THE BABINSKI RESPONSE : A REVIEW AND NEW OBSERVATIONS

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REVIEW OF THE ANATOMICAL EVIDENCE

Probably the most famous sign in clinical neurology is the plantar response described by Babinski. Babinski wrote that this sign indicates a disturbance of function of the pyramidal system. Textbooks usually state, however, that this sign indicates a lesion of the pyramidal tract, and so one might well imagine that the significance of such a well established sign had been amply proved.

There are four points concerning the Babinski response that need to be stressed :

(1) Babinski stated that his sign "paraît être" ; he was not definite about the matter.

(2) Babinski eventually described two forms of abnormal plantar response. These are separate and clearly different. There is "Extension des orteils et plus particulièrement du gros orteil : j'ai appelé ce mouvement 'le phénomène des orteils', et mes collègues ont bien voulu le dénommer 'le signe de Babinski' (1904). There is also : "L'excitation de la plante du pied provoque parfois, entre autres mouvements réflexes, une abduction plus ou moins marquée d'un ou de plusieurs orteils" (1903). Although Babinski observed that the latter sign can be found in the normal, it is particularly common in subjects "atteints d'une perturbation du système pyramidal". Dupré named this sign, "le signe de l'éventail". It is usual, at least here in Britain, to speak of the Babinski response only when both these signs are present. But many workers consider the extension of the great toe as the essential sign, and speak of the Babinski response when only this sign is present.

(3) The phenomenon was described as a disturbance of functioning. Babinski at first held the opinion that there need be no anatomical or histological lesion of the pyramidal tract to account for the presence of this sign. Indeed, he recorded the presence of the sign in a case of strychnine poisoning ; when the poisoning passed off, the abnormal sign gave way to the normal response. Babinski thought that the sign could be the first and only evidence of this disturbance in functioning. Thus

it did not seem to Babinski that it was necessary to give any histological verification of damage to the pyramidal tract. As he said later (1922), he was content "à se cantonner dans le domaine de l'observation clinique".

(4) It is clear that Babinski used various methods of stimulation to obtain the response. In his original description of extension of the toes (1896), he described the stimulus as a "piqûre de la plante du pied". In his more detailed and important communication on the new sign (1898), he wrote of the effects of stimulating the internal part and the external part of the plantar surface. And he also wrote that in some subjects it is necessary to prick the plantar surface of the foot to elicit his reflex.

Babinski's sign met with immediate success ; and as an additional sign of hemiplegia and crural monoplegia it deserved the success. This was doubtless what Babinski intended the new sign to be ; for in his time terminology was less precise than it is now. It is likely that to Babinski the terms "a sign of hemiplegia" and "a disturbance of function of the pyramidal tract" were equivalent. However, when anatomical evidence presented itself, it began to be obvious that Babinski's statements were wrong. Babinski himself reported cases which did not accord with his previous statements. For instance, in 1899, he reported three cases of paraplegia in flexion. He stated that in all three there was no histological evidence of degeneration of the pyramidal tract. Yet in the first case, the plantar responses were normal, in the second case, the "phénomène des orteils" was present, and in the third case "tickling the plantar surface of the foot gives reflex movements of the whole limb". As Babinski was concerned in this paper with demonstrating that there is such a thing as paraplegia in flexion without involvement of the cortico-spinal tracts, he seems to have failed to realize that he had recorded different forms of plantar response, one of which was the Babinski response, all present with normal cortico-spinal tracts. On his own premises, his Case 2 proved his supposition

about the significance of "le phénomène des orteils" to be wrong.

By 1911 Babinski had come to the conclusion that paraplegia in extension with increased deep reflexes is due to involvement of the cortico-spinal tracts, and that paraplegia in flexion is due to involvement of other tracts, the cortico-spinal tracts being normal or almost normal. In support of his view of the mechanism causing these two forms of paraplegia, he stated (1911) that paraplegia in extension is always accompanied by the Babinski response, whereas paraplegia in flexion is usually accompanied by this response, but can occur with a normal response. It is obvious that on his premises paraplegia in flexion should always show a normal response, for Babinski expressly stated that in this condition there is normal or almost normal functioning of the pyramidal tract. In 1912(b) he wrote that in the condition of paraplegia in extension, the "signe des orteils" is present; and in the condition of paraplegia in flexion "dans la grande majorité des cas, le signe des orteils" is also present. Thus it will be observed that he has described the Babinski response in two conditions, in one of which the pyramidal tracts are said to be abnormal and another in which they are said to be normal.

As Babinski collected anatomical evidence, he should have been forced to the conclusion that his sign was not related to the normality or abnormality of the cortico-spinal tract. It becomes clear why he preferred to remain in a "realm of clinical observation". He never modified his original suggestion about the significance of his sign, and never pointed out that histology failed to support the belief that the sign indicates a disturbance of the cortico-spinal tract. It is also clear from remarks that he made in discussions, reported over the years in the *Revue Neurologique*, that he forgot the evidence he had himself produced in earlier years; he would state that with paraplegia in flexion his sign was absent, and with paraplegia in extension it was present. Finally, it is justified to point out that as neither Babinski nor any of us know what the function of the pyramidal tract is, it is impossible to discuss a perturbation of that function.

Following Babinski's original description, many papers appeared in Europe and America devoted to the new sign. As none of the authors of these papers investigated the location and extent of the lesions at post-mortem examination, these papers will not be reviewed. A glance, however, at the first paper in English describing the new sign shows how errors creep into the neurological literature. Collier (1899) examined 100 normal adults, 100 normal children, and 300 cases of nervous disease;

he had no post-mortem evidence. Nevertheless the fact that he had no evidence did not prevent him making such a statement as "According as the lesion of the pyramidal system be partial, the flexor and extensor responses may be combined in the plantar response". Collier seems to have been the first to introduce the term flexor response for the normal response, and extensor response for the Babinski response. Collier's also seems to have been the first paper in which the common perversion of Babinski's statements is made; for he wrote that "Babinski found" that this reflex was "pathognomonic of a lesion of the pyramidal system"; "paraît être" has become "pathognomonic", and "perturbation dans le fonctionnement" has become "a lesion"; it is likely that most readers would understand under the term "a lesion", an anatomical lesion; indeed, this interpretation of the term was soon used by the writers of textbooks.

The literature of those cases in which histological examination of the central nervous system was carried out will now be considered in two parts. First, there will be reviewed those papers that are devoted to this sign. Secondly, cases and papers will be mentioned which have been noted during general reading of neurological literature. The authors of this material have mentioned the presence or absence of Babinski's sign *en passant* and have presented post-mortem evidence showing the location of the lesion. But these authors have not been primarily concerned with this sign; most of them have inadvertently provided the evidence on which the relationship between the sign and the location of the lesion could be determined.

Harris (1903) devoted a paper to the Babinski response; in his third case of hemiplegia there was a frontal glioma "pressing on the pyramidal fibres in the corona radiata"; the contralateral plantar response had been abnormal but it was not the Babinski response.

The next authors to correlate Babinski's sign with post-mortem findings seem to have been Potts and Weisenburg (1910). They showed a case of a tumour "situated in the upper portion of the pre-central convolution"; it primarily involved the face and upper limb, and only eventually involved the lower limb. As long as the tumour interfered with tracts supplying the face and upper limb, the plantar response was normal. As the tumour grew, "there was first present an increased patellar jerk, then hypertonicity of the whole limb with hyperextension of the great toe, and finally the Babinski response appeared". This case thus showed that the lesion has to involve that part of the tract mainly supplying the lower limb in order to get the Babinski response.

In 1912 Dejerine and Long demonstrated in Paris the histological findings in a case previously reported by Dejerine and Lévy-Valensi (1911). The patient had been an acrobat, aged 17, who had lived for 10 weeks after falling on the back of his neck; the fall had caused a complete transverse lesion of the cord at the seventh cervical segment. During life the patient had shown absence of the deep reflexes of the lower limbs, with normal cremasteric, abdominal, and plantar reflexes. The authors were well aware of the importance of their case in providing evidence concerning the plantar responses; the subsequent discussion reported in the *Revue Neurologique* is very important. Dejerine and Long stressed that throughout the patient's life following his fall the plantar reflexes were normal in all respects and were easily obtained. After death it was found that there was complete and total degeneration of the cortico-spinal tract, in both its lateral and ventral components. "Ce fait prouve que le signe des orteils n'est pas conditionné seulement et uniquement par la dégénérescence du faisceau pyramidal." In the ensuing discussion, Felix Rose (1912) reported a case with a complete lesion of the cord at the third thoracic segment; in this case the cremasteric and abdominal reflexes were absent, and both plantar reflexes showed the typical Babinski response. At this meeting the important fact was pointed out by Sicard (1912) that during the course of paraplegia the reflexes often changed. Babinski (1912a) was present at the meeting, and reported in the discussion that he had seen a case in which there was an apparently complete lesion at the seventh thoracic segment, and the plantar responses were normal. Later Babinski (1912b) quoted Dejerine and Lévy-Valensi's case in support of his contention that the "réflexe de défense" may be associated with a normal plantar response or with the Babinski response; but he did not mention that this case proved his interpretation of the relation between the cortico-spinal tract and the abnormal plantar response to be wrong.

The experience of the first world war soon showed that the Babinski response was frequently not found with proved total division of the cortico-spinal tract. The Dejerines and Mouzon (1914) reported two cases with necropsy confirmation of complete transverse lesions of the spinal cord; neither showed the Babinski response. They emphasized that the usual reflex in such cases of total division of the cord is "la flexion plantaire du gros orteil. Le fait que dans les sections complètes de la moelle épinière la réaction à l'excitation de la plante du pied se traduit habituellement par la flexion plantaire du gros orteil, montre que, pour

conditionner le signe des orteils, il faut autre chose que la dégénérescence du faisceau pyramidal". In 1917, Guillain and Barré reported 15 similar cases, in all of which the total division of the cord was proved after death; although the plantar responses were abnormal, they were not of the type described by Babinski.

It is sometimes stated that the removal of the function exercised by area 4 of Brodmann causes the Babinski response to appear. However, Papez and Vonderahe (1947) reported the case of a man who showed no pathological reflexes during his life. After his death it was found that area 4 was absent, and "there was a complete absence of the cortico-spinal (pyramidal) tract on the left side".

There are two series of cases which are important although there was no necropsy evidence provided by the authors. Hyndman (1941) performed cordotomies for the relief of pain, under local anaesthetic; from sensory testing during the operation he was able to show where in the cord he had made the incision. He was led to conclude: "In all cases of complete bilateral cordotomy, in which the anterior and anterolateral columns were sectioned, so-called signs of upper motor neuron involvement (hyperactive knee and ankle jerks, patellar and ankle clonus, and Babinski's sign) did not develop." He considered that the lateral cortico-spinal tracts would often be "partly injured, if only by transient oedema," yet "the expected signs of upper motor neuron involvement did not develop". Of great importance are those cases in which it was the purpose to divide the lateral cortico-spinal tract as therapy for severe Parkinsonism. Oliver (1953) in *Parkinson's Disease and its Surgical Treatment* reports the state of the plantar response in many such cases. The common consequence of this operation is the Babinski response, but it is far from being invariable. Oliver obtained a normal response in four cases, no response in one case, and an equivocal response in three cases; in one case a Babinski response later became equivocal; in one case, after dividing the lateral cortico-spinal tract on one side, he obtained a bilateral Babinski response; and in one case, after dividing the right cortico-spinal tract in the cord, he obtained a normal response in the right foot with a Babinski response in the left; one year later the response on the right had become a Babinski response. To be set over against these variations, there was the typical Babinski response ipsilaterally following 30 divisions of the tract in the cord.

Further information can be obtained—as has been mentioned above—from that literature

where the sign was mentioned *en passant* and where necropsy and histological evidence was available. This material will be divided into three groups: (1) cases with severe lesions of the cortico-spinal tracts and with the Babinski response; (2) cases with severe lesions of the cortico-spinal tracts and with the normal response; (3) cases with normal cortico-spinal tracts and with the Babinski response.

(1) It may seem curious to start this list with a case reported by Babinski himself. For this is a list of those cases found in the literature in which the authors did not pay attention to the correlation of the histological lesion and the plantar response. Yet in 1902 Babinski and Nageotte reported the case of a syphilitic with multiple gummata and thrombosis of the basilar artery. There was a Babinski response on the right; "le faisceau pyramidal est altéré dans toute la hauteur de la moelle". Babinski did not realize that this was the first evidence he had brought forward that his sign was related to a disturbance of the pyramidal tract.

In 1903 Marie and Guillain reported a case with an enormous lesion of the left hemisphere in the distribution of the middle cerebral artery; there was a contralateral Babinski response. Lewandowsky (1905) reported a similar case with a lesion affecting the whole cortico-spinal tract; here again there was a contralateral Babinski response. Kattwinkel (1907) reported a case with bilateral Babinski responses associated with bilateral cortico-spinal sclerosis. Gierlich (1910) reported a case of monoplegia due to a cerebral thrombosis; the cortico-spinal tract was degenerate and there was a Babinski response. Davison, Goodhart, and Savitsky (1935) reported a case of occlusion of the left superior cerebellar and left middle cerebral arteries; there was demyelination of the cortico-spinal tract and the patient had shown a Babinski response. Davison in 1937 reported two cases of occlusion of the uppermost portion of the anterior spinal artery; both had Babinski responses with involvement of the cortico-spinal tracts. Putnam in 1940 introduced the operation of cutting the lateral cortico-spinal tract as therapy for Parkinsonism; he obtained a Babinski response. In 1944 Davison reported two further cases of thrombosis of the anterior spinal artery in the medulla; they also showed involvement of the cortico-spinal tracts and Babinski responses. In 1954 Siekert and Sayre reported a case of thrombosis of the basilar artery; at necropsy they found a large lesion involving at least half the pons, including its medial part; it undoubtedly destroyed the great majority of the cortico-spinal fibres; there was a bilateral Babinski response.

(2) In 1907 Roussy published two cases in which there was no Babinski response; in both of them there was degeneration of the cortico-spinal tract.

(3) In 1929 Mathieu and Bertrand published their classical paper on cerebellar degenerations. It contains the following two cases. In the case of Mme. Lec. there was "un état de contracture et d'hypertonie généralisée, mais prédominant aux membres inférieurs"; on the right there was a Babinski response and on the left there was also a Babinski response, but it was "moins nette"; histological examination showed: "Les voies pyramidales directes et croisées sont intactes, sauf une atteinte légère à droite du segment antero-externe de la voie pyramidal croisée", in the cord; in the peduncle the cortico-spinal tracts were normal. In the case of Mme. Quer. both plantar responses were of the Babinski type; both cortico-spinal tracts were normal throughout.

In 1938 Waggoner, Löwenberg, and Speicher, reported a case of hereditary cerebellar atrophy. "There was a Babinski response bilaterally . . . the pyramidal tracts, both direct and crossed, were well-preserved."

Lassek (1945) has also reviewed the subject of the Babinski response. He collected cases reported in the *Archives of Neurology and Psychiatry* (Chicago), the *Journal of Nervous and Mental Disease*, and *Brain*, but he had no post-mortem evidence of the nature of the lesions.

Finally, it is essential to know whether the Babinski response ever occurs in the normal. Babinski wrote that abduction of the toes can occur in the normal; he believed that extension of the big toe never occurs in the normal. This question may now be regarded as settled by Davidson (1931), Yakovlev and Farrell (1941), and Morgenthaler (1948). Davidson examined 130 adults under usual clinical conditions. He came to the conclusion that "extension of the toes, even of the big toe, is compatible with a normal motor system", but what is pathological is "isolated extension of the big toe with fanning of the other toes". Yakovlev and Farrell examined soldiers before and after marching 14 miles: 7.2% of them developed extension of the big toe on one side, 1.2% bilaterally. One conclusion from this paper, which the authors do not draw, is that isolated extension of the big toe is an insufficient index of abnormality. It is for this reason that many neurologists speak of the Babinski response only when there is extension and fanning of all toes.

Morgenthaler (1948) examined 200 schoolchildren taken off a playground. He found that extension of the big toe alone occurs in 1.5% (± 0.5), and spreading of the toes occurs in 7.5% (± 2.5). He agreed with

Davidson that the combination of extension of the big toe with fanning of the other toes never occurs in the normal.

If we now sum up the findings from the literature, the following facts become clear :—

(1) Babinski did not at first claim that his sign indicated an anatomical lesion of the pyramidal tract.

(2) He at first claimed that it indicated a "perturbation dans le fonctionnement" of this tract. However, it is unclear what Babinski meant by the function of a tract. Within the present state of knowledge of the physiology of the nervous system, the term could only be vague when applied to any tract, unless it is clearly defined on each occasion; in relation to the cortico-spinal tract, agreement would not be reached concerning the function of this tract. Further, if anatomical evidence does not show a specific relation between the cortico-spinal tract and the Babinski response, there is no basis for the conjecture that there is a physiological relation between the type of response and the function of the tract.

(3) Babinski knew that his sign could be absent when the spinal cord was totally divided. He never stated that complete removal of the influence of the cortico-spinal tract does not necessarily give his sign. Although this removes the validity of his original statements, he never retracted them.

(4) Extension of the toes, even of the big toe, on plantar stimulation, is compatible with a normal motor system; isolated extension of the big toe with fanning of the other toes is an abnormal sign, and indicates abnormality of the central nervous system.

(5) Cases have been reported in which there were histological lesions of the cortico-spinal tract and in which there was no Babinski response.

(6) In cases of complete division of the cord, there may be a normal plantar response, a Babinski response, or various forms of plantar response. Moreover, the kind of response may change with time; it often changes within a few days of the infliction of the lesion, and within a few days of death; but it may change also weeks or months after the infliction of the injury and weeks or months before anaemia, uraemia, or death arrive.

(7) The Babinski response may appear in normal people during hypoglycaemia, during general anaesthesia, and after the injection of hyoscine; it can occur in epileptics during or after the fit; it can occur in the normal during sleep.

All these satisfactorily established facts, although some of them are well known to neurologists, do not seem to have entered the corpus of medical or

neurological teaching. It can be pointed out, however, that there never has been a correlation of this sign with histological evidence of the state of the central nervous system performed in an adequate number of cases. To fill this gap, we present our evidence.

NEW OBSERVATIONS

Material and Methods

The material of this investigation consists of patients examined before and after operations on the spinal cord. After death, the brains and cords were removed and examined histologically. Transverse sections of the cords in the region of the operation are presented here in the form of diagrams. The reasons for showing diagrams rather than photographs are the ease with which one case can be compared with another, and the fact that in some cases the angle made by the knife at operation is not a right angle to the long axis of the cord, and so no true view of the maximal area of damage is given by one photograph. The case numbers are those used throughout our series of cases, and so the diagrams may be compared with photographs of the cords given in our other papers. A photograph of a transverse section from the lumbar cord of one case from each group has been included, to show the extent of the descending degeneration.

All the patients whose cords are shown died from cancer; in none of them did the cancer involve the central nervous system. A control group of eight patients dying of cancer was also examined during life and after death histologically; none of these patients had abnormal plantar responses and none of them showed degeneration of tracts in the cord. Being normal in all the respects that concern us here, the patients of this control group will not be mentioned again. All the patients of the main series had various forms of cordotomy designed for the relief of pain. The operations were performed by various neurosurgeons working in London; most of them were done by Mr. Wylie McKissock. It is to be stressed that for the relief of pain the lesions are not usually made of such an extent as some of those shown here. The cases with most extensive lesions are relevant to the subject under consideration, and it is particularly these cases that are presented here.

This material can be used only to answer questions concerning the relation of the plantar response to histologically demonstrable changes in the tracts of the spinal cord. No lesions of tracts in the brain have been included, and no reference is made to cases of total transverse cord lesions.

In all patients, the observations on the plantar responses were made before and after cordotomy; thus the observations during the period before the operation form a control for the type of plantar response observed after operation. All the observations were made by one person. The patients were examined when they were warm in bed. They were lying on their backs with the trunk slightly flexed, and the lower limbs slightly flexed

at the hips, and loosely extended at the knees. One hand of the examiner was placed on the dorsal surface of the ankle, while the other manipulated the instrument for stroking the plantar surface. No force was applied to the knee to prevent it flexing, if this tended to occur. The instrument used was a Yale key or the writing end of a pencil. It was dragged along the plantar surface of the foot from the lateral part of the heel, along the lateral part of the plantar surface of the foot, stopping at the metatarsal head of the little toe. The plantar response was regarded as normal when there was flexion of the big toe, with or without flexion of the other toes. The plantar response was described as the Babinski response when there was extension of all the toes, with at least a slight degree of fanning. Variations and other observations on reflexes will not be given here; for the purpose of this paper is to correlate the lesion in the central nervous system with the sign as elicited by clinicians during their routine examination of patients. The kind of response found during the first 24 hours after the operation and during the period when the patient was clearly moribund will not be mentioned; thus the plantar response given here is that found between these episodes. This period after the operation and before death varied between three weeks and 14 months. In all cases shown here, histological examination of the spinal cord and brain was carried out; and so the exact extent and position of the lesion are known.

Results

In the diagrams the area blocked in represents the maximal area of damage; it is the area of the operation, and shows the extent of the lesion made by the knife. In this area there are no normal fibres; the region left unshaded is normal histologically. The material is divided into six groups.

Group I: Babinski Response.—This group contains those cases where there was the typical Babinski response and damage to the lateral cortico-spinal tract. The operation areas are shown in Fig. 1 in Cases 5, 53, 34, and 22. The descending degeneration in the lumbar region in Case 5 is

FIG. 1.—Diagrams of operation areas of spinal cords of patients showing the Babinski response.

shown in Fig. 7. In these patients, the plantar response remained the typical Babinski response from 48 hours after the operation till death.

Group II: Normal Response.—This group contains those bilateral cases where the plantar response was consistently normal for several weeks after the operation. From this group it can be seen how extensive a lesion of the cord can be and normal plantar responses be retained. The operation areas are shown in Fig. 2 in Cases 4, 10, 1, 6, and 3; in

FIG. 2.—Diagrams of operation areas of spinal cords of patients showing the normal plantar response.

Case 6 the lesion involved the lateral cortico-spinal tract on both sides. It is striking how similar the lesion was on the two sides, and yet on the left there was a normal plantar response and on the right there was the Babinski response. Case 3 is the most striking in this group, for the lesion involves a great deal of the lateral cortico-spinal tract. This is amply confirmed by tracing descending degeneration, yet the plantar responses remained normal for four and a half months after the operation; they changed to the Babinski type 14 days before death. The descending degeneration in the lumbar region in this case is shown in Fig. 7.

Group III: Babinski Response.—In this group are placed three selected bilateral cases in order to bring out further points. In these patients the plantar response was persistently of the Babinski type. The operation areas are shown in Fig. 3. In Case 52 it will be seen that the lesions are not large and that not much of the lateral cortico-spinal tract has been involved. In Case 33 it will be seen

FIG. 3.—Diagrams of operation areas of spinal cords of patients showing the Babinski response.

that the lesion scarcely involves the lateral cortico-spinal tract. In Case 19 the response was persistently of the Babinski type on both sides for the survival period of four months. The slight amount of descending degeneration in the region of the lateral cortico-spinal tracts in Case 33 is shown in Fig. 7.

From this group we see that the Babinski response can be associated with histological lesions which scarcely involve the cortico-spinal tracts.

Group IV: Varying Response.—In a fourth group are placed two categories of bilateral cases: those in which the plantar response was neither normal nor of the typical Babinski type and those in which the type of response changed during the period of survival. The operation areas are shown in Fig. 4. In Case 7 at first the plantar response on

FIG. 4.—Diagrams of operation areas of spinal cords of patients showing varying plantar response.

the right was normal, but after 10 days it changed to the Babinski type. In Case 21 at first the response on the right was normal and there was no response on the left; 44 days after the operation the response on the right became diminished, and there was definite extension of all the toes but no fanning; that on the left was the Babinski response. The descending degeneration in this case is shown in Fig. 7. In Case 47 at first the response on the right was normal, although it needed firmer pressure than usual to bring it out; the response on the left was of the Babinski type.

Group V: Normal Response.—In this group is placed a selection of cases with large unilateral

FIG. 5.—Diagrams of operation areas of spinal cords of patients showing normal plantar response.

lesions. In all the patients the plantar response was normal. The operation areas of Cases 37, 39, 40, and 44 are shown in Fig. 5; it will be noted that in the latter the anterior cortico-spinal tract is completely divided. In this group it is seen that all the lesions are large. In Case 37 the lesion is so deep that it involves the grey matter and also extends posteriorly so as to involve the anterior part of the lateral cortico-spinal tract. The descending degeneration in this case is shown in Fig. 7. From this group we see that large unilateral lesions, involving part of the lateral cortico-spinal tract and the entire anterior cortico-spinal tract, may be associated with a normal plantar response.

Group VI: Two Operations.—Two patients are placed in this group, as both had two cordotomies; at first one side of the cord was operated on and later the other side. The results of these two operations on the plantar responses were unexpected. The operation areas are shown in Fig. 6;

FIG. 6.—Diagrams of operation areas of spinal cords showing changing plantar responses.

relevant parts of the history of these two patients follow.

Case 38.—After the operation on the right side of the cord, the left plantar response became of the Babinski type, whereas the right was more like the normal than like the Babinski response, although the toes did not readily plantar flex. But within a fortnight the left plantar response had become normal, and the right had changed definitely to the Babinski response. The left plantar response remained normal, until all response was rendered impossible owing to carcinomatous involvement of the sciatic nerve. Following the second operation, this time on the left side of the cord, the right response changed from the Babinski type to the normal.

Case 32.—After the operation on the right side of the cord, both plantar responses were normal. However, 14 days after the second operation had been done on the left side of the cord, the right plantar response changed to the Babinski type, and remained of this type till the patient's death. The left remained normal, until it eventually became unobtainable due to involvement by cancer of the peripheral nerves in the left wall of the pelvis. There was no involvement of the nerves running to the right lower limb. The descending degeneration in this case is shown in Fig. 7.

The fact that after an operation on one side of the cord the plantar response on the other side changed to

the Babinski type for a fortnight may indicate that the amount of trauma involved is enough to cause the response to be of the Babinski type. But when the tissue reaction has subsided, that is to say, 14 days after the operation, the plantar response of the operated side changed to the Babinski type. This response became normal after the opposite side of the cord had been incised.

FIG. 7.—Photographs of transverse sections of the lumbar cord taken from one case in each group. In Cases 5 and 3 the photographs are from Weigert Pal preparations, in all the other cases they are from Marchi preparations.

It is clear that lesions of the spinal cord may or may not cause a Babinski response. From cases like Case 32 and Case 38, it seems that conclusions regarding the actual tract involved by a lesion cannot be drawn from the form of the plantar response.

Conclusions

From our evidence we are led to conclude that the Babinski response may accompany large lesions of the anterior half or more of the cord, the lateral cortico-spinal tracts remaining intact. It may also accompany total lesions of the lateral cortico-spinal

tract. Our evidence also leads us to conclude that the normal plantar response may occur with large lesions of the anterior half or more of the cord, and it may also accompany extensive lesions of the lateral cortico-spinal tracts.

If we go into further detail we note that small lesions, such as those shown in Fig. 3 (Case 52), or superficial lesions such as those shown in Fig. 3 (Case 33), may be associated with the Babinski response.

Although it may be surprising that such small anterior and antero-lateral lesions can be associated with the Babinski response, it is perhaps to be expected. For it is well known that this response can be caused by hyoscine, alcohol, fatigue, or cerebral anoxia. It is clear that it does not need much trauma of any kind to bring about this pathological response. Any operation on the cord might constitute such trauma. Indeed, we have had one case in which a bilateral Babinski response followed a unilateral cordotomy, and cases where, following an operation on one side of the cord, the Babinski response occurred on the opposite side of the body. Of greater interest perhaps are those cases in which there were persistently normal responses. Most extensive lesions of the cortico-spinal tract are shown in Fig. 2 (Case 3); this patient had normal plantar responses bilaterally for many months after the making of these lesions.

It is instructive to compare the lesions of the cases of the different groups. Thus the lesions shown in Fig. 1 (Case 34) are similar to those shown on the left side of Fig. 2 (Case 6) and the right side of Fig. 5 (Case 40); and yet in Case 34 there were always Babinski responses, and in Case 6 the response was always normal, and in Case 40 the response was normal for three months after the operation. Similarly the lesion on the right side of Fig. 1 (Case 53) is similar to that on the right side of Fig. 6 (Case 32), and yet in the former patient there was always a Babinski response and in the latter patient the response was normal for six weeks after the operation. It is striking to note how in Fig. 2 (Case 6) the lesion on the left side of the cord is more extensive and involves more of the lateral cortico-spinal tract than that on the right side of the cord; and yet the former lesion was associated with a normal plantar response, and the latter with the Babinski response. The lesions shown in Fig. 3 (Case 19) bilaterally were less extensive than those shown in Fig. 2 (Case 4); in the former patient there was a bilateral Babinski response and in the latter a normal response bilaterally. And the lesion shown in Fig. 3 (Case 52) on the left side was associated with a Babinski response whereas that

shown on the right side of Fig. 6 (Case 32) was associated with a normal response for several weeks.

Thus a comparison of the various lesions of this series lends little support to a belief that there is a particular relationship between the lateral cortico-spinal tract and the plantar response.

A comparison of the cases having unilateral lesions with those having bilateral lesions immediately shows the following: a unilateral lesion can be large and associated with a normal plantar response whereas a small bilateral lesion may be associated with the Babinski response.

It is certainly necessary to justify the taking out from the gamut of signs one particular reflex response and discussing it divorced from the other manifestations of neurological functioning. The reason for doing this is that this sign is often used just in this manner. When the response is the Babinski response, physicians are accustomed to believe that there is a disorder (if not a gross anatomical lesion) of the cortico-spinal tract, and when the plantar response is normal they are ready to assume that the cortico-spinal tract must be normal.

The plantar response was considered by Fulton and Keller (1932) in great detail in their book *A Study of the Evolution of Cortical Dominance in Primates*. They came to the conclusion: "It is justifiable to conclude that in the higher primates the sign of Babinski is associated with isolated destruction of the pyramidal pathways." In view of our evidence we cannot support this statement. We would say: "The Babinski response may be associated with no histological lesion, or it may be associated with lesions in many parts of the spinal cord." Fulton and Keller continue: "There are cases in the literature in which the sign was said to be present in the absence of injury to the cortico-spinal pathways, but in none of these instances has there been decisive anatomical evidence of the integrity of the pyramidal system." We would like to suggest that this series of proved lesions has now provided such anatomical evidence.

It is well established that the normal plantar response can occur in total division of the spinal cord; experience has also taught one that even if the normal response is not obtained, other forms of plantar response, which are not the Babinski response, are often found in such cases. A spinal cord, or the caudal part of a spinal cord, which is functioning independently, cut off from its normal relation to the rest of the central nervous system, may not be compared to a spinal cord in which certain tracts are divided and other tracts intact. To regard the Babinski response as a spinal reflex whose manifestation is prevented by the functioning

of one, and only one, descending tract, is an oversimple conception of neurophysiology.

SUMMARY

An account is given of Babinski's contributions to the study of the normal plantar response and the response named after him.

The literature correlating the normal plantar response and the Babinski response with the state of the cortico-spinal tract (as shown histologically) is reviewed and summarized.

A correlation of the plantar response with proved lesions of the spinal cord is presented. This material consists of 38 cases of antero-lateral cordotomy.

It is concluded that any lesion of the lateral and ventral columns of the cord may, or may not, cause the Babinski response; that conclusions cannot be drawn with regard to the tract involved when the Babinski response is found; that the Babinski response is often found with histologically normal cortico-spinal tracts; that a lesion of one side of the spinal cord may be associated with a Babinski response on the opposite side of the body; that lesions of the anterior half of the spinal cord may accompany the Babinski response; that apparently identical lesions on the two sides of a spinal cord may be associated with a normal plantar response on one side and a Babinski response on the other; that small bilateral lesions of the cord are more likely to cause a Babinski response than large unilateral lesions.

This may be summarized by the statement: there is no particular relation between the anatomical state of the cortico-spinal tracts and the form of the plantar response.

The Babinski response is a pathological response; it may be taken as an indicator that there is an abnormality of function in the central nervous system.

Patients 4, 6, 19, 32, 33, 34, 37, 38, 39, 40, 44, and 47 were in the National Hospital. Their hospital case numbers were respectively 31751, 18299, 16162, 29786, 30036, 32673, 41002, 36799, 14334, 39150, 17537, and 35455.

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