

The Goulstonian Lectures

ON

SPINAL INJURIES OF WARFARE.

DELIVERED BEFORE THE ROYAL COLLEGE OF PHYSICIANS
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II. THE CLINICAL SYMPTOMS OF GUNSHOT INJURIES OF THE SPINE.

DURING the past thirteen months we have been able to observe several hundred cases of spinal injury, and at present have clinical notes on over 300; these will form the basis of the remarks and conclusions which will be put forward in the next two lectures.

But even this material is so large and the variety of symptoms is so great that it will be necessary to select only the most striking and special symptoms for consideration. We have found every segment of the cord from the second cervical to the conus affected, but in the cases that have reached the base hospitals the injury has been most common in the middle and lower dorsal segments and in the cervical enlargement; the fourth, the fifth, or sixth cervical segment was damaged, for instance, in 51 cases, while in 65 the lesion lay between the sixth and ninth dorsal segments. It is not proposed to deal at present with injuries of the cauda equina, of which a large number came under observation.

Even an ordinary transverse lesion of a dorsal segment produced directly or indirectly by a bullet, piece of shrapnel or shell casing, presents striking symptoms.

When the patient is seen a day or two after the infliction of the wound, there is usually complete flaccid paralysis of the lower limbs and of the trunk muscles to a level varying with that of the lesion, sensory loss to the corresponding level, absence of all reflexes in the lower limbs, except, perhaps, of the flexor withdrawal reflex in incomplete lesions, and retention of urine.

LOCALIZATION OF THE LESION.

The segmental level of the lesion can be usually recognized as accurately by the extent of the motor paralysis as by the upper border of the sensory disturbance; and since the evidence it gives is less equivocal and as easily interpreted in both military and civil practice, some emphasis may be laid on its importance. The segmental innervation of most of the muscles of the upper and lower limbs is now known, and this knowledge has been applied in clinical work. A paralysis of all the movements of the wrist and fingers as well as of the triceps while the biceps remains strong or only slightly weakened is usually, for instance, taken as an indication of a lesion in the seventh cervical segment, but hitherto little attention has been given to the evidence of the level afforded by the palsy of the trunk muscles. When, however, one of the lower six dorsal segments is involved, the part and the extent of the muscles of the anterior abdominal wall which are paralysed form an easy and certain guide to the segment in which the lesion lies. If, for instance, the eleventh is involved the whole rectus abdominis contracts when the patient raises his head, attempts to sit up, or coughs, but the iliac regions bulge owing to paralysis of the lower portion of the obliqui abdominis, and their failure to contract can be easily recognized by the observer's fingers. Similarly if the ninth segment is injured, it is obvious to the finger that the recti abdominis downwards from about 1 in. above the umbilicus do not contract, but are, in fact, passively stretched by the tension produced on them by the shortening of the upper segments. Owing to the same fact the umbilicus, as Beevor first pointed out, rises towards the xiphoid. The state of the intercostals is an equally reliable guide to the level of the injury, and permits a local diagnosis in the upper as well as in the lower dorsal segments. If the fingers are firmly placed in series on the intercostal spaces the unaffected muscles are felt contracting on each deep inspiration, and form a firm shallow floor to the space, while in paralysed spaces no contraction can be felt, and

on deep inspiration the finger sinks deeper between the ribs; in lean subjects this may be, in fact, visible to the eye. As the intercostal muscles have only unisegmental innervation, and as each receives its nerve supply from the correspondingly numbered dorsal root, the highest space which is paralysed indicates the level of the spinal injury.

The upper limit of disturbance of sensation is the means most commonly used in civil practice to determine the segmental level of the spinal lesion, and if proper care is taken the evidence it gives is reliable, but, as we shall see later, in incomplete lesions, and more especially in those which are wholly or chiefly unilateral, errors may easily occur, and an exact local diagnosis may not be always possible from even an accurate sensory chart; this is due to the oblique course of the decussating sensory fibres in the cord. In a complete or very severe lesion, light contacts are usually felt a short distance below the limit of complete analgesia, but there is frequently some disturbance in tactile sensibility above the level of the latter. The appreciation of moderate temperature is often lost slightly higher than that of painful stimuli.

The disturbance in the appreciation of vibration may be also a valuable indication of the level of the injury, especially in incomplete cases in which the dorsal columns only are damaged and sensibility to touch and pain is unaffected, since the vibrations of a heavy tuning-fork cannot then be recognized below the corresponding segmental area. This can be determined by drawing the base of the vibrating fork upwards over the soft parts. This method is particularly valuable on the trunk when the state of the other elements of sensation conducted through the dorsal columns cannot be investigated; the base of the fork may be simply drawn over the anterior abdominal wall till the level is reached at which the patient feels the vibrations, but, as the thorax can act as a sounding box and transmit the vibration widely over it, it is necessary to apply the fork here only to folds of skin raised gently between the observer's fingers and thumb.

When one of the lower abdominal segments is involved, the level of the lesion may be also accurately determined by observing the segment below which the abdominal cutaneous reflexes cannot be obtained.

It must be remembered, however, that the lesions produced directly or indirectly in the spinal cord by a gunshot wound are often very extensive, and that a clinical examination can, as a rule, indicate only their oral limit.

REFLEXES AND REFLEX TONE.

In all severe lesions the lower limbs are found flaccid at least as early as one day after the infliction of the wound, and within three or four days their muscles become toneless and flabby; if the lesion is complete or almost so they remain flaccid and waste gradually; later the atrophied muscles, especially those of the calf and the flexors of the toes, undergo fibrous contracture. In less severe cases the muscles regain tone and the limbs become slightly rigid, generally within fourteen to twenty days. In one case, however, we observed slight rigidity in a limb five days after the wound was inflicted, but in another spasticity appeared only after eighty-four days. In slight cases there may be no obvious defect of muscle tone, or, if diminished, as it frequently is at first, it rapidly recovers.

In those cases in which some rigidity develops early reflex spasms of the legs of the flexor type are apt to occur; they are, as a rule, seen only a few days after the limbs have become somewhat spastic, but we have observed them occasionally as early as the sixth to tenth day, when the tone of the muscles was not yet exaggerated.

In one interesting group in which pains due to higher spinal lesions occur in the legs, these limbs are often held stiff and rigid, but careful examination shows that there is no true spasticity, and reflex spasms do not occur; in these cases the spinal lesion is not severe, and voluntary movement is either not lost or has recovered rapidly.

The state of the reflexes in the affected parts presents interesting problems. Except when the spinal lesion is slight the knee and ankle jerks are almost invariably lost at first, and in severer cases remain absent during the period in which we have been able to observe them—that is, in some instances, for as long as six to ten weeks. The teaching of Dr. Charlton Bastian that these reflexes are

permanently abolished in total transverse lesions of the cord is generally accepted now, and our experience seems to confirm it, though in one case in which a fragment of shell-casing lacerated the cord in the lower part of the fourth dorsal segment and passed downwards through the next three lower segments, apparently destroying them completely, feeble knee-jerks could be obtained from the fifteenth day onwards; whether or not there was a total transverse lesion has not yet been determined by microscopical examination.

In less severe injuries the knee-jerks return, but generally not earlier than within two or three weeks; the re-appearance of the ankle-jerks is always later than of the knee-jerks, but occasionally ankle-clonus could be obtained while the knee-jerks were still absent or much depressed. In a few cases in which paraplegia in flexion developed after the return of the knee-jerks we saw these again disappear as the flexion rigidity increased. In lesions of the upper four cervical segments the arm-jerks are usually lost at first, independently of the severity of the injury, and seem to recover less early than the knee-jerks.

Not only are both knee and ankle jerks absent for a considerable time in transverse spinal injuries, but with unilateral lesions of the cervical or dorsal segments neither can usually be obtained in the paretic leg for some days, or they are at least much diminished on this side compared with the normal. The paretic leg is also usually flaccid. In these cases, however, the reflexes return earlier than in transverse lesions of the same degree of severity, but usually not till at least ten to twelve days after the infliction of the wound; in one patient with a unilateral cervical lesion we could elicit only a very feeble reflex after thirty-five days, and it was almost two months after the injury that the jerks of the homolateral limb were as brisk as normal.

On turning to the superficial reflexes we find the abdominal and cremasteric more easily abolished than the tendon-jerks; in fact, when the lesion lies above the mid-dorsal level, both remain permanently absent as long as there is any obvious motor weakness of the lower limbs.

In spinal injuries above the lumbo-sacral enlargement we would expect, on stimulating the sole, to obtain constantly the abnormal type of plantar response originally described by Babinski. When the lesion is complete or particularly severe, however, no movement of the toes may result, and there may be no reflex contraction of the hamstrings or of other muscles; and this holds not merely for the first few days when extensive functional disturbances might be attributed to "shock," but the condition may persist for several weeks at least.

In some cases, however, probably when the transverse lesion is not total, stimulation of the sole produces only a simple flexion of the great toe, often associated with slight flexion and adduction of the smaller toes; this flexion of the great toe can be produced when the outer border of the sole only is stimulated, and consequently it cannot be attributed to direct mechanical irritation or stretching of the small flexor muscles of the sole. The movement differs from the normal flexor response in that it is slower and smaller in range, and in that it is chiefly a flexion at the metatarso-phalangeal joint. Occasionally the only effect is contraction of the inner hamstrings, but as a rule this is associated with slight flexion of the toes.

In less severe injuries stimulation of the sole still evokes flexion of the great toe with contraction of the hamstrings, while, if the lesion is still less serious, a withdrawal reflex of the whole limb, in which the hamstrings, tensor fasciae, flexors of the hip, and the dorsiflexors of the ankle are concerned, may be obtained, but still with flexion of the great toe. In many cases, however, an extensor response can be elicited from the sole, but clinical experience and *post-mortem* examinations tend to show that during the first week or ten days at least Babinski's sign occurs only with transverse lesions, which are not complete. We have repeatedly seen a flexor movement of the toes give place to an extensor between the seventh and the twentieth day after the injury, and in certain cases this has been a precursor to improvement. Even in one case in which a unilateral lesion of the fifth cervical segment produced a flaccid paralysis of the limbs of the same side the plantar reflex was absent, or only a slight slow flexion of the great toe could be obtained during the

first two weeks, after which it gave way to a pure extensor response.

SPINAL SHOCK.

This state of the reflexes, more especially the abolition of the tendon-jerks and the absence of Babinski's sign, in severe but not necessarily complete anatomical lesions raises many points of interest. Even if we accept Dr. Bastian's doctrine, we must be surprised to find the tendon-jerks absent, for a time at least, in such a large proportion of incomplete injuries. This differs from what we find in ordinary civil experience, except in cases of fracture dislocation of the vertebral column, and in this condition the medullary injury resembles that produced by gunshot wounds of the spine. The nature of the lesion cannot, however, explain it, and as the reflexes disappear even when the highest spinal segments are injured their absence cannot be attributed to the distant disturbances that have been described in the first lecture. The most obvious common factor is the sudden severance of a portion of the cord from the influence of more orally situated centres by an abrupt section or by a physiological block. This produces the condition which is generally known as "spinal shock." It is recognized in the experimental laboratory, as high trans-section even in the frog leaves all four limbs flaccid and inactive to stimuli for half an hour or so, and the higher the animal stands in the scale the more pronounced and persistent are the symptoms of shock. In man, in whom the spinal mechanism is most subordinated to the higher centres, the effects of shock are naturally most pronounced, and the caudal portion of the cord is least capable of acting alone as an effective central organ. Our observations, therefore, only extend and confirm the experiences of physiologists, and show that the sudden isolation of a portion of the cord from the rest of the central nervous system leaves it incapable, for a time at least, of subserving even the simplest reflex.

The unilateral absence or depression of the tendon-jerks in cases of unilateral lesion is interesting, as it shows that their abolition is not due to a state of general shock, or to a sudden gross traumatic injury of the cord, but that it must be attributed to an interruption of impulses that descend through the homolateral half of the cord, which produces a functional depression on this side only.

We have not yet had the opportunity of determining whether, in cases in which the structural lesion is not complete, the absent reflexes eventually return, at what date they reappear, and with what other symptoms of recovery their reappearance is associated. We have, however, seen the knee and ankle jerks absent during the first and second week in cases which have recovered sufficiently to stand, and absent for longer periods in patients who later regained some power of movement while under observation.

The inability to elicit reflex movements from the sole in cases of complete transverse lesions must be also attributed to the functional depression, either temporary or permanent, of the isolated segments of the cord. It has been pointed out that in less severe cases only flexion of the toes, or this associated with contraction of the hamstrings, is obtained, and that only in less severe or longer standing injuries can the complete flexion reflex be evoked. This we might expect, for when the activities of the isolated portion of the cord are depressed by shock the relatively complex mechanisms of commissural and intersegmental association naturally suffer more than the simpler and more rudimentary unisegmental functions. And as the sole, from which the reflex is most easily evoked, lies within the sensory distribution of the first sacral root, and the flexors of the toes and the hamstrings are innervated chiefly by the ventral root of the same segment, the contraction of these muscles on stimulation of the sole can be regarded as a unisegmental reflex; additional segments would be concerned in flexion of the hip and knee and the contraction of the tensor fasciae femoris and adductors, which are included in the full flexion reflex. Further, in these cases the receptive field of the reflex is much narrowed, and is in fact almost invariably limited to the sole, where the threshold of effective stimulation is normally lowest.

It might be expected that the effects of shock on the lumbo-sacral enlargement would be more pronounced the lower the lesion lay in the cord, but we find little to

support this view; the lower limbs have been as flaccid and toneless in cases of high cervical injury as when the lower dorsal segments were damaged, and when the lesions have been probably of equal severity there has been no evidence of less shock or of earlier recovery when it lay high rather than low in the cord. This would support the conclusion drawn from the observation of unilateral lesions that shock is not a direct mechanical disturbance of functional activity, but that its effects depend on the interruption of the neuronic impulses that normally flow continuously from the higher to the lower levels of the central nervous system.

Sherrington has pointed out that the effects of spinal shock are seen in experimental animals only in the aboral direction, and it is obvious that in man they are limited to segments distal to the lesion, as in even the rudest transverse lesion no symptoms are found above its level which are attributable to shock.

"AUTOMATIC" MOVEMENTS.

But, though the shock effect of these severe spinal traumata almost invariably abolishes or depresses seriously the functions of the isolated segments, in a group of four cases in which the lowest dorsal or highest lumbar segments were involved, "automatic" movements, such as are observed in certain spinal animals, occurred, and their occurrence can be interpreted only as the result of a reflex over-activity of the isolated segments. In one of these cases the lesion involved the first and the upper part of the second lumbar segment; in another it extended from the lower part of the twelfth dorsal to the middle of the second lumbar segment; in a third it reached as high as the eleventh dorsal segment and probably extended some distance downwards, while in the fourth it was probably limited to the third lumbar segment. In these cases the lesions were severe or total, and as the involuntary movements were identical or very similar in all four, their nature can be best conveyed by describing one case in detail.

CASE II.

Pte. D., 7687, who was first seen on January 6th, 1915, was wounded two days previously by shrapnel while crouching. He fell back and lost power in both legs at once and had since retention of urine. There was a small dry scabbed wound one inch to the left of the tenth dorsal spine.

His legs were flaccid and no voluntary movements of them were possible, but their muscles were not quite toneless. The trunk muscles were unaffected. Sensation was completely lost to the level of Ponpar's ligament on the right side and to a slightly lower level—that is, to the lower margin of the first lumbar root area—on the left. His knee and ankle jerks were absent; an indefinite extensor response was obtained on the right side, but only flexion of the great toe on the left. (In the other three cases only flexion of the toes could be elicited.)

There were constant involuntary rhythmical movements of both lower limbs, which apparently occurred apart from any peripheral stimulation. At first they occurred every four to seven seconds, but their rate later became somewhat slower. They consisted in alternate but not quite regular rhythmical flexion of the knees, with dorsiflexion of the feet, extension of the great toes, and slight flexion and outward rotation at the hips, followed by active extension of all segments of the limb. They were usually more marked in the right than in the left limb and were often grouped—that is, the movements of left succeeded those of the right almost immediately. They were not influenced by the position of his limbs, and occurred equally whether these were flexed or straightened out, and whether he lay on his back or side. Stroking or pricking either sole produced a fairly brisk withdrawal reflex; it did not interrupt the sequence of the movements, however, but delayed them when the sole of the limb in which they were next due to appear was stimulated; stimulation of the sole of the limb in which the movements had just occurred had no effect. On the other hand, striking the great toe with a percussion hammer immediately excited the movements, but only when they had last occurred in the opposite limb—in fact, in each limb the movements were followed by a refractory phase, during which they could not be again obtained till they had occurred in the opposite limb; their sequence could not be altered by any method that was tried, but their rhythm was accelerated for a time by pricking the inner sides of the thighs or the perineum.

Percussion of the patellar ligament did not give a knee-jerk, but was followed immediately by contraction of the hamstrings.

Four days after the infliction of the wound Lieutenant-Colonel Sargent performed a laminectomy. It was noted that the movements of the legs ceased when the chloroform anaesthesia became sufficiently deep to arrest consciousness.

The left side of the eleventh dorsal arch was found fractured, and a small sharp-edged fragment of the articular cartilage,

which measured 1 by 0.5 cm., had penetrated the dura and lacerated the cord at the level of the upper margin of the eleventh dorsal vertebra.

The patient recovered rapidly from the operation, but died fifteen days after receiving the wound. The rhythmical movements and his other symptoms persisted unaltered till death.

On *post-mortem* examination a laceration was found on the left side of the dorsal surface of the cord in the upper part of the second lumbar segment, and a piece of shell casing, which measured 3 by 4 by 7 mm., was removed from its right side at this level; it had passed through and destroyed the dorsal half of the cord, but a part of its ventral surface seemed little injured. On microscopical examination the dorsal columns were found destroyed in the lower part of the first and the upper part of the second lumbar segment, as well as the dorsal part of the left lateral column. The right lateral column was less extensively injured, but was softened; the ventral columns were not directly affected. There were practically no pathological changes in either the grey or the white matter below the second or above the first lumbar segment.

In another of the cases in which a *post-mortem* examination was made, it was also only the ventral columns that had escaped total destruction in the lower part of the twelfth dorsal and the upper two lumbar segments.

These alternate flexion and extension movements of the lower limbs obviously represent the rudiments of the lower physiological mechanism of gait, and are very similar to the "mark time" or progressive movements seen in the "spinal" dog; their nature must be the same as these reflex movements which Sherrington has described in the spinal animal.

It is interesting, however, that we have seen such involuntary reflex movements only when the lesion involved the upper lumbar segments of the cord, and that they occurred in a considerable proportion of all serious injuries at this level. In the only two cases in which the spinal cord has been examined there was exceptionally little distant disturbance, and the lower lumbar and the sacral segments were in both almost intact. It is also surprising that they should occur at least as early as the second day. Further observations will be necessary to determine the significance of the absence of direct structural damage in the ventral columns in the two cases which came to autopsy.

We have not observed any "automatic" movements of the limbs when the higher cervical segments were injured; in fact, these are always then flaccid and toneless, and their muscles usually wasted early. We have, however, obtained a reflex—which, as far as we know, has not been yet described—in cases in which the lesion lay in or above the fifth cervical segment, and produced paralysis of the upper limbs. Pricking, pinching, or firm stroking on the inner side of the arm then evoked, generally after a short latent period, a sudden and strong inward rotation and adduction of the arm on the same side, the inward rotation being apparently the prime and chief movement. We obtained this reflex in most of the cases of severe cervical lesions in which we examined for it, provided there was not an atrophic palsy of the arm.

CERVICAL SOFTENING.

Injuries in different portions of the cord naturally produce clinical symptoms differing not only in the extent, but also in nature of the paralysis. One of the most striking types is that which results from an incomplete lesion of the cervical enlargement. Since haemorrhages and secondary changes undoubtedly occur as a result of concussion more readily in this than in any other region of the cord, and since they are more liable to damage the grey than the white matter, the arms are frequently seriously paralysed, though there is fair or unaffected power of movement in the lower limbs. Not infrequently the paralysis, especially that of the arms, develops some time after the infliction of the wound, but, on the other hand, it is not uncommon to meet patients with gunshot wounds of the neck in whom all four limbs were at first paralysed, who had regained power within a week or so, the arms recovering almost invariably later than the legs.

The following case illustrates the chief clinical features of such an injury.

CASE III.

Lance-Corporal G., 11060, was wounded by fragments of a high explosive shell on September 15th, 1914. He found immediately that he had no power of movement in his right arm, but the left was unaffected; he was able to pick up his tobacco pouch with it and put it in his pocket. He walked thirty yards or so, stumbling and faint though his legs seemed quite strong, till he reached shelter. There he lost consciousness, and on

regaining it, twenty-four hours later, found both upper limbs completely paralysed and both legs weak. He had no sphincter trouble, and neither delay or difficulty in passing urine.

He was first seen by us five weeks later. Then there were three small scars on the right side of his neck opposite the spines of the third, fourth, and fifth vertebrae, and an x-ray examination revealed a fragment of shell casing at the level of the body of the seventh cervical vertebra.

Both arms were wasted, the left more than the right, and the only movement possible in the latter was feeble adduction at the shoulder. Practically no movement at the left shoulder or elbow was possible, and flexion of the wrist and of the fingers was very feeble, but the power of extension, adduction, and abduction of the fingers was fair. The trunk movements, as well as those of the right leg, were unaffected, but the left lower limb was somewhat rigid, and its distal movements were slightly feebler than those of the right. He was able to stand and walk easily, and his gait was almost normal.

The right arm-jerks were absent; the left knee and ankle jerks were increased, and stimulation of the left sole gave an extensor response. There was slight loss in the appreciation of pain and light tactile contacts on the left side up to the upper margin of the fourth cervical root area, and complete loss of recognition of posture, passive movement, form, and the compass points in the left arm. The knowledge of position and the discrimination of compass points were only diminished in the left lower limb and unimpaired in the right.

In this case a secondary hæmorrhage or softening had obviously occurred in the cervical enlargement as a result of concussion, and the greater affection of the grey than of the white matter had produced an atrophic palsy of the upper limbs, which is probably permanent, while the weakness of his lower limbs had gradually diminished.

Lesions of certain regions of the cord also produce special local symptoms. We have, for instance, repeatedly seen unilateral paralysis of the diaphragm, and in two cases at least bilateral palsy, due to lesions at the level of the fourth or fifth cervical segment; unilateral palsy of the diaphragm also occurred in two cases in which the main lesion was to the second cervical segment, but it was not observed in any patient in whom it lay lower than the fifth. The occurrence of nystagmus has also been described as a result of lesions in the higher cervical region, but we have observed it in only 3 of the 63 cases in which the cervical segments were injured, in lesions of the second, fifth, and seventh segments. It was slight and ill-sustained in all three, and disappeared rapidly, save in one patient, in whom it persisted at least fifteen days; but as in this case the exit wound was in the neighbourhood of the tip of the mastoid labyrinthine concussion cannot be here excluded.

PALSY OF THE CERVICAL SYMPATHETIC.

Disturbances of the functions of the cervical sympathetic occurred with lesions of all segments between the second cervical and the second dorsal included; they are referred to in our notes on 36 cases, and in the great majority at least of these injury of the sympathetic fibres in the neck could be excluded. The most common and prominent symptom was miosis, or, in unilateral lesions, inequality of the pupils, the smaller being on the side of the lesion, and this, as a rule, failed to dilate, or dilated less rapidly and less completely on shading the eyes. A narrowing of the palpebral fissures in one or both eyes and some anophthalmos was also pronounced in most of the cases. Ptosis was also frequently observed, especially with lesions of the lower cervical and the first dorsal segments.

Disturbances in sweating on the affected side were also present in most of the cases; as a rule, the skin of the face, neck, and shoulders, as well as the hair of the head on the side of the spinal injury, was merely drier and less greasy than on the opposite side; but during the warm weather of the late summer, or in any condition that induced sweating, there was a very obvious difference, for the skin of the face, neck, and shoulder to the level of the second rib remained dry on the one side, while it was moist and covered with beads of sweat on the other. In certain unilateral lesions, too, a diminution of tear secretion was observed on the affected side, the eye being obviously drier and presenting a more staring and glassy appearance than the normal; a few patients even complained of this eye being "stuck" or difficult to open in the morning owing to the lids being adherent as a result of the drying of the undiluted conjunctival secretion.

Definite vasomotor disturbances associated with paralysis of the cervical sympathetic were less common, but

in several cases the face was more flushed and highly coloured on the affected side, especially after shaving.

It is known that the cilio-spinal centre lies in the lowest cervical and first dorsal segments, while the spinal centre of the other components of the cervical sympathetic is found in the two upper dorsal segments, and that these are influenced or controlled by efferent bulbar fibres which descend uncrossed through the cervical cord. It must be to disturbance of the latter that the symptoms just described are due when the lesion lies above the eighth cervical segment, while the spinal centres themselves are injured when the lesion lies below this. It is an interesting question if the symptoms due to lesions in these two sites differ. We have not, however, observed any essential or obvious difference, though both the ocular and secretory disturbances seemed to be on the whole more prominent and permanent when the spinal sympathetic centres were damaged than when the bulbar efferent fibres were involved; in fact, in the latter case the symptoms usually subsided quickly, and often disappeared under observation.

Symptoms of irritation of the cervical sympathetic did not occur in any case in which the spinal cord only was injured.

HYPOTHERMIA.

One of the most interesting types we have observed was due to injury of the lower part of the cervical enlargement, and was characterized by subnormal temperature, slow pulse, low blood pressure, and scanty secretion of urine. All the 10 patients in whom these symptoms occurred died within eight days after the infliction of the wound, and in all the lesion lay in approximately the same region.

On admission to a base hospital, generally one or two days after the injury, the most striking feature was the cold, collapsed condition of the patient. The skin was generally dry and remarkably cold even to touch, and it was noted in some that the superficial temperature on exposed parts, as the face or hands, was apparently no

lower than that of covered parts. When the temperature was very low, a touch reminded one forcibly of the coldness of death—this was especially so in a man seen at a casualty clearing station soon after he received the wound. The skin was also generally cyanosed, and the face of a curious slate colour. The temperature varied in different cases, and as unfortunately a special thermometer to register it was not always available, in four of the ten cases we can only say that it was lower than could be registered in a clinical thermometer (that is, 36° C. = 95° F.). In one of the other six it sank to 78.8° F. (26° C.) in the rectum, and did not rise above 80° F. during the twenty-four hours he lived under observation, but in most of those in which accurate observations were made the lowest recorded lay between 80° and 84° F. In a few it rose suddenly before death to above the normal, and in one case which has been already recorded by Lieutenants Oliver and Winfield,¹ actually rose from 80.4° to 105.6° F., that is, 25° F., in twenty-six hours (Fig. 2); in others it remained low till the patient ceased to live. In one case the patient lived at least three days with a temperature not rising above 90° F., and in two it did not exceed 85° F. for twenty-four hours, but as these cases usually did not come under our observation

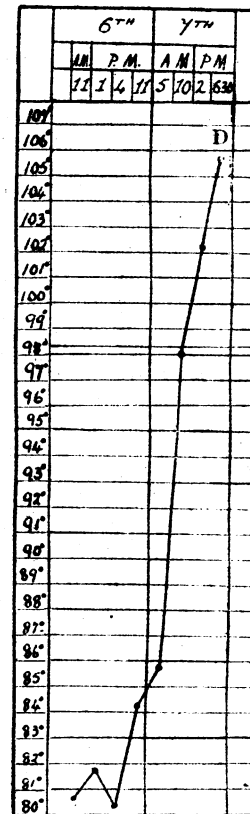


Fig. 2.—D, Death.

till the third day, it is probable that life could be maintained even longer with this low temperature.

The temperature was always taken in both the mouth and axilla, and in a few instances in the rectum too; the thermometer in the mouth generally registered slightly higher than in the axilla, but, except in one case in which it was a few degrees higher, the rectal temperature was approximately equal to that in the mouth.

In all cases, too, the pulse-rate was very slow, while the temperature remained low, and it increased in frequency as this rose; in one case it was only 22 per minute, and in the others ranged between 30 and 50 per minute till the temperature approached normal limits. In one patient it was 32 when the temperature in the mouth was 80.6° F., and rose to 102 when this reached 98.8° F. The pulse was also very soft and of low tension while the temperature remained down; unfortunately, sphygmomanometric observations were possible in only three cases, and in these the pressure registered 56, 72, and 73 mm. of mercury.

As the intercostal muscles were paralysed in every case, respiration was wholly diaphragmatic, but its rate was approximately normal, except in one in which it was only

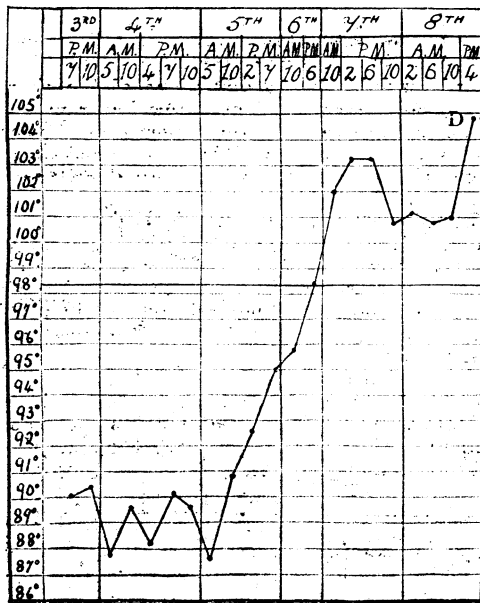


Fig. 3. - D. Death.

9 per minute, while the temperature remained under 80° F. It must be, however, remembered that when the respiratory movements are much restricted their rate is usually increased, and consequently we may assume a relative slowing of respiration.

The fourth special symptom was the small amount of urine passed. In one man who lived forty-eight hours no urine was secreted; another secreted only 20 oz. in three days; a third probably only 8 oz. in four days; while from a fourth (Fig. 3), whose temperature varied between 87° F. and 105° F. and his pulse-rate between 40 and 104, only 20 to 25 oz. could be drawn off during the first three days, but the daily amount increased to 50 to 60 oz. for the last two days, when his temperature ranged between 100° F. and 105° F. The amount of urea was estimated in two cases in which very little urine was secreted, and its percentage was approximately normal.

The mental state of these patients was another interesting feature: when the temperature was very low, or at least below 85° F., they were stuporose or extremely lethargic, but, with the exception of one case, they could be roused, and then appeared quite intelligent and answered questions rationally, though they always tended to drift quickly again into a lethargic and apathetic state, unconcerned with their condition and immediate wants. As their temperature rose this mental lethargy quickly passed off, and they became bright and fully conscious of their serious condition—in fact, their mental state varied directly with their temperature.

The general appearance of these patients with low temperature, slow pulse-rate, stupor or mental lethargy,

and low metabolic exchange, as indicated by the small amount of urine of normal constitution secreted, reminded one strongly of an animal in hibernation, and as in the hibernating animal the pulse-rate and amount of urine secreted increased and the stupor passed off as the temperature rose to normal limits.

Post-mortem examinations were obtained in nine of the ten cases; in two the chief injury was to the sixth cervical segment, in two to the seventh, in one the seventh and eighth cervical segments were damaged, and in the remaining four the eighth cervical and the first dorsal. In four of these cords there were practically complete transverse lesions; in the others the injury seemed to be only partial, but except in one of these a microscopical examination has not yet been made. Further, from the clinical signs a complete transverse lesion would not be diagnosed in at least three of these cases—in fact, one was able to move both legs from the time he came under observation till his death. In his cord microscopical examination revealed haemorrhages with oedema and foci of necrosis in the seventh and the upper part of the eighth cervical segments, small haemorrhages and swollen axis cylinders above the lesion as high as the fourth, and a cylindrical cavity descending through the dorsal columns from the first to the third dorsal segment.

A condition similar to that above described has been repeatedly produced in animals by section of the cervical cord; this is, in fact, followed by a fall in temperature and

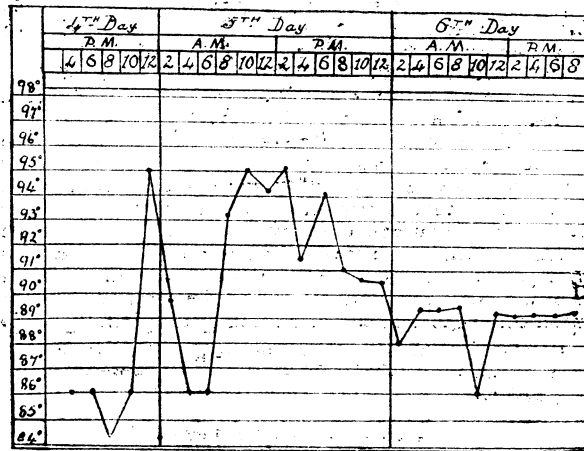


Fig. 4. - D. Death.

blood pressure, a slowing of the pulse and of respiration, diminished secretion of urine, and death within a few days. And the same symptoms have been observed in man when the cervical cord has been injured by a fracture or dislocation of the neck. Parkin,² for instance, records a case of destruction of the fifth to the seventh cervical segments, in which the temperature fell as low as 78° F. and the pulse-rate to 26-37 per minute; and Nieden,³ another case of dislocation of the first dorsal vertebra, in which the temperature gradually fell to 80.6° F. before death on the eleventh day, and the pulse-rate sank to 30 per minute. The blood pressure was evidently very low in both of these cases, as the pulse was described as hardly perceptible.

On the other hand, we have seen several cases of complete or very severe injury between the fifth cervical and the first dorsal segment in which these symptoms were not present.

We have some evidence that these patients do react to some extent as cold-blooded animals, and that their temperature may vary with the external temperature; in one patient, for instance, the temperature rose from 84.2° to 95° F. (Fig. 4) when he was placed on a hot-water bed and packed around with hot-water bottles, and another from 86° to 105.6° F., when he was brought into a room heated to 70° F. and also surrounded by warm bedclothes and hot-water bottles. This interpretation of the latter observation is not, however, beyond doubt, as a final rise of temperature occurred in other patients.

In another case an injection of pituitrin brought the temperature for a few hours almost up to normal, and

increased the pulse and respiratory rates, while at the same time the patient, who had been very dull and lethargic, became temporarily bright and intelligent.

The interpretation of these observations cannot be attempted here; they might be taken as evidence of the existence of a heat regulating centre in the lower part of the cervical enlargement, as Dr. Hale White has assumed, or, on the other hand, the fall of temperature might be attributed to diminished heat production consequent on muscular inactivity; a similar fall occurs in curarized animals. Probably the most important factors are deficient thermogenesis and a visceral vasomotor palsy produced by shock in the sympathetic system. Captain Shorten,⁴ however, in a short comment on the case published by Lieutenants Oliver and Winfield, suggested that the symptoms may be due to the interruption of descending fibres in the cord which control and regulate the activity of the adrenals, and Professor Harvey Cushing, who kindly saw one of our cases, had suggested previously to us that a cervical sympathetic palsy may disturb the functions of the pituitary and that this may interfere with the correlated activity of the suprarenals. If Captain Shorten's hypothesis is correct we could expect to find hypothermia and its associated symptoms more commonly in cervical and bulbar lesions, and its absence after section of the cervical sympathetics argues against Dr. Harvey Cushing's suggestion. The adrenals appeared normal to the naked eye in one of our cases.

CERVICAL PYREXIA.

Benjamin Brodie, Chossat, and others have described a rise of temperature in animals after injury of the cervical cord, and Sir Jonathan Hutchinson,⁵ Sir Hermann Weber,⁶ and numerous other clinical observers have observed pyrexia with similar injuries in man. As in most of our patients there were septic wounds associated with the spinal lesion, and as in several cystitis coexisted, particular care is necessary in interpreting our observations on this point, but some are unequivocal. In one patient, for instance, with symptoms of a partial lesion in the fourth cervical segment and a small clean entry wound of a rifle bullet just below the tip of the right mastoid, in which there were no signs of infection, the temperature on several occasions rose to 104° F. and quickly fell again to

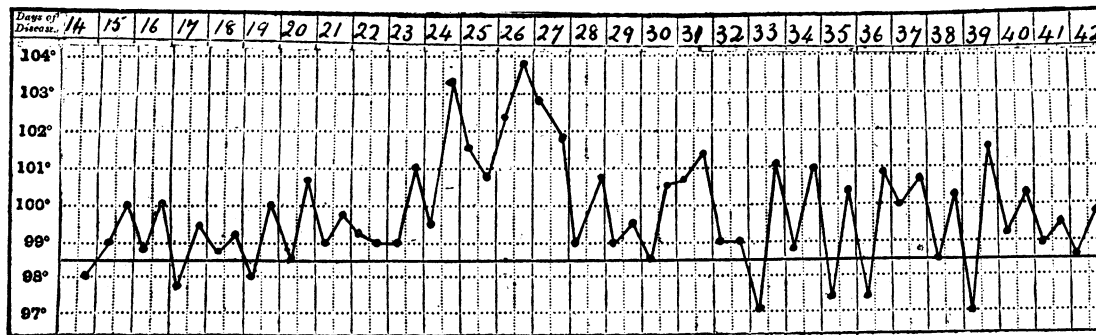


Fig. 5.

normal (Fig. 5). In this and in other patients the pyrexia was not associated with any signs of illness or discomfort, and the pulse-rate did not vary as the temperature rose. In several other patients with partial or unilateral lesions between the third and sixth cervical segments, whom we were able to keep under observation for several weeks, the temperature was frequently above normal, and often reached 102° F. to 103° F. without any apparent cause.

Another interesting observation was persistent shivering of the shoulders, neck, and face without any rise of temperature or disturbance of the pulse-rate, and without any subjective feeling of coldness associated with lesions of the lowest cervical and upper three dorsal segments. This occurred only in severe injuries of this region, and persisted over several days.

POLYURIA.

We have described diminished secretion of urine with lesions of the lower part of the cervical enlargement, but the daily quantity is frequently much increased when the

injury lies in the middle of the dorsal cord, especially between the fifth and eighth dorsal segments. From one patient with a total transverse lesion between the seventh and eighth dorsal segments an average of 145 oz. was drawn off by catheter during the first six days he was under observation, even 215 oz. in one day. During the next six days and till death the average daily amount secreted was 90 oz. In another patient with a severe lesion of the fifth dorsal segment the average amount drawn off during the first eighteen days was 80 oz.; and in a third, who had sustained a complete destruction of the eighth dorsal segment, the daily average during the first three weeks was 125 oz., but fell during the next three weeks to a daily average of 66 oz. In fact, in the majority of patients with injuries to this region of the cord in whom observations were made, an excessive amount of urine was secreted. Unfortunately, we have not yet obtained a complete analysis of the urine when it is in great excess.

This polyuria is probably due to paralysis of the sympathetic fibres, and especially of the vaso-constrictors, to the kidney. Claude Bernard and Sir John Rose Bradford, it will be remembered, produced it by section of the splanchnics and of the lower dorsal roots.

PULSE-RATE.

While a slow pulse-rate has been one of the characteristic symptoms of severe lesions of the lower part of the cervical enlargement, a marked and persistent acceleration of its rate was often present in partial lesions of this region, especially when the upper two dorsal segments were involved. In one case of partial destruction of the second dorsal segment, for instance, it rarely fell below 100 per minute and was frequently 120, and this independently of any rise of temperature or other obvious cause. In another severe injury of the same segment it ranged between 72 and 140 per minute, and in a third it never fell below 120 per minute. But the most striking alterations are perhaps seen with partial injuries of the four lower cervical segments in which the patient seems in perfect health apart from his spinal injury. In one such patient, who remained three months under observation with an originally slight injury of the fourth cervical segment which later progressed, the pulse-rate constantly

lay between 100 and 120, and only occasionally in the latter part of this period fell to 90 per minute, and in a similar uncomplicated case of injury to the fifth cervical segment the rate varied between 96

and 130 per minute. It was always regular, however, in these cases and of good volume and fair tension.

VOMITING.

When the mid-dorsal region is severely injured the abdomen is frequently tense and blown out and the patient presents the symptoms of paralytic distension of the intestines. But a more striking symptom which is sometimes associated with it, but which often occurs without any objective symptoms of abdominal disturbance, is vomiting. In the larger proportion of the cases in which it was observed the lesion lay in the sixth, seventh, or eighth dorsal segment.

It was often so persistent that it threatened life, as in severe cases no nourishment could be kept down. In several instances it set in within a few hours of infliction of the wound, and in many severe cases persisted till death or as long as we had the patients under observation. It was generally forcible and projectile, and was apparently associated with much discomfort, but with little nausea, though a few patients complained of the feeling of sickness.

In mild cases it occurred only some time after taking food, and this alone might be brought up in a half-digested state, but when severer it was more or less constant and mucous stuff occasionally coloured with bile, and in a few instances blood-stained, was ejected. In some of our notes the similarity to the vomiting of a tabetic crisis is remarked on.

As in the large majority of cases in which this type of vomiting occurred the lesion lay in the region of the sympathetic outflow to the stomach it might be attributed to irritation or disturbance of the function of these fibres. And there is much evidence that this is its cause. Almost without exception these patients complained of girdle pains around the body, or on one or other side, between the level of the xiphoid and umbilicus, and of great tenderness to light contact, rubbing and other stimuli in the region in which the referred pain and tenderness associated with gastric disease occurs. Further, in several there was a persistent local contraction of a portion of the abdominal muscles between the xiphoid and the umbilicus corresponding to the cutaneous hyperaesthesia, which increased and produced pain when this area of skin was stimulated. In fact, the firm resistance and tenderness of this area to touch occasionally gave rise to the suspicion of a large intra-abdominal lesion. In a few patients the intercostals innervated by the same dorsal roots were also in contraction, and everted the ribs to which these were attached.

Vomiting occasionally occurred after injury to other regions of the cord, too, but in most of these cases it was associated with and probably due to intestinal paralysis, to severe septic infection, or to the cystitis or pyelonephritis which occur so frequently with spinal lesions. In a few cases of cervical injury, however, it was a prominent symptom, and could not be attributed to any of these causes.

When severe and frequent, such vomiting naturally exhausted the patient and induced emaciation. Great loss of flesh also occurs, as might be expected, in severe cases which run a downward course, but it is an interesting fact that it was seen also in patients with relatively slight injuries of the cervical enlargement who took food well and even had excessive appetites. We have observed several patients, for instance, with unilateral lesions of this region producing the Brown-Séquard syndrome, but apparently not affecting their general health, in whom there was extreme emaciation. In some of these the pulse-rate was increased, and there was slight pyrexia, but otherwise the visceral functions seemed unaffected.

PRIPAPISM.

Numerous other symptoms occurred as a result of spinal lesions, to which time will not permit reference here. Priapism has been frequently described, especially with lesions in the cervical region, but we have observed it in only a small proportion of our cases, and it seemed to occur relatively as frequently with lesions of the dorsal as of the higher segments. It was usually merely a soft turgescence of the penis. If, as is assumed, it is merely due to vascular engorgement, it is interesting to note that it occurred in two of our patients with low temperature, low blood pressure, and a slow pulse-rate; it was present in one man when the blood pressure was only 73 mm. of mercury.

TROPHIC DISTURBANCES.

Various trophic disturbances were common in the severer cases, especially bullae and blisters in those parts of the paralysed regions which were subjected to any pressure. Irregular patches of red or strawberry-coloured discoloration, which were scarcely modified by pressure and disappeared slowly leaving a slight mottling of the skin, also occurred frequently in the same parts. Joint changes were not common in the early stages, though there was occasionally effusion with the knees or ankles when the legs were completely paralysed, and in a few patients we observed early arthritic affection of the fingers and wrist when the cervical cord was damaged.

HERPES.

Herpes occurred in nine cases, either immediately above or at the upper margin of the sensory loss. It developed between the third and the fifteenth day, and in three instances recurred in the same area. It usually first appeared as a zone of diffuse erythema with small papules which later became vesicular or pustular, generally in a

region in which there was either pain or tenderness. It usually lasted seven to fourteen days and disappeared, leaving some desquamation and brownish discoloration of the skin. Such larger vesicles as are seen in idiopathic herpes were not observed, and in one case there were only papules and vesicles without any erythema of the skin. In two cases in which *post-mortem* examinations were obtained the corresponding spinal ganglia were found bruised by displaced fragments of the vertebral column, and the clinical symptoms or the course of the missile made it probable that a ganglion was damaged in the other cases too; its pathology is consequently allied to that described for idiopathic herpes by Bärensprung, and confirmed by Drs. Head and Campbell.

The state of sensation in the herpetic zone was variable; in some cases there was only excessive tenderness to contact, rubbing, cold, and other stimuli, associated with spontaneous pain; in other there were the symptoms of a root-lesion, that is, a band of insensitiveness to pin-prick and to moderate degrees of temperature, with loss or diminution of tactility within it. In those cases in which there was definite sensory loss it was found that this was not coterminous or did not correspond with the area of the eruption; Sherrington has shown that the dermatomeres are not superimposed in the myomeres, and it is obvious, too, that the peripheral distribution of the radicular fibres, which, when injured, are concerned in the production of herpes, do not coincide accurately with either.

REFERENCES.

- ¹ Oliver and Winfield, *BRITISH MEDICAL JOURNAL*, 1915, vol. i, p. 247. ² Parkin, *Guy's Hospital Reports*, 1891, vol. xlviii, p. 107. ³ Niden, *Trans. Clin. Soc. London*, 1873, vol. vi, p. 75. ⁴ Shorten, *BRITISH MEDICAL JOURNAL*, 1915, vol. i, p. 801. ⁵ Hutchinson, *Lancet*, 1872, vol. i, p. 714. ⁶ Weber, *Trans. Clin. Soc. London*, 1868, vol. i, p. 163.

Memoranda:

MEDICAL, SURGICAL, OBSTETRICAL.

CONGENITAL ABSENCE OF RADII.

THE publication in the *JOURNAL* of September 11th, by Major Mansel Sympton, of a case of congenital dislocation of the right foot with almost complete absence of the fibula tempts me to put forward a somewhat similar case, in which, however, both upper limbs are affected.

The patient, E. H., aged 16 years, an inmate of Dr. Barnardo's Homes, is an intelligent child whose father, however, is insane and an epileptic.

Both hands are dislocated to the ulnar side, and are at right angles to the forearms; the radiograms—a drawing from one of which is reproduced—show that there is complete absence of both radii. The radiographs were taken by Dr. G. Gushue-Taylor in November, 1910.

In spite of her deformity she can write distinctly, and is being taught to do various kinds of embroidery, which she does very well.

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London, E.

"CHLORINE WATER" AS A DRESSING.

In the *JOURNAL* of May 8th I published an article on the "Sterilization of Water by Chlorine." It occurred to me over two years ago, when working at this subject, that in addition to using my method for water purification, one might also use the "chlorine water" thus prepared as an antiseptic lotion. By doing this one would have on

