THE PATHOLOGY OF GUNSHOT WOUNDS OF THE SPINAL CORD:

AS ILLUSTRATED BY THE SPECIMENS IN THE WAR OFFICE COLLECTION.

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THE War Office Collection of injuries of the spine and spinal cord now lodged in the Royal College of Surgeons is extensive, and contains specimens of almost every type and result of gunshot wound. In a previous communication¹ the writer has, with George Richardson, illustrated many of the osseous lesions from personal specimens, now lodged in the museum, and Keith and Hall² have also described others of the dry preparations. It is now proposed to give some account of the wet specimens, of which there are altogether nearly a hundred. These specimens have been dissected and mounted by Mr. Cecil Beadles, and each is accompanied by a description by Professor Shattock. The drawings which illustrate this paper have been made for me by Mr. S. A. Sewell.

In considering the material at our disposal it will be convenient to classify the wounds met with under certain obvious headings. A missile may lodge in the spinal cord or meninges, may pass directly through these structures, or may merely run in more or less close proximity to the contents of the spinal canal. Again it may, either with or without puncturing the canal, impel fragments of bone or of clothing into the interior, thus producing results closely similar to those of its own impact. In all these cases we find a primary injury of the cord, of its nerve roots, or of the meninges, and as a result of such primary mechanical injury we may meet with secondary infection or other local lesions, and with more distant and remote effects, such as those found in the bladder, kidneys, and lungs.

I. CASES IN WHICH A FOREIGN BODY OR FRAGMENTS OF BONE OR CLOTHING ARE LODGED WITHIN THE SPINAL CANAL.

Case 1 is illustrative of many of the conditions produced by a 'lodging wound' of the cord and meninges. A fragment of high-explosive shell was embedded in the back at the level of the 6th dorsal vertebra, and slightly to the left of the middle line. 'Flaccid paralysis' ensued at once. On the fifth day there was paralysis of both lower limbs: anæsthesia to a line about two inches above the umbilicus on the right side and to a slightly lower level on the left; the bladder was paralyzed; plantar reflexes were of flexor type; no knee-jerks, ankle-clonus, abdominal or cremasteric reflexes. Twenty-four hours later there was found a small 'patch of sensation' on the arch of the right foot and some urethral sensation on catheterization. On the eighth day the patient had definite girdle-pain at the level of the 7th ribs, especially on the left side, and the whole urethra presented some sensation. A skiagram showed two metal fragments, of which one appeared to lie inside the spinal canal. One day later the dorsal wound was excised under local anæsthesia. "The left lamina of the 6th dorsal arch was found fractured and depressed, several pieces of bone evidently pressing on the dura mater; two pieces of shell casing were removed, one somewhat superficial to the fractured lamina, the other actually sticking in the dura mater". On removal of the latter fragment, cerebrospinal fluid flowed into the wound, and there was fully exposed a hole in the theca "about the size of an almond"; "the cord immediately in front of the opening was injured a little, white matter being adherent to the deeper of the metal fragments and to one or two of the bony fragments". The wound was drained.

After operation there was a good deal of collapse and vomiting, but the girdle-pain was diminished; there was some cramping pain in the left lower limb. There followed much headache and increasing retraction of the neck. Lumbar puncture removed turbid blood-stained fluid sterile on culture. Nine days later the patient died with symptoms of severe cystitis, and with a continuation of the headache, retraction of the neck, some divergent strabismus, a tendency to opisthotonos, and marked Cheyne-Stokes respiration.

At the autopsy, on exposure of the spinal theca it was "seen to be bulging particularly towards the head"; the meninges were bound down to the spinal cord at the seat of operation. There was intense hæmorrhagic cystitis.

The specimen (*Fig. 123*, W.O. 391*) shows the changes met with eighteen days after a lodging wound in the mid-dorsal region. The large aperture to the left of the theca is well seen. A minute fragment of metal still remains within the spinal cord. The latter has undergone much local degeneration, but is not completely divided. The theca is deeply blood-stained, and beneath the arachnoid is a purulent and blood-stained exudation more marked below the wound. The bulging of the upper part of the theca observed at post-mortem examination,

and the clinical symptoms, alike point to a meningitis much more widely spread than is seen in the local focus. The presence of girdle-pain before operation and the incomplete anæsthesia are alike explained.

(This case is much more fully reported than are most of the war specimens. The medical officer was Lieut. Bligh, the operation was performed by Colonel Sir Henry Gray, and the autopsy was by Captain W. S. Lazarus-Barlow, No. 9 General Hospital, France.)

Case 2.—With the above may be compared the very similar injury in specimen W.O. 2206. The wound was at the level of the 9th dorsal vertebra about an inch to the left of the middle line; motor and sensory paralysis were complete below the umbilicus; the bladder was distended, and was catheterized twice on the first day, after which urine was allowed to overflow for several days. On the seventh day a rigor was followed by a rise of temperature to 103°; there were 'evidences of cystitis', and the bladder was irrigated with boracic lotion. Rigors and fever continued, death occurring on the twelfth day.

The specimen (*Fig. 124*) shows a small hole in the theca and a fragment of shell-casing deeply embedded in the

FIG. 123.—Fragment of metal impacted in cord; tear in theca, hæmorrhage and septic meningitis.

FIG. 124.—Fragment of metal impacted in cord; tear in theca, localized meningitis.

* The letters W.O. followed by a number refer to the War Office number quoted in the College of Surgeons Museum.

spinal cord, which was lightly adherent to the dura. There is here far less local inflammation than in *Case 1*. The dura presents no hæmorrhage, nor is there any marked effusion beneath the arachnoid. The cord presents local crushing with some slight effusion of blood, necrosis around the wound, and turgidity of its vessels. At the post-mortem examination a little early bronchopneumonia of both bases was found.

FIG. 125.—Kidney from same case as Fig. 124; hæmorrhagic pyelitis.

The bladder was much distended, its walls were thick and inflamed, and there was plastic peritonitis in the pelvis, with a small amount of turbid fluid among intestinal coils higher in the abdomen. Both kidneys presented hæmorrhagic pyelitis (*Fig. 125*, W.O. 2206 B), shown in the annexed drawing, to which we shall again refer.

These two cases may be taken, then, as representing a closely similar injury, leading in the one to severe meningitis, and in the other to death from the secondary results of vesical paralysis with no grave local infection.

Case 3 (W.O. 1829) is another illustration of local infection. There was a fracture of the third dorsal lamina on the right side, and a fragment of metal with some adherent khaki cloth had been driven into the spinal cord at this level. The cord is here quite soft and diffuent.

There is a good deal of surrounding meningitis, and some two inches below the crush of the cord is a small patch of meningeal hæmorrhage about a millimetre in thickness, with surrounding œdema. The drawing

(*Fig. 126*) shows the small piece of cloth below the metal fragment, and also a slight depression at the site of the more remote hæmorrhage. There was some extradural hæmorrhage. The direct cause of death was acute pulmonary œdema with bronchopneumonia and an infarct in the left lung.

Case 4 (*Fig. 127*, W.O. 2026) is a further illustration of the extent of the intramedullary destruction met with in nearly all direct wounds of the cord. A shell wound was received in the left loin opposite the 1st lumbar spine, and paraplegia was complete; 'laminectomy' was at once performed, and the large fragment shown in the drawing was removed from the spinal canal; but death followed the day after injury and within a few hours of operation. A large piece of cloth, not removed at operation, was found embedded in the cauda equina. There is complete destruction of all the nerve-roots and conus medullaris, with hæmorrhage and early acute meningitis, causing subarachnoid exudation as high as the upper part of the specimen. At the upper limit is shown a transverse section of the cord which presents a small hæmorrhage into the anterior cornu, and a second one beneath the arachnoid. In this case there was no time for the development of secondary urinary troubles, and death must have been the direct result of initial shock and septic infection. Few of the cases have been so quickly fatal, and the extent of the hæmorrhage into the cord and rapid spread of meningitis are well shown.

Case 5 (*Fig. 128*, W.O. 263) is an illustration of a wound in which the metal fragment

FIG. 126.—Metal and cloth impacted in spinal cord; meningeal hæmorrhage and meningitis.

has passed tangentially to the spinal canal, but in which a fragment of bone has been detached and has given rise to a 'lodging wound'. A piece of shell passed from left to right across the back at the level of the 3rd and 4th dorsal vertebræ, penetrating the chest, wounding the apex of the right lung, and lodging in the right side of the neck. The right chest is described as having been found full of blood, but the duration of life is not stated, and there is no clinical history. In its course, the piece of shell has grazed the right laminæ of the 3rd and 4th dorsal vertebræ, detaching two small fragments of bone. These are seen to have been driven in, cutting the dura mater and partially dividing the right side of the spinal cord. There is here no direct septic infection of the theca or its contents, and the local conditions are therefore more like those of a simple fracture than of a gunshot wound with direct entry of the missile. Hence there is an absence of severe meningitis, and in many such cases there is also neurological evidence that the cord is only partially injured, so that the symptoms are often of the Brown-Séquard type.

Case 6.—A similar example is furnished by a case which came under my own observation in France. There was a small clean wound on the right side of the neck, with paraplegia. On admission, the arms were folded on the chest with the forearms supinated. All four limbs and the intercostal muscles were paralyzed; there was no knee-jerk, and no sole reflex; urine was retained. Epicritic and protopathic sensation were lost, except that some vague deep sensation was retained in the right thigh. On the fourth day, when I saw the patient, he could feebly move all muscles of the left upper limb except those of the hand; in the right upper limb contractions could be defined in the deltoid and flexors of the elbow; there was slight power of moving the hips and flexing the ankles; the intercostal muscles were acting feebly but distinctly. Knee- and ankle-jerks were present and exaggerated; the sole reflex was extensor. The bladder could be emptied voluntarily. Anæsthesia of the trunk extended to the level of the cervical nerves; the right upper limb was anæsthetic, except on its outer side (5th segment); the left upper limb was anæsthetic only as high as the distribution of the 8th cervical or 1st dorsal segment. (The Brown-Séquard type of paralysis was thus indicated clearly in the upper limbs.) Some improvement continued for over three weeks,

FIG. 128.—Impaction of fragments of bone in spinal cord; no septic infection.

FIG. 127.—Impaction of large fragment of metal and large piece of cloth in cauda equina; hæmorrhage and meningitis.

at the end of which time the medical officer operated, exposing the 4th, 5th, and 6th cervical laminæ. A small punctured fracture was found on the left side of the 5th cervical lamina, which was removed, exposing an opening in the theca adherent to the spinal cord. The adhesions were separated, when there was a free flow of cerebrospinal fluid. Respirations became very slow and feeble, and death occurred as the skin wound was being closed.

The specimen (*Fig. 129*, W.O. 2472) shows a small metal fragment and a spicule of

bone derived from the 5th cervical lamina but lying just under the 4th. Both fragments have penetrated the theca, and have been carried slightly upwards to the left of the spinal cord, which is partially divided at about the level of the 6th segment. The fragment of bone is resting in the cord, the metal applied to the theca between it and the cord. There is no meningitis, and the area is apparently quite free from sepsis.

FIG. 129.—Impaction of metal in theca and of bony fragment in cord; no septic infection.

This case is of very great interest from several points of view. It illustrates the absence of marked secondary infective changes in many of the wounds due to clean fragments of metal or detached pieces of bone. The clinical symptoms were characteristic of this type of lesion. The case was one of the comparatively few examples in which laminectomy could have been of real value, and a successful result was to be anticipated. Without considering minutely the indications for such an operation, it is clear that a lodging wound presents a mechanical objective which does not otherwise obtain. Equally, if after recovery from the early stages of spinal shock there be limited symptoms with a tendency to recovery, the cord cannot be entirely destroyed, and it should be relieved of any foreign body or clot which is in contact with it. And again, the absence of vesical symptoms and of any obvious wound sepsis render such a case eminently favourable. Those present at the operation were unable to give me a clear account of why, in this unfortunate instance, it was directly fatal.

II. CASES IN WHICH THE MISSILE OR OTHER FOREIGN BODY HAS TRANSFIXED THE CONTENTS OF THE SPINAL CANAL.

FIG. 130.—Entry wound through laminae (Case 7).

FIG. 131.—Penetration of laminae (Case 7).

In the preceding group we have cases in which some foreign substance has entered and remained within the spinal cord or its nerve-roots (lodging wounds), and we may now

turn to a group in which the mechanical cause of injury has passed on, leaving a similar wound with similar ultimate results, although the foreign body is no longer present.

Case 7.—In this case we have a whole series of specimens showing in detail a course of events which is quite common under such conditions (W.O. 594 A and 594 B). The patient was admitted to No. 9 General Hospital with a 'dirty-looking wound', about an inch in diameter, to the right of the spine at the level of the iliac crests. (A second through-and-through wound of the gluteal region is of no practical importance.) No vertebral injury was detected, and there is said to have been no paralysis and no alteration in reflexes. The man looked very

FIG. 132.—Penetration of theca and cord (*Case 7*).

FIG. 133.—Septic meningitis extending up entire cord (*Case 7*).

ill, and, on admission, complained of pain in the neck; temperature 102° ; the wound appeared to run towards the lumbosacral joint. On the following day abdominal pain was found to be due to a distended bladder, and, although small quantities of urine had previously been passed, he had retention to the end of life. On the third day he was very ill, with muttering delirium and a temperature of 104° . Lumbar puncture yielded a very small quantity of fluid under low tension; it was slightly turbid and gave a pure culture of streptococci. On the fourth day he died.

The autopsy was made by Captain Lazarus-Barlow. From behind there is seen (*Fig. 130*) a wound through the ligamenta subflava, between the 4th and 5th lumbar laminae, and in this region a little pus lay outside the spine. Looked at from the front (*Fig. 131*) the specimen shows a small sharply-cut fracture of the 5th lumbar arch. The subjacent theca is cleanly perforated, and the cauda equina partly, but by

no means completely, torn (*Fig. 132*); the nerves and meninges in this region were blackened. Finally, the foreign body was discovered only on section of the vertebral bodies,

FIG. 134.—Lodgement of metal fragments (*Case 7*).

part to bony débris. There is little meningitis, though the post-mortem examination of other regions shows that life must have been preserved for some time. A bullet had entered the 9th intercostal space in the left mid-axillary line, passing through the pleura, the posterior margin of the spleen, and the middle of the left kidney, to the right lumbar region, whence it was extracted by operation. There was blood in the pleura and in the

FIG. 136.—Section of spinal cord; slight secondary changes.

peritoneum, with slight fibrinous peritonitis, much perirenal hæmorrhage with purulent fluid in the retroperitoneal tissues, a fibrinous clot closing the wound in the spleen, pus around the resting-place of the bullet, cloudy swelling of the liver and right (un-injured) kidney, acute cystitis with hæmorrhagic foci, and œdema of the descending colon. Hence the specimen illustrates the severe mechanical injury and comparatively slight sepsis of a clean bullet wound of the vertebral canal.

Case 9 (Fig. 136) shows equally a severe mechanical injury with slight meningitis. The bullet had perforated the arch of the 7th dorsal vertebra, transfixing the theca, almost dividing the cord, and then tearing a large ragged hole in the right lung. The drawing (*Fig. 136*) illustrates the condition of the medullary vessels in an early case of this type. (No clinical notes are obtainable.)

Case 10 (W.O. 411) illustrates a perforation in which life was prolonged for nearly a month. On Nov. 4, 1915, the patient was wounded by a piece of shrapnel on the right side of the neck, three inches below and a little posterior to the tip of the mastoid process. There was complete paraplegia below the nipple, but the arms are said to have presented no paralysis or anæsthesia. On Nov. 8, laminectomy was performed, and a fragment of shrapnel-casing measuring $\frac{3}{8}$ in.

which exposed a fragment of metal lying deeply in the 4th-5th intervertebral disc (*Fig. 134*). Meningitis extended upwards as far as the 1st dorsal vertebra, and the entire cord is here reproduced to show the extent of the exudation (*Fig. 133*). In addition to the intense congestion of the lower part of the meninges and of the medullary vessels, subarachnoid exudation is shown running up the cord, and we have a complete picture of a streptococcal spinal meningitis of four days' duration.

Case 8 (W.O. 350) shows a similar injury, with greater mechanical damage but far less serious septic infection. The theca is perforated transversely at the level of the 1st lumbar vertebra, and the cauda equina is almost torn across, a small fragment of bone still present (*Fig. 135*) showing the injury to have been due in part to the missile and in

FIG. 135.—Transverse section of cauda equina; little meningitis.

by $\frac{1}{8}$ in. was found to the left side of the cord. The dura was torn, as were the posterior fibres of the spinal cord (*Fig. 137*). The wound healed aseptically, but paralysis was not improved, and death occurred on the twenty-eighth day. The very clean perforation is here represented by a glass rod, and it is clear that there has been no spreading meningitis.

III. CASES OF CONTUSION OF THE CORD BY DIRECT IMPACT OR BY TANGENTIAL WOUND.

In the two last groups of cases we have been concerned with injuries in which the missile or a fragment of bone has penetrated the dura mater and wholly or partially divided the spinal cord or its roots; we may now pass to those in which there has been no mechanical section, but in which the injury is due to a mere bruise. Such a bruise can be inflicted in one of several ways, which are illustrated by the following examples.

Case 11.—(*Fig. 138*, W.O. 2724). In this case, of which there are no clinical notes, a

Fig. 138.—Lodging shrapnel bullet with contusion of cord.

Fig. 137.—Perforation of spinal cord; no septic changes. Result after one month.

shrapnel bullet has impinged upon the 1st lumbar arch, and, entering the spinal canal, has come to rest on the right side, where it lies between the intact theca and the fractured lamina. It will be sufficiently obvious from the drawing how in such a case the cord is contused, and if the blow be sufficiently severe is converted into a mass of debris and blood-clot. This type of injury was rather common in the lumbar region, where the spinal canal is large, and was not infrequently due to shrapnel bullets of low velocity. Paraplegia naturally ensued, and the specimen is accompanied by the bladder and kidney, which well illustrate the usual method of death in such cases. The bladder, shown from its inner aspect (*Fig. 139*), presents intense congestion, with thrombosis of its veins and scattered patches of ulceration. The kidney presents numerous cortical infarcts, and should be compared with the kidney of *Case 2*, in which we have a quite different type of secondary lesion; in the latter the inflammation has taken the form of a hæmorrhagic pyelitis; in this instance (*Fig. 140*) the pelvis had undergone little damage, but the cortical metastatic lesions are well defined.

Case 12 (W.O. 881) is an illustration of a slightly less obvious contusion, and presents several points of interest. *Fig. 141* shows from behind a rifle bullet embedded between

FIG. 130.—Bladder from case shown in *Fig. 138*, inverted; cystitis, ulceration, thrombosis.

FIG. 140.—Kidney from case shown in *Figs. 138, 139*; cortical infarcts.

FIG. 141.—Bullet with base projecting into spine; fragments of casing shown in its track.

FIG. 142.—Projection of base of bullet into spinal canal tear of dura mater, contusion of cord.

the 5th and 6th dorsal spines. To the left of the bullet are seen bright specks of copper from its casing, and such are often of practical value, as they stand out as minute shadows in a skiagram and may usefully indicate the course taken by the bullet. In the present instance it is obvious that this has entered and has come to rest with its base in front. Turning now to the opposite side of the specimen (*Fig. 142*), we find that the base of the bullet has just failed to enter the spinal canal, but has here produced a salient, impinging upon the posterior aspect of the theca, in which are two small tears with a little hæmorrhage. The cord was here reduced to blood-stained débris.

Case 13 (W.O. 384) shows a third form of contusion, in which the injury is tangential to the cord. A bullet entered one inch below the angle of the jaw on the left side and passed out to the right of the cervical spine. Its track is shown (*Fig. 143*) skating the arachnoid, which is here torn, and there is a thin layer of subarachnoid hæmorrhage extending for a considerable distance on either side of the glancing blow. The patient died on the third day, with complete paralysis and anæsthesia below the 8th cervical segment. In such cases the injury inflicted upon the cord is apt to extend far beyond the region of direct contusion, and the accompanying drawings (*Figs. 144 and 145*) of specimen 384 A are introduced to show how widely spread is the necrosis produced by the same bullet in the tissues of the back and at the point of exit. Even allowing for the fact that at this stage it would be accompanied by fragments of bone from the cervical laminæ, its 'divulsive' action has inflicted an amount of damage upon muscle, fat, and skin which fully prepares us for the widespread injury of the less resistant spinal cord.

FIG. 143.—Tangential wound of meninges; contusion of cord (*Case 13*).

FIG. 144.—Track of bullet (*Case 13*); extensive hæmorrhage and necrosis.

FIG. 145.—Exit of bullet (*Case 13*).

Case 14 (W.O. 1433) is a further illustration of the result of a tangential injury, and is accompanied by a specimen of the aorta from the same case to allow comparison

FIG. 146.—Tangential wound of spinal cord.

of a similar injury to these two very different structures. The bullet entered to the right of the 1st dorsal vertebra, passing through the spine, driving bony splinters into the hilum of the left lung, and then becoming embedded in the upper lobe of the latter, with its point projecting on the pleural surface. The patient, who was paraplegic, died in sixty hours with the symptoms of severe hæmorrhage. The left pleura was full of blood, and left lung collapsed. The aorta "seemed to have been untouched", but "lay immediately adjacent to the track of the bullet" (*Fig. 147*). On its inner aspect, at the point which the bullet had crossed, are a few minute cracks in the intima, and a small clot projecting like a polypus. As regards the spine, the bullet is found to have

FIG. 147.—Tangential injury of aorta from same case as *Fig. 146*.

passed through a spinous process, grazing the left side of the dura mater, which presented a tear $1\frac{1}{2}$ in. long (*Fig. 146*); the spinal cord showed no external change, but paraplegia was complete. (Another specimen shows the remainder of the spine with exit of the bullet through the left side of the body of the vertebra.)

Case 15 (W.O. 313) is an example of a form of injury which is probably quite uncommon. A bullet entered the left side of the neck just behind the centre of the sternomastoid muscle, and passed out immediately above the upper angle of the right scapula. Paralysis was complete, and death followed within thirty-six hours from respiratory failure. The bullet was found to have traversed the base of the 7th cervical spinous process, without penetration of the vertebral canal; but, on laying open the bones, there is here found a partial dislocation of the spinal column; between the last cervical and first dorsal vertebræ is seen a horizontal tear in the ligamenta subflava, and three or four of the vertebral bodies have been slightly wrenched apart into a position of hyper-extension. The whole of this region of the

FIG. 148.—Contusion of membranes and cord without penetration of vertebral canal.

spine thus presents an exaggeration of its normal anterior convexity; there is hyper-extension of the cervicodorsal junction as from a severe but widely diffused impact upon the back of the neck; the divulsive action of the passing of a missile at high velocity is thus carried to an extreme degree, and the contents of the spinal canal have suffered from subluxation in extension instead of from the subluxation in flexion which is so characteristic of the injuries of civil life. (This bony specimen is in the museum, but the condition cannot be shown on a plane surface.) There was much diffused hæmorrhage into and around the bones, and the vertebral canal was palpably full of blood.

The specimen (*Fig. 148*) illustrates admirably the usual appearances of extensive hæmorrhage into the membranes and cord. It is important to note that in this and other similar cases the amount of hæmorrhage, although sufficiently great having regard to the region in which it is situated, is rarely if ever sufficient to fill up the theca or to yield any large amount of blood from lumbar puncture. Cerebrospinal fluid obtained

by the latter means may present slight reddening or may show blood-cells microscopically, but we have not found such quantities of blood as to produce any direct pressure in distant parts of the theca.

The above cases illustrate the *mechanism* of contusion of the spinal cord; those which follow show some of the *results* of such injury.

Case 16 (W.O. 469) is an example of severe hæmorrhage from contusion in the cervical region. The bullet entered the right side of the neck behind the sternomastoid muscle, splintering the right lamina of the 7th cervical vertebra and coming to rest in the muscles of the back near the 1st dorsal spinous process; from its short course and ready arrest its velocity was probably low. The theca is quite uninjured, but there is extensive hæmorrhage in the arachnoid and cord, extending well above and below the region struck (*Fig. 149*).

It is noteworthy, however, that in this instance, in which the velocity was probably not high, the hæmorrhage is far more localized and well defined than in most of our cases.

Case 17 (W.O. 2027) is that of a man who died six days after a wound in the neck. There was a fracture of the 6th and 7th cervical spinous processes and laminae, with complete paraplegia, hyperpyrexia, and pneumonia. The post-mortem examination showed a large amount of extradural blood-clot extending over the lower cervical region and reaching to the upper dorsal vertebræ: but the theca was untorn, no foreign body was found in the spinal canal, and there was no meningitis or intrathecal hæmorrhage. The specimen (*Fig. 150*)

FIG. 150.—Extensive softening of cord from contusion; no injury to theca.

FIG. 149.—Contusion of cord; no injury to theca.

shows an extensive area of softening in the lower cervical region. In this case it is

possible that there may have been a direct bruise of the contents of the vertebral canal by bony fragments which have subsequently recoiled; or alternatively, the bruise may have been due to the divulsive effect of the bullet upon surrounding soft parts, as shown in

Case 13. The lesion of the cord is not of a type which could be produced by the mere pressure of extrathecal hæmorrhage.

A similar condition is better shown in the coloured drawing of *Case 18* (W.O. 2072). Here death occurred on the sixth day after a wound in the middle line over the 2nd dorsal spinous process causing complete paraplegia. At the post-mortem was found a fracture of the 2nd dorsal spinous process, and a piece of metal one and a half inches in length, with some fragments of cloth, was embedded in the left lamina of the 4th dorsal vertebra, at which point it had projected slightly into the spinal canal without dividing the theca. There was an extradural hæmorrhage, with some pus, over an area four inches in length. (Other post-mortem findings were cystitis, pyelitis, œdema of the lungs, and some gas infection of liver, spleen, and kidneys.) The specimen (*Fig. 151*) shows a slight indentation of the dura opposite the 4th dorsal lamina, with remains of the extradural coagula, and contusion of the cord with numerous hæmorrhages into its substance extending over an area of about four inches. It is here obvious that any direct bruise can only have occurred in the lower part of the damaged area, while the more severely injured part above could only be affected by transmission of the mechanical impulse through soft tissues or unbroken laminae.

Lastly, in *Case 19* (W.O. 451) we have a case in which a shell wound in the cervico-dorsal region caused a fracture of some of the spinous processes, but did not open the vertebral canal.

A series of sections taken over a distance of three inches (*Fig. 152*) shows admirably the extent of hæmorrhage into the cord in such a case of contusion, or as it is sometimes called, 'concussion'. The bleeding, which is more severe on the left side, shows a marked tendency to affect the grey matter rather than the firmer white fibres, and takes the general form of a much tapering spindle, an arrangement which is also commonly seen in the hæmorrhage which extends above and below the crushing injuries of fracture-dislocations in civil life. The same arrangement can be demonstrated clinically to have occurred in many cases which recover, leaving an atrophic paralysis of certain segmental areas, with little evidence of injury to ascending and descending fibres.

MENINGITIS.

Reference has been made in several of the above cases (notably *Case 6*) to the adhesions by which apertures in the theca may be sealed as are aseptic wounds of the cerebral membranes. Such local repair can, however, occur only in the absence of septic infection, the adhesions produced are generally very feeble, and the theca presents great powers of complete repair. It is quite usual for the separation of such adhesions to be

FIG. 151.—Slight bruising of theca; extensive injury to cord.

FIG. 152.—Extensive hæmorrhage from slight bruising (or concussion) of cord.

followed by a gush of cerebrospinal fluid, and in many cases this release has been described at operation as due to the opening of a subarachnoid cyst. In some, no doubt, there is a localized collection of fluid, but in others there is merely a release under normal tension

FIG. 153.—Extension of septic meningitis upwards along cord.

FIG. 154.—Lower part of cord from same case as Fig. 153, showing extent of meningitis.

of the fluid above and below, and it is not unusual for such fluid to be projected for a vertical distance of several inches through a small incision in the arachnoid.

In gunshot wounds there is, however, a grave risk of septic infection, and many of the above cases illustrate the appearances produced by such local infection. The dura

is reddened and congested, while exudation within the arachnoid covers the surface of the cord with a creamy layer of pus. Definite abscesses are rarely if ever found, and I have not met with any evidence of local accumulation of gas, probably because death precedes the development of such conditions.

The meningitis presents a strong tendency to spread, which is well shown in *Case 20* (W.O. 1832) (*Figs. 153, 154*). This man was admitted to hospital with a through-and-through bullet wound passing from right to left across the back at the level of the 12th dorsal vertebra. He presented complete flaccid paralysis of both lower limbs, with paralysis of bladder and rectum. All power of sensation was lost from (? including) the 1st lumbar segment, except a small triangle under Poupart's ligament on the left side. There was a fracture of the spine, of which the exact nature is not described. Laminectomy was performed the day after the wound, and the cord was exposed through the 12th dorsal and 1st lumbar laminæ. On the ninth day there is a note reading, "Meningitis—general condition worse—paralysis never improved", and on the twenty-third day he died. Supplementary clinical notes, which unfortunately bear no date, refer to diminution of sensation of touch and pain below the 5th dorsal segment, hyperæsthesia to rubbing in both flanks, weakness of the lower part of the rectus abdominis, and exaggeration of abdominal reflexes on the right side with diminution on the left.

FIG. 155.—Septic meningitis with much exudation.

The post-mortem examination by Captain T. H. O. Shore showed extradural hæmorrhage extending from the wound up to the mid-dorsal region, intradural hæmorrhage and purulent meningitis to the upper dorsal region, and softening of the cord about the wound. In the brain there was extensive purulent meningitis, with pus in the ventricles and a small hæmorrhage in the floor of the 4th ventricle. It is noticeable—especially in connection with the next case—that extensive as is the spinal meningitis, it tends to fade away in the upper part of the thecal canal, while it is again more active in the cerebral meninges. Also it is here remarkable that the extension has occurred solely in an upward direction, the subarachnoid space below the lesion having apparently been sealed off by adhesions (*Fig. 154*). Such a distribution is quite usual, and for this reason a thecal puncture below the level of the lesion may fail to indicate the severity of the meningitis above.

In the great majority of such cases of meningitis—which are probably due to a streptococcal infection as in *Case 7*—the inflammation is, as would be expected, directly continuous; but the following is a remarkable illustration of what might at first sight appear to be a separate focus of infection.

Case 21 (W.O. 468) is that of a man who had received two wounds thus described in the post-mortem report by Captain Hubert Henry, 13 General Hospital, Boulogne: (1) "A large gaping septic wound over lower lumbar region in middle line, with tearing of the base of the dural sac"; (2) "A second smaller wound over 10th and 11th ribs, two or three inches to right of mid-dorsal line", slight and superficial. There was no head injury. The note adds: "Said to be a case of pure infection with *B. perfringens*". No clinical history is obtainable.

The lumbar region of the spinal cord (*Fig. 155*) shows a typical area of septic meningitis, with the usual accumulation of pus beneath the arachnoid, and with prominent congested vessels in the cord; the dura mater presents little if any change. On the vertex of the brain there is another area of similar inflammation (*Fig. 156*). There is

here a thick deposit of densely-packed yellow pus with well-defined margins, almost limited to the vertex but extending slightly towards the Sylvian fissures. The post-mortem report states that "there is little evidence of meningitis at the base"; the specimen shows none, nor does the upper part of the spinal cord. This is the only case in which we have found so isolated a patch of remote meningitis, but there is no

FIG. 156.—Brain from same case as *Fig. 155*, showing vertical meningitis.

reason to regard the condition as a pure metastasis; it probably resulted from a direct extension of infection which has failed to evoke active reaction at lower levels, and has thus, by allowing life to be prolonged, had the opportunity to develop to an unusually high degree at its upper limit, a tendency to remote exacerbation also seen in *Case 20*.

SUMMARY.

In concluding this survey of a selection of specimens from the very fine collection in the War Museum, we may perhaps lay down the following general propositions :—

Gunshot injury of the spinal cord may be due to :—

1. The direct impact of a missile, which may either penetrate it completely, or remain embedded in it, and which is liable to be accompanied by fragments of clothing, and especially of bone.

2. The indirect impact of fragments of bone, which again may penetrate completely, may remain embedded, or may recoil towards the positions from which they were dislodged, although such recoil is far less common and less obvious than in fractures of the vertebral bodies as seen in civil life.

3. Contusion by : (a) Foreign bodies which enter the spinal canal but do not penetrate the theca ; (b) Displaced fragments of bone protruding slightly into the vertebral canal ; (c) Displacement of the soft parts only, or, rarely, subluxation of the bones (*Case 15*)—the widely-spread divulsive or ‘explosive’ action of a missile passing by at a high velocity.

In all cases the cord is liable to present mechanical destruction and hæmorrhage extending widely beyond the area of apparent injury, and affecting especially the grey matter of the anterior cornua, where it produces long spindle-shaped areas of destruction. Such extension of hæmorrhage is more widely spread where the missile is of higher velocity.

In the case of direct impact by foreign bodies, septic meningitis will generally ensue, but such meningitis is less common when impact is due only to fragments of displaced bone. It is generally absent in contusions of all forms, and the untorn dura mater is highly resistant to infection.

Meningitis tends strongly to extend upwards rather than downwards, and is usually continuous, but may spread unobtrusively along the membranes, to blaze up at remote points.

Hæmorrhage sufficient to cause serious compression is very rare, but it is usually present in such quantities that, should life be prolonged, it may readily give rise to well-defined cicatrices, which will tend to assume the annular and constricting type often found at operation.

REFERENCES.

¹ THORBURN and RICHARDSON, *Brit. Jour. Surg.* 1918, vi, 481

² KEITH and HALL, *Ibid.*, 1919, vii, 67.