

COMPLETE DIVISION OF THE SPINAL CORD IN LOWER DORSAL REGION

A CASE WITH CONSERVATION OF SPINAL REFLEXES BELOW
LEVEL OF LESION *

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SUMMARY OF CASE HISTORY

An adult man rendered totally paraplegic following fracture of the tenth dorsal spine and consequent direct injury to the cord. First observation one year and three months after injury. Examination disclosed exaggerated inferior tendon reflexes, accompanied by pathologic pyramidal tract signs, marked defense reactions, preserved muscle tonus and patellar clonus. Total absence of voluntary motion in lower extremities. Involuntary action of sphincters, decubitus ulcers over both hips. Absolute anesthesia below the ninth and tenth dorsal radicular skin distribution. Because of the abnormal motor phenomena a compression of the cord was suspected, and a laminectomy performed by Dr. Emmet Rixford, Feb. 3, 1917. A complete division of the cord tissue proper was found. The ends of both cord fragments were trimmed off and preserved for future examination. An effort to suture the two ends of the spinal cord was made and found impossible. Reexamination Feb. 22, 1917, nineteen days after operation, showed the same clinical signs as before operation.

History.—B. F. H., aged 46, on Oct. 12, 1915, fell a distance of 8 feet from a walk plank placed over two ladders; he landed on a carpeted floor; had no recollection of the manner of his fall, his last remembrance of the occasion being the swaying of the ladders toward the wall which he was painting. No one saw him fall, but he was found unconscious immediately afterward; he remained so for about 20 minutes; on awakening he complained of severe pain in the pit of his stomach, felt "dead" below the waist, and was unable to move any of his muscles below the waist; sensation was abolished below the same line. After the injury there was retention of urine, necessitating catheterization for about ten days; a mild cystitis was set up which subsided in a few weeks; this retention was succeeded by loss of voluntary control which has persisted to date. The urine dribbles away but also comes at times in quantities; there is a sensation of pain in the region of the bladder, which precedes urina-

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tion. Defecation has been involuntary since the accident, although bowel movements have not been continuous. It is necessary to take large quantities of physics to produce a motion. Often the simple insertion of an enema tube will be followed by a bowel movement. Enemas are not found to be as efficacious as the foregoing. Burning pain in the epigastrium and along the costal margin continued to be very severe after the injury requiring morphin.

Three days after the fall the patient was operated on by Dr. George White of Sacramento. The exact nature of the operation is unknown to patient, but he was told that the operation was one of decompression. An excellent operative recovery was made, but no improvement in motor or sensory function resulted. Following an attack of malaria six weeks after leaving hospital, decubitus ulcers developed over both trochanters and in the gluteal fold of the left side, and these ulcers have persisted to the present time. In the past year the condition has been practically unchanged. Subjective sensation of burning and tingling are said to be present in the soles of the feet, in the epigastrium and along the costal margins. The general physical condition has remained good, weight has been constant or slightly increased, appetite is good, and sleep excellent. The patient states that within a month after injury "life" came back into lower extremities—there were twitchings observed in both legs; and definite movements were said to have taken place about two months later. These movements were a drawing up of the lower extremities; they increased in force and extent up to within six or eight months from the present date—January, 1917.

Neurologic Examination.—This was made, Jan. 29, 1917. It revealed a total paraplegia of the spastic type, no voluntary movements at the ankle, knee or hip joints, some contraction of the abdominal muscles most marked in the upper part of the abdomen. Inspection of the dorsal spine presents a gibbus at the ninth to tenth dorsal spines. No muscular atrophy in the lower extremities is noted that cannot be accounted for by disuse, with the possible exception in the right thigh muscles where there may be some true atrophy; this is more marked posteriorly. Decubitus ulcers present over both hips.

Reflexes: Patellar and Achilles' tendon reflexes both present and very active. Babinski, Oppenheim and Gordon reflexes positive. Ankle and patellar clonus is active but inhibited almost immediately by spasm of the quadriceps group.

Sensibility: Superficial and deep sensibility totally lost below the level of the ninth to tenth dorsal segments; the sensibility for pain and temperature is lost about from 4 to 5 cm. above the loss for light touch, and the levels vary on the two sides of the body as shown on the accompanying chart. After the examination has been continued for a certain time the levels of anesthesia are found lower at the end of the examination as compared with the beginning of the examination. The levels are constantly higher on the left side of the body than on the right—this is particularly well marked posteriorly. It is noteworthy that no areas of distinct hyposensibility or hypersensibility exist at the level of anesthesia, which appears sharp and well defined. Position of great toe not recognized. Pressure sense appears to be perceived at first, but it is a question whether patient does not sense certain reflex movements. These reflex movements of the nature of defense reactions are constantly present by stimulation of both the plantar and dorsal surface of both feet, most readily by pinching the skin and by pin prick, but also, though to a lesser extent, by heat and cold. They consist of an exaggeration of the tendency of the great toes to extension and flexion at the ankle, knee and hip. Excitation of the skin of the leg and thigh cause less marked reactions excepting in the right quadriceps region.

Roentgen-Ray Examination.—Made by Dr. Walter Boardman, Jan. 25, 1917. "Examination shows narrowing of the body of the tenth dorsal with obliteration of the tenth intervertebral space and angulation of the spine at this spot."

Impression: Traumatic injury of spinal cord above the lumbar enlargement and opposite the level of the tenth dorsal vertebra. The possibility of a compression must be considered because of the paraplegia of the spastic type and the prominence of the defense reactions. Exploratory laminectomy was advised.

Operation.—The operation was performed by Dr. Emmet Rixford, Feb. 3, 1917. Dr. Rixford's notes on the operation follow:

Assistant, Dr. Melville E. Rumwell. One lamina removed below the gibbus. Evidence of considerable new growth of bone at the site of Dr. White's laminectomy, so that the cord was very well protected. The cord being exposed above and below it was found to be completely cut off at the

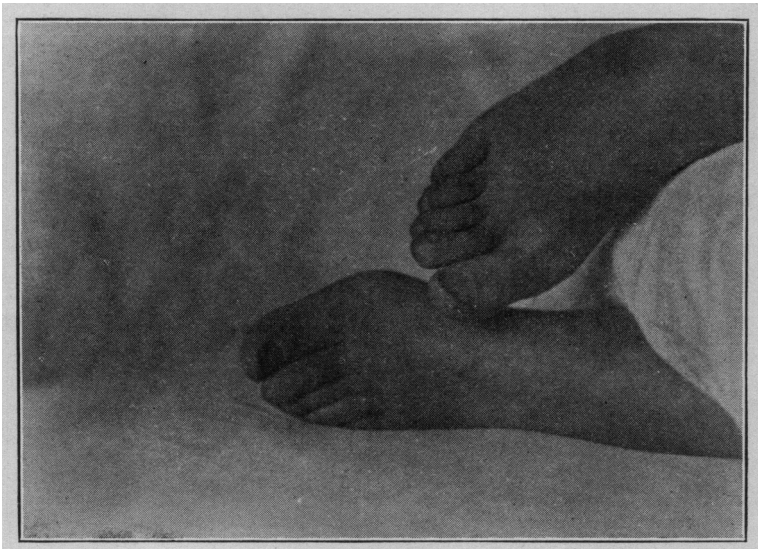


Fig. 1.—Constant tendency to extension of the great toes in the resting stage.

level of the gibbus. It was noted that there was cerebrospinal fluid within the dura below the point of injury. It, therefore, seemed probable that there was connection across, but this could not be found by means of a probe passed from either above or below. The scar which united the dura was then split longitudinally and an effort made to trace connection between the upper and lower dural sacs, but this was not successful. The dura was then lifted off the bone and the upper part turned upward and the lower downward. With a chisel, a considerable amount of the bone of the anterior wall of the canal was cut away, especially the upper edge of the eleventh dorsal vertebra. It would appear that the injury consisted of a driving forward of the tenth on the eleventh dorsal vertebra. The cord was absolutely cut across with no detectable fibers of communication. When at the lower border of the wound the cord was touched, the legs contracted. Evidently the injury was chiefly above the lumbar enlargement. There was no pulsation of the dura, but it expanded and contracted with respiration. This was detected also after the dura had been lifted off the bone and the parts

definitely separated. It was therefore quite evident that the pulsation and variation in pressure due to respiration was a local matter in the cord rather than the result of transmission from the brain. The dura was drawn together with catgut and an attempt made to suture the cord. The ends of both fragments were trimmed off and preserved for examination. Two catgut sutures were then passed through the spinal cord in an effort to draw the ends together, but it was not possible to approximate them within less than one-half inch.

Condition After Operation.—The patient made a good operative recovery. Re-examination neurologically, Feb. 22, 1917, nineteen days after operation, showed practically the same clinical findings as before the operation. The following details were noted: When questioned as to sensation in the lower extremities, the patient states that he feels tingling, numbness, sensations of heat and cold and also pain at times in the feet, legs and thighs of both



Fig. 2.—Flexor response by defense movements.

extremities. He states that he can feel the breeze from an electric fan in the room. Re-examination of the sensibility revealed the same levels of anesthesia for cutaneous sensation. Deep sensibility lost, tested by the Luer fork for osseous sensibility, by pressure and by notion of position. The subjective sensory impressions were judged to be the hallucinations of sensation and also due to transmitted impulses from reflex defense movements.

Reflexes: Babinski and Schaeffer reflexes are present bilaterally and constantly; Oppenheim present, questionably, however, on the left side. Gordon and Mendel-Bechterew reflexes are variable, at times absent. Patellar and ankle jerks very lively.

Muscular System: A comparative atrophy existed in the paralyzed limbs and rump, but was of the degree which is found in emaciation or disuse. Electric examination by both faradic and galvanic currents showed response of the muscles without qualitative change. There was, however, a relative hyperexcitability to both forms of current, amounts of galvanic current as high as 10, 15 or 25 ma. being necessary to produce muscular contraction. The

external popliteal nerve was excitable to the electric current. Tonus: The muscle tone was found either normal or increased.

Reflex Defense Movements: As the patient lay in the supine position the lower extremities were in extension, but it was noteworthy that the great toes were slightly extended rather than partially flexed as seen in flaccid paralysis. On irritation of the plantar surface of the feet this extension was so markedly increased that the great toes were at an approximate right angle to the plane of the foot. Repeated examinations of the plantar, tibial and calf reflexes gave the impression that the Babinski sign was the most frequently positive, the Oppenheim less often so and the Gordon reflex was at times evidenced by flexion rather than extension of the great toes. As to the reflex defense movements proper, they were elicited most conveniently by pin prick. It was not established that touch produced these reflexes except pinching the integument or rather pressure. As was the case in previous examinations, temperature also

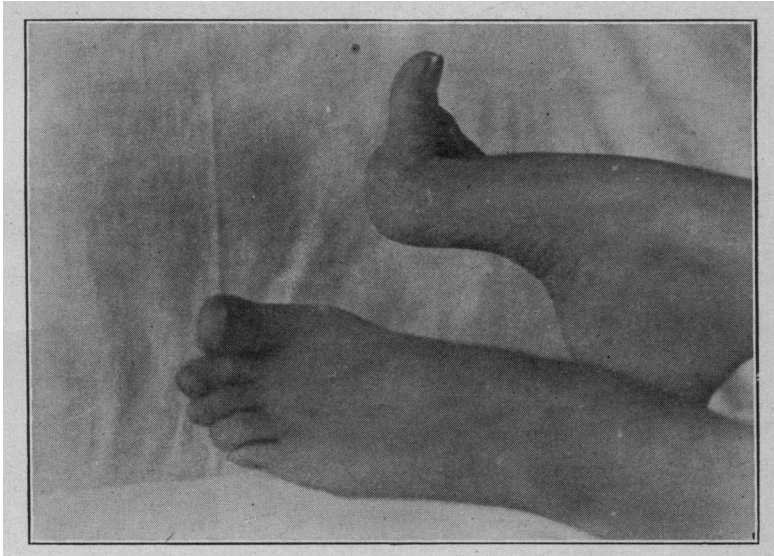
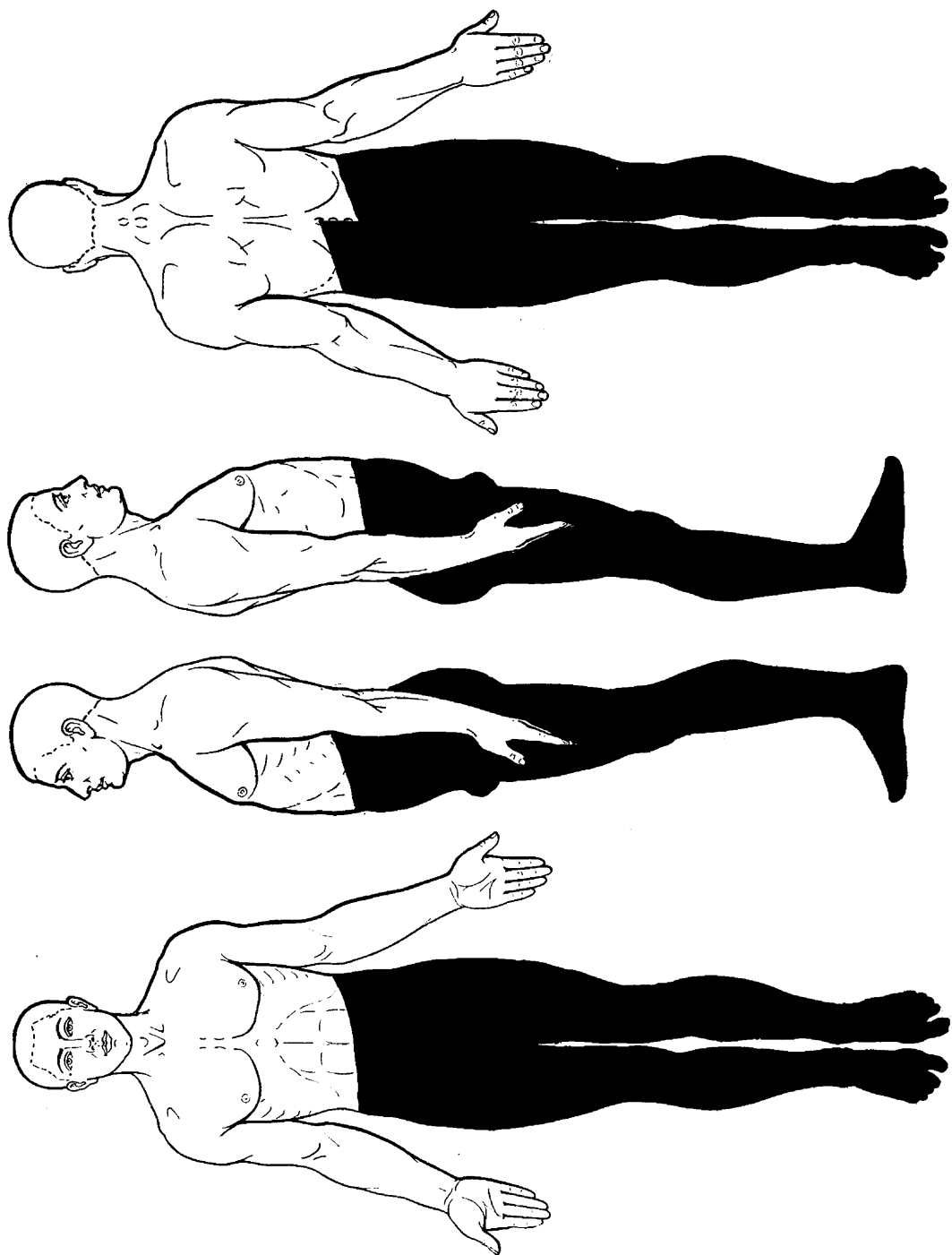


Fig. 3.—Extensor reflex in the Babinski sign.

produced the defense movements. The flexor sign of Marie, *signe des raccourcisseurs*, was present. By pin prick different surfaces of the lower extremities, anteriorly, posteriorly and laterally, were stimulated, with the result that the movements were generally of the same kind, irrespective of the site of stimulation, namely, in flexion. The thigh was flexed on the pelvis, the leg on the thigh, and the foot dorsally flexed on the leg. The tendons of the sartorius, the adductors, the hamstrings, were seen to contract.

The patient was questioned as to whether the lower extremities were ever forcibly involuntarily extended from the flexed position. This was stated to be sometimes the case. By passive motion of the lower extremities at the different joints there occurred at times a certain rigidity of the member in extension, the knee not being readily bent and the foot plantar flexed. These movements were not as vigorous as the movements of flexion just described. In observing the muscular contractions in the flexor movements, there was observed a concomitant and independent movement and increased tonus in the anterior thigh and calf muscles as if the muscles of the entire lower extremity were brought



Black areas indicate complete sensory loss (superficial and deep sensibility). There is complete absence of sensibility below the level of the ninth and tenth dorsal segments.

into play, but the flexor movements predominating. The flexor and adductor movements of the thigh were vigorous enough to retain the thigh flexed on the pelvis for quite an appreciable length of time after the stimulus has been withdrawn, and held adducted so as not to fall outward by its own weight, but remaining a considerable distance above the level of the bed. The tendons of the adductors and sartorius were seen to stand out boldly leaving between them a considerable fossa. During the examination there was observed a partial erection of the penis. Patient stated that on occasions there was a complete erection, but without any sensation of sexual desire. The state of the anal and vesical sphincters have been previously mentioned and remained the same.

Subsequent Examinations.—The patient was next examined, March 3, 1917, and two days previously also, for the height and localization of areas which, when stimulated, produced defense reactions. It was found that on the anterior aspect of the thigh, these reflexes did not take place when stimulation was applied above the lower third of the thigh or at most above the upper half of the thigh. On the posterior aspect of the extremity and buttocks, however, reflexes took place when points as high as the ischii were stimulated; and in the thigh and leg it can be said to be true that stimulation on the posterior aspect of these portions or the lower extremities, produced more active and strong contractions than stimuli applied to the anterior aspects of the extremities. In the foot, there appeared to be no difference in intensity of reaction on plantar or dorsal stimulation. The patient, after the foregoing examination, returned to his home in the Sacramento valley and was not re-examined until Nov. 17, 1917, and on this date the following note was made: Patient examined in Live Oak, Calif.; with the exception of a complication bladder infection, the condition remains about the same. In particular, contra-lateral reflexes were tested for, but neither defense movements, the Babinski toe reflex nor contralateral adductor reflexes, were noted in the contralateral limb, following any kind of stimuli to the one lower extremity.

The patient was next examined, Jan. 1, 1918. The neurologic status was practically unchanged at this time. The general condition of the patient, however, was not so satisfactory, as the bladder infection, in spite of extreme care, appeared to be progressive and was suspected of ascending to the kidneys. Particular attention was directed on this examination to the state of the skin reflexes and the existence or nonexistence of contralateral reflexes. No contra-lateral responses were observed. The plantar reflexes were only present on the side stimulated; also the defense reactions were present only on the side stimulated, and in eliciting the patellar reflex and percussing the different bony prominences in the lower extremities there were no contralateral adductor responses. The left cremasteric reflex was definitely present; on the right side a slow vermicular contraction of the scrotal musculature was observed differing from the quick cremaster reflex as seen on the opposite side (Dartos reflex). The abdominal reflexes were not found definitely present. The Babinski, Oppenheim, Rossolimo and Gordon reflexes were found to be present.

Final Result.—By practice and experience the patient was, to a certain extent, able by taking advantage of his own defense reflex movements and consequent rigid and fixed position of his lower limbs, to utilize these movements in assisting himself to changes in position. While sitting in a wheel chair he was able to clear his thighs and buttocks from the seat of the chair, the knees being rigid and the ankles fixed for support. In this manner by a pulley arrangement above his bed he was able to clear himself from his chair, swing on to the bed and content himself with the idea that he had a certain return of motion more or less voluntary in the affected extremities.

LITERATURE

Bastian,¹ in an article written in 1890, stated that the prevailing notion of this time was that in man, after a total transverse lesion of the spinal cord, the reflexes were exaggerated below the lesion following the period of shock. This notion was based on the experiments of physiologists. Bastian's contention, based on his own personal experiences in cases of transverse softenings of the cord and references to the literature of the subject, was opposed to this view. In 1882, in an article in Quain's Dictionary of Medicine (page 1480) he had already expressed a very definite opinion on this subject, based on an observation of three cases of total transverse lesions of the cord (softening). In his later article he reported four cases with verification by necropsy and study of ascending and descending degenerations. In this series the longest period of duration of the paralysis was seventeen weeks. Bastian states that, although there was not in all of these cases a record of the condition of the reflexes up to the termination of the illness, his memory enabled him to say most definitely that the limbs in all remained in a condition of flaccid paralysis with no signs of rigidity even up to the end. This condition of areflexia with flaccidity and sensory paralysis was hereafter known as Bastian's Law in complete lesions of the cord. The explanation of the phenomenon was that the autonomy of the spinal cord decreased as we ascend the vertebrate scale; and that further loss of pain sensation was the determining factor which brought about the loss of reflexes. This loss included both the cremasteric and abdominal reflexes. It is, however, interesting to note that Bastian admitted the persistence in the plantar reflex and also to a certain extent the vesical and rectal sphincter action evidenced by the periodical discharge of urine in small quantities, and the loss of power to control reflex action concerned in defecation when this action had been strongly excited as by laxatives. Furthermore, the persistence of the idiomuscular contraction due to mechanical stimulation was noted, but explained as not being a true reflex.

Bastian's Law, accepted by Ludwig Bruns² and sometimes called the Bastian-Bruns Law, was, however, the subject of considerable controversy. Oppenheim,³ in his textbook (1913), and particularly Lapinsky,⁴ who gives a large bibliography on the subject and his

1. Bastian, H. Charlton: On the Symptomatology of Total Transverse Lesions of the Spinal Cord, Tr. Royal Med. and Chir. Soc., London, **73**:151, 1890.

2. Bruns, Ludwig: Arch. f. Psychiat., **25**:759, 1893.

3. Oppenheim, H.: Lehrbuch der Nerven-Krankheiten, **1**:136, 1913.

4. Lapinski, Michael: Arch. f. Psychiat., **42**:55, 1906.

own personal experiences on clinical observations and animal experimentation, discusses the various observations and opinions. This latter author and Henneburg,⁵ also Kausch⁶ (1901), reported cases of complete transverse cord lesions above the lumbar enlargement which were followed by preserved tonicity and tendon reflexes and appeared definitely to contradict Bastian's Law. Previously, certain observers had intimated that skin reflexes were persistent—but few, if any, undisputed cases of preserved tendon reflexes were reported. Jolly,⁷ however, also reported such a condition. The condition described by Bastian appeared to be explained then by lesions affecting directly the reflex centers, shock, extensive alterations in the cord, blood and lymph circulation disturbances, tearing of posterior roots, increased cerebrospinal fluid pressure, or chronic degenerative changes in muscles, peripheral nerves, ganglion cells or posterior roots.

RECENT CONTRIBUTIONS

Since the beginning of the great war there have appeared numerous observations of complete traumatic transverse cord section, and in the great interest which attaches to the clinical manifestations of this condition there have been many careful and detailed reports. Of these observations, the following may be mentioned:

Observation of Dejerine and Long⁸: Cervical paraplegia of traumatic origin, motor and sensory paralysis below the lesion, abolition of tendon reflexes, conservation of cutaneous reflexes. The plantar reflex occurred in this case always in flexion which was interpreted by Dejerine to mean that the pathologic extension reflex of the great toe was not conditioned solely by pyramidal tract degeneration, but for its production an intervention of superior centers was necessary, such as cortical, subcortical and mesencephalic centers.

Observations of Dejerine and Mouzon⁹ covered seven cases: in all but one, absence of tendon reflexes. Preservation of defense reactions and cutaneous plantar reflex. This plantar reflex was in flexion confirming Dejerine in his previous notion of the supermedullary factor in the production of the extension reflex of the great toe. Report of a further patient (Case 10) presenting crossed defense reflex reactions.

5. Henneberg: *Charité—Ann.*, **31**:161, 1907.

6. Kausch: *Mitteilung aus den Grenzgebieten der Med. u. Chir.*, **7**:541, 1901.

7. Jolly: *Neurol. Centralbl.*, **21**:334, 1902.

8. Dejerine and Long: *Soc. de Neurologie, Seance du 12, Decembre, 1912, Rev. neurol.*, **24**:769, 1912.

9. Dejerine, James A., and Mouzon, J.: *Sur L'Etat des Réflexes dans les Sections Completes de la Moelle Epinière, Rev. neurol.*, **28**:155, 1914-1915, *ibid.*, 201.

Observation of Gustav Roussy:¹⁰ Total destruction in the region of the lumbar enlargement of cord in two cases. Flaccid paraplegia with anesthesia and loss of defense reactions and cutaneous reactions.

Observation of Claude and Petit¹¹—three cases: Absence of all reflexes, complete anesthesia below the lesion. The longest duration of life after injury was one month and three days.

Observation of Claude and Lhermitte:¹² Destruction at the eleventh dorsal segment. Duration of life after injury, 136 days. Preservation of tendon and skin reflexes. The plantar reflex was in extension, but later changed to flexion.

Observation of Guillain and Barre¹³—fifteen cases: Longest duration of life was forty-one days—in most of the cases, considerably shorter. In all but one, loss of tendon reflexes, plantar reflex, flexion of great toe. Defense reactions present in but three cases.

Observation of Head and Riddock¹⁴—eight cases: Divides the course which the cases run into three stages: 1. Stage of flaccidity. 2. Stage of reflex activity. 3. The stage of gradual failure of reflex functions. The contents of the bladder and rectum may be voided automatically. A widespread reflex action consisting of flexor spasm of lower extremities, abdominal wall, evacuation of bladder and sweating is designated as "mass reflex" in complete section. The flexor muscles in all phases show more tone than do their antagonists. Comparing the manifestations of complete and incomplete lesions, the authors state that there are no manifestations by which we can be certain that the spinal cord has been anatomically divided. But certain manifestations were found in incomplete lesions, not occurring in complete lesions; of such, noteworthy were the difference in character of flexor responses as compared with the "mass reflex"; a slower relaxation phase in the knee jerks; no obvious tonus difference in flexor and extensor groups; and especially the presence of extensor responses designated as postural reflexes, dependent on the integrity

10. Roussy, Gustav: Deux Cas de Section de la Moelle par Plaie de Guerre suivis d'Autopsie, Soc. de Neurologie, Seance du 5, Novembre, 1914, Rev. neurol., **28**:206, 1914-1915.

11. Claude et Petit: Trois cas de Section Complete de la Moelle Epiniere par Balle, Soc. de Neurologie, Seance du 3, Decembre, 1914, Rev. neurol., **28**:217, 1914-1915.

12. Claude et Lhermitte: Les Reflexes Tendinaux et Cutanes, les Mouvements de Defense et d'Automatisme dans la Section Totale de la Moelle d'apres une Observations, *Anatomo-Clinique Ann. de med.*, **3**:407, 1916.

13. Guillain et Barre: Etude Anatomo-Clinique de Quinze Cas de Section Totale de la Moelle, *Ann. de Med.*, **4**:178, 1917.

14. Head and Riddock: The Reflex Functions of the Completely Divided Spinal Cord in Man, Compared with Those Associated with Less Severe Lesions, *Brain*, **40**, Parts 2-3, 1918.

of certain descending propriospinal paths. Examples are homolateral or bilateral extension of the lower extremities by stimulation of upper receptive fields or by gently pressing on the sole when the limb is passively flexed (extensor thrust). Further, in these cases of incomplete division, muscular action of the ipsilateral limb is diphasic in character (flexor and extensor) as compared with the undiphasic type (flexor) as seen in complete lesions. In certain cases of incomplete lesions the action is comparable to the steppage movement of the spinal dog. Tonus of all the muscles is constantly below normal in the resting state after total transection.

Two important articles on spinal injuries in warfare have recently appeared by Holmes and by Collier. Gordon Holmes¹⁵ is of the opinion that in total transverse lesions of the cord the knee and ankle jerks are probably permanently absent. Preservation of tone in the muscles is an indication that some improvement may be expected. The amount of reflex movement obtained by stimulation of the soles varies more or less inversely with the severity of the injury. In less severe lesions, in the early stages, he speaks of a unisegmental reflex of flexion of the toes, or flexion of the toes associated with contraction of the hamstrings by stimulation of the receptive field of the first sacral segment in the sole.

James Collier¹⁶ postulates four consecutive stages of plantar reflexes following a transverse cord lesion: "1. An initial extensor response. 2. Either a complete absence of any reflex which may be the result of shock or of isolation alteration, or a reduced flexion reflex which is the result of isolation alteration coming on rapidly. 3. The extensor response which when persistent is indicative of a less severe lesion or alternatively of more recovery than the reduced flexion reflex. 4. The normal reflex which returns when recovery is complete."

COMMENT

The case reported in this paper is a striking example of spinal automatism after cord transection. It is noteworthy particularly because of the following considerations:

1. Long duration of life (patient is still alive, September, 1918).
2. Persistence of the extensor toe reflex.
3. Exaggerated patellar and ankle jerks.
4. Patellar clonus.
5. Automatic bladder and rectum.

15. Holmes, Gordon: Goulstonian Lectures, *Brit. Med. Jour.*, **2**:769, 815, 855.

16. Collier, James: Gunshot Wounds and Injuries of the Spinal Cord, *Lancet*, London, **1**:711, 1916.

6. Preserved muscle tonus of normal or increased degree. This state of tonicity is emphasized by the constant tendency to extension of the great toes in the resting stage, there being no contractures or joint complications present.

7. Presence of extensor as well as flexor responses in the same extremity. Head and Riddock report contralateral extensor responses accompanying flexor movements in one extremity. Such contralateral responses, although not searched for, were not noted in this case.

8. Concomitant flexor and extensor responses of unequal intensity in the muscles of the same extremity. This observation would be in opposition to the theory of reciprocal innervation of antagonistic muscles. Tilney has recently stated (personal communication) that in physiologic experimentation, myographic tracings of flexor and extensor groups of an extremity when the whole limb is set into action appear to throw some doubt on the correctness of this theory.