly observed. The position of the bird is important, inasmuch as carbon monoxide gas is lighter than air, and is uppermost. One exploration party at Senghenydd almost ended disastrously by omitting to observe the above precautions.

The earliest sign noticeable in the bird is a ruffling of the breast feathers; then it becomes unsteady, and assumes a position of roosting, and would remain so until it fell off the perch. The plan adopted by the superintendents of the rescue brigades at Senghenydd, to whom I am indebted for the account of the symptomatology of carbon monoxide poisoning in birds, was to shake the canary off its perch whenever it showed a tendency to adopt a roosting position, and if it failed to rise from the floor of the cage, or would flutter its wings in an attempt to do so, this was sufficient evidence that the bird was affected.

A constant watch should be kept for evidences of early embarrassment in the bird. When a canary was put suddenly into an atmosphere charged with carbon monoxide it fluttered quickly and died, but rescue parties should not wait for this, inasmuch as an atmosphere highly dangerous to life may be reached before the canary actually dies in the way indicated.

POST-MORTEM APPEARANCES.

The following notes on the *post-mortem* appearances of 400 bodies refer to external appearances for the most part, inasmuch as permission could not be obtained to do any dissections.

Although some of the bodies were not recovered for several months, and were consequently in an advanced state of decomposition, yet typical signs of carbon monoxide poisoning were present in nearly every case.

The face was the part usually examined for the presence of the characteristic coloration, and, if not evident here, a part of the chest would be washed free from coal-dust, or incisions made in the limbs.

The colour in most instances was bright pink, and was evident even in portions of flesh exposed by injury, such as in torn ends of muscles around joints from which the limbs had been blown off. Many of these bodies were not recovered for several months, and yet the typical pink coloration of the exposed part, just described, was still evident. This indicates the firm stability of the compound formed by the union of carbon monoxide with haemoglobin.

In another instance the brain was exposed and lacerated by a compound comminuted fracture of the skull. The meninges and brain substance were bright pink in colour, and no haemorrhages were seen. The cerebral substance showed many small white areas, almost circular in shape, and about the size of a pea. These were probably areas of unaltered brain substance.

The colour of the gums in a large number of bodies closely resembled that of the enamel used in making false teeth, and, until the parts were closely examined, in many cases artificial teeth were believed to be present.

In no instance were false teeth found to be loose, and this points to the absence of convulsions in most instances. In one only was the tongue found to have been bitten.

The tongue in a large number of bodies was swollen in almost the whole of its extent, the tip only remaining

normal in size, and considerable difficulty was experienced in removing false teeth for the purposes of identification.

Superficial burns on exposed parts were common, and in a large number of instances coal dust had been driven into the skin, and had to be scraped off before the typical colouring could be ascertained.

Tattoo marks were very distinct, and the delineations of certain celebrities could be easily made out at almost first glance.

The features of many of the earlier bodies were swollen, and a sanguineous froth exuded from the mouth and nostrils, and showed the typical coloration.

A small pool of blood was found by the side of one body, and was fluid even after the lapse of thirty hours, and of a characteristic bright pink colour.

Fractures and dislocations of almost every possible variety and description were found, and such was the terrible force of the explosion that some bodies were blown to pieces and the limbs of others evulsed at the joints, even the lower limbs being separated in this way without fracture from the hip-joints.

Most of the bodies were found close to the coal faces, and were for the most part in groups, within 100 yards of the working places. The positions were variable, and many were killed whilst actually at work, and just fell over from the position they were in at the time. Thus many were found actually at the coal face on their knees, hauliers beside their trams, and engine men in their seats. Some had tied mufflers round the mouth and nostrils, others their vests or waistcoats; another had plugged his nostrils with cotton-wool.

There were evidences in some instances that boys had been carried by men before both were overcome. Four men had rushed out in one district arm in arm, and had fallen together about 60 yards from the coal face.

Five bodies were found in the No. 1 North Road under a fall, and recovered five weeks after the date of the explosion. They were men working in the Bottanic district, and were seen by the survivors after the explosion happened. One was a master haulier and a man of experience, and probably persuaded four others to accompany him in a bid for safety. These men rushed to their doom, for the No. 1 North Road at the time was heavily charged with after-damp, which entered the narrow passage leading to the Bottanic district, and which convinced the others that escape in this direction was impossible. Inasmuch as there was an equal number of survivors and dead in the district, it is probable that had the five men remained with the others, two at least would have survived. The bodies of these men were greatly mutilated, but one showed unmistakable evidences of carbon monoxide poisoning, and thus the injuries must have happened either after death or whilst he was in an unconscious state from CO asphyxia.

In the West York district four men got within a short distance of the shaft before being overcome, and were at variable distances from the 15 to 100 yards proportionate to their respective strengths. All had fallen forward on their faces, and evidently whilst running. Thus the first body was that of a young man of fine physique, and the fourth that of a boy. Ten others had traversed 600 yards before becoming unconscious on the main road close to the Mafeking return. These were in groups of three, and appeared to have sat together and to have gone off to sleep. Two were on opposite sides of a rail, and appeared to have been leaning against each other. The body of the district overman was about 10 yards in front of this group and out-bye to the Mafeking return, whilst the others were in an in-bye position. He had fallen forward on his face, and it is probable that he was leading this group of men to safety, and, being a man of considerable experience and sound judgement, knew that the critical point along the road would be near the Mafeking return, which conveyed the air from this district towards the upcast shaft. He halted his men in-bye to this point, and decided to make a test of his own life, and his fellows were to follow if the glimmer of his lamp was seen to be receding, or that he was to shout to the others. This view is held by his old friends, and is highly probable, for he was a man of fine physique, and could have got as far as the four mentioned above, for these, too, had travelled from the coal face, and several of the group of nine might have reached a near

point to the shaft as well. Thus, amidst the gloom and horror of a terrible disaster, there were evidences of heroism of the finest description.

I am particularly indebted to Dr. Phillip James, the doctor of the colliery, for much valuable information, and to many of the colliery officials for their courtesy and help.

Presidential Addresses

TO THE

BRANCHES OF THE BRITISH MEDICAL ASSOCIATION.

METROPOLITAN COUNTIES BRANCH.

SOME OBSERVATIONS ON MODERN VASCULAR PROBLEMS.

By FRED. J. SMITH, M.D., F.R.C.P.,

Physician, London Hospital.

SOME two or three years ago Dr. James Mackenzie delivered a lecture in which he stated that physicians had been in the habit of making two fundamental errors in their teaching of the pathology of cardiac disorders; and my first object is to show that these errors existed only in his own mind, and arose from his ignorance of the teaching (at any rate at the London Hospital) of cardiology, and from his lack of appreciation of the lessons conveyed by the literature of the subject.

His first statement was that we physicians had taught that a valvular bruit heard in the heart invariably meant the commencement of a condition certain to grow worse, was always an omen of dreadful things to come—was, in fact, the handwriting on the wall of a fate from which none of the possessors of a bruit could ever hope to escape. I take this opportunity, belated though it be, of flatly contradicting such a pernicious error of statement.

Evidently Dr. Mackenzie had never had the advantage of hearing the late Sir Andrew Clark speak on the subject. I well know that Clark was constantly teaching that bruits were not always to be looked upon as such dreadful portents, for he had collected (and I believe published) a large number of cases in which in the course of routine examination he had found valvular murmurs without any signs whatever of cardiac insufficiency, cases which he labelled "murmurs without heart disease," and against which he warned us especially to be on our guard lest we should frighten some poor soul into a serious illness. Nor could Dr. Mackenzie have heard of Sutton's teaching. I had the good fortune to be his house-physician, and many is the time I have heard him say, "Gentlemen, it is my good fortune to be a little deaf, so that I cannot always hear these murmurs of which you speak"; and we who knew him were always proud to admit that Sutton with his one ear could hear more than we could with our two, by which we meant that his clinical knowledge could see much farther into the case than our stethoscopes could take us.

These two instances are quite sufficient to show Dr. Mackenzie's ignorance of the teaching of his time, and as an old pupil of these great masters of medicine I must confess to some little soreness at hearing a specialist express in public a disregard for, and ignorance of, their teaching.

The second error of which Dr. Mackenzie accused us has as little foundation in fact as had the first. Dr. Mackenzie says that as he reads books on cardiac disease it would appear that it was taught that back pressure caused heart failure. Having evolved this absurd piece of topsy-turvydom, he then proceeded to hold us up to ridicule for having taught it, and in very grave language to inform us that the horse drew the cart and not the cart the horse—an observation of which I do not believe that any modern physician can be asserted to be ignorant.

I have now relieved my mind of a portion of the indignation I have felt at the publication of these statements, which are not only absurd and incorrect in themselves but unjust to the memory of my dead teachers, and must proceed to express my admiration for the extreme beauty

DR. IVOR J. DAVIES: CARBON MONOXIDE POISONING IN THE SENGHENYDD EXPLOSION.

FIG. 1.—Case III of series. Showing disposition of erythematous lesions. Desquamation resulted, as shown in the photograph.

FIG. 2.—Case II of series. Showing disposition of erythematous lesions. The swelling of the affected buttock is well shown in the photograph.

FIG. 3.—Case IV of series. Showing effect of peripheral neuritis, resulting in foot-drop with atrophy of the affected muscles.