OBSERVATIONS ON REFLEX CHANGES IN THE LOWER LIMBS IN SPASTIC PARAPLEGIA IN MAN

BY

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Since Babinski (1911) published his observations on spastic paraplegia, it has been customary to divide the condition into two types, paraplegia-in-flexion and paraplegia-in-extension, according to which muscles, flexor or extensor, had an excess of tone. When tone predominated in the flexor muscles, the hip and knee became flexed and the ankle and toes dorsiflexed, thus approximating the limb to the trunk; when tone was greater in the extensor muscles, the hip and knee were extended and the ankle and toes plantar flexed, the lower limb being thrust out as a rigid structure. Though the distribution of tone in the muscles was the basis of the distinction between paraplegia-in-flexion and paraplegia-in-extension, associated changes in the cutaneous and other reflexes were recognized as essential distinguishing marks between the two types of paraplegia. Thus Babinski (1911) believed that exaggeration of cutaneous reflexes was only found in paraplegia-in-flexion and wrote: "L'exageration de ces reflexes cutanes constitue peut-etre le caracter qui differencie le mieux les deux formes de paraplegie spasmodique." Walshe (1914) stated that the crossed extensor reflex only occurred in paraplegia-in-extension, while the crossed flexor reflex was a sign of an extreme paraplegia-in-flexion. Marie and Foix (1915) on the other hand, believed that flexor and extensor reflexes were not incompatible. They obtained well-marked ipsilateral flexor and extensor reflexes from the same limb, and noted that a flexor reflex could be interrupted by an extensor and vice versa.

Riddoch (1917) studied 8 cases of verified transection of the cord and many incomplete transections, in a group of young adults who differed from previous series by being healthy apart from their paraplegia. He observed that extensor reflexes returned after total transection of the cord, but maintained that the receptive fields for flexor and extensor reflexes were always mutually exclusive. In partial lesions the extensor reflexes were better developed, but again he observed no overlap of their receptive field with that of the flexor reflexes. Riddoch believed that there were, "no
manifestations by which we can be certain that the spinal cord has been anatomically divided," but he did think that a probable opinion could be given on the basis of the vigour of the flexor reflex and the extent of its receptive field. He maintained with Head (Head and Riddoch, 1917) that, "when an extensor reflex can be obtained from the thigh as a primary response, this great widening of the receptive field (of the flexor reflex) does not occur."

Despite the observation of Riddoch, many observers believed that the type of paraplegia indicated the integrity or otherwise of the connexions between the spinal cord and higher centres. Thus, the presence of paraplegia-in-extension was regarded as evidence that certain pathways between the spinal cord and brain-stem were intact; paraplegia-in-flexion was believed to indicate anatomical or functional isolation of the spinal cord.

The work of Sherrington (1910a) on the flexor reflex of the spinal dog was often quoted as supporting the view that the reflex changes in the two types of paraplegia were mutually exclusive; paraplegia-in-flexion in man was equated with the condition of the spinal dog, and paraplegia-in-extension with the decerebrate preparation. Yet a careful perusal of Sherrington's work shows that such support was not in fact forthcoming. His description of the flexor reflex of the spinal dog (1910a) was followed (Sherrington and Sowton, 1911) by a demonstration that modification of the stimulus applied to a sensory nerve changed the motor response obtained from a flexor to an extensor reflex. Likewise Graham Brown (1911, 1912) in a long series of experiments on the spinal cat, observed extension as well as flexion of the ipsilateral limb in response to a stimulation; he declared: "Of late it has been assumed that such phenomena as the flexion reflex and the extension reflex are specifically distinct. But in reality it may well be that no sharp line of demarcation may be drawn between." In 1912 Graham Brown and Sherrington reported their joint experience: they showed that the type of reflex response obtained from the hind-limb of the spinal dog depended largely on the site and nature of the stimulus, and emphasized that ipsilateral extensor reflexes could readily be elicited.

It was apparent that even if paraplegia-in-flexion and paraplegia-in-extension were equated with the spinal dog and the decerebrate preparation respectively, the attempt to distinguish between them on the basis of the reflex responses obtained was not supported by physiological observation. The spinal and decerebrate dog differed indeed, in many respects, but both gave ipsilateral flexor and extensor reflexes in response to appropriate stimulation.

Studies of patients with traumatic spastic paraplegia since the 1939-45
war have been more in accord with the early clinical observations of Marie and Foix (1915), and with the physiological observations of Sherrington and Graham Brown. Elkins and Wegner (1946), Pollock (1951) and Guttmann (1952) found no clear-cut distinction between paraplegia-in-flexion and paraplegia-in-extension, and were able to obtain both flexor and extensor reflexes from patients with complete transection of the cord. Kuhn (1951) made extensive studies of 29 patients with complete transection of the spinal cord verified at operation, and demonstrated that both flexor and extensor reflexes could be obtained. He found, however, that “in the present series, cutaneous stimulation proved to be relatively ineffective in the elicitation of strong extensor activity. The stimulus _par excellence_ was proprioceptive in nature, preferably in the form of abrupt, passive stretch of certain large muscle groups.”

Hagbarth (1952) was able to elicit ipsilateral extensor reflexes from the spinal cat by means of stimuli which were entirely cutaneous, and which did not excite proprioceptive end-organs. He also demonstrated that stimulation of the skin overlying the extensor muscles tended to give extensor reflexes, whereas cutaneous stimulation over flexor muscles produced flexor reflexes.

The present paper reports a series of observations on the reflexes obtainable from the lower limb in patients with spastic paraplegia due to disease of the spinal cord. Studies of reflex changes in spastic paraplegia due to disease is not so satisfactory as in traumatic paraplegia, for the opportunity of ascertaining the degree of interruption of spinal pathways is rarely afforded. Nevertheless spastic paraplegia due to disease is a common clinical condition, hence a re-examination of the reflex changes which accompany it, in the light of modern experience with traumatic paraplegia is desirable. Moreover, if a reflex formerly believed to be pathognomonic of isolation of the spinal cord coexists with a reflex equally believed to indicate continuity between the spinal cord and higher centres, it is clear that the significance of these reflexes requires review.

**Material and Definitions**

These observations were made on 44 patients with spastic paraplegia, in whom there was satisfactory clinical evidence that the lesion was in the spinal cord. The patients were not selected but were the first 44 whom it was possible to examine. The paraplegia varied in severity from those with slight weakness, spasticity and mild impairment of sensation to those with complete motor, sensory and sphincter paralysis.

Attention was mainly devoted to the occurrence of five cutaneous reflexes, though in a few patients the occurrence of extensor thrust was
also observed. The skin of the lower limbs and perineum was systematically stimulated and the incidence of the various reflexes, the nature of the stimuli required to elicit them, their receptive fields and their relationship to one another and to other signs of flexor or extensor activity in the limb were observed.

To facilitate subsequent description these reflexes will be briefly described here.

The flexor reflex.—This reflex is best elicited by a noxious stimulus applied to the skin or deep tissues of the foot, but the receptive field may extend over the whole of the lower limb even on to the anterior abdominal wall. The movements in this reflex are flexion at the hip and knee, and dorsiflexion of the ankle and toes. The Babinski response (so-called extensor plantar response) is part of the flexor reflex (Walshe, 1914).

The crossed extensor reflex occurs in the opposite leg during the elicitation of the flexor reflex. The hip and knee are extended and the ankle and toes plantar-flexed (extended). The receptive field is identical with the flexor reflex occurring in the opposite limb at the same time.

The ipsilateral extensor reflex occurs on the same side as the stimulation and consists of extension of the hip and knee and plantar flexion (extension) of the ankle and toes. Classically its receptive field is restricted to the buttock, perineum and upper fourth of the thigh, though in this study it was found possible to elicit it from a wider receptive field.

Ipsilateral flexion with extension of the foot also occurs on the side stimulated, having the same field as the flexor reflex, and consists of flexion of the hip and knee but plantar-flexion (extension) of the ankle and toes.

The crossed flexor reflex occurs in the opposite leg to the one stimulated and consists of flexion of the hip and knee and dorsiflexion (flexion of the foot). The field is the same as that of the ipsilateral flexor reflex.

Extensor thrust.—In this reflex pressure is exerted on the pads of the toes to dorsiflex them. The hip and knee extend and the ankle and toes plantar flex (extend).

The terms flexion and extension will be used in the physiological sense, flexion meaning dorsiflexion of the foot and extension being plantar flexion of the foot.

Observations

The nature of the stimulus.—The effective stimulus for the elicitation of flexor and extensor reflexes is usually described as a noxious stimulus, implying that it threatens harm to the body. This in general was found to be true with certain exceptions.
The most effective stimulus for all the reflexes was dragging a blunt point such as a bodkin across the skin. This had to be sufficiently sharp, or pressed sufficiently hard, to produce a scratch upon the skin. The intensity and duration of this stimulus had a notable effect upon the type of reflex elicited. A short drag with heavy pressure almost invariably produced a flexor reflex, whereas a prolonged drag with moderate pressure produced an ipsilateral extensor reflex.

These differences are illustrated in figs. 1 and 2. Fig. 1 shows a brief stimulus giving rise to an ipsilateral flexor reflex. The reflex follows rapidly upon the commencement of the stimulus, and subsides quickly after its cessation. In fig. 2, made with the recording drum moving at the same speed, the prolonged stimulus necessary to produce an extensor reflex is shown. The long interval between the beginning of stimulation and the start of the motor response, and the prolongation of the response after the stimulus had ceased to act, are clearly seen. These differences are typical features of the reflexes as described by Graham Brown.

Thus from the same skin area it was possible to vary the type of reflex response by adjusting the character of the stimulus. Of the two factors, intensity and duration of the stimulus, the latter seemed of the greater importance, for frequently it was possible to produce an ipsilateral
extensor reflex with heavy pressure by a very slow, prolonged drag of the stimulator.

Ipsilateral flexor and extensor reflexes were also elicited by pin-prick. A single prick, if it produced anything, invariably gave rise to a flexor reflex. Multiple pricks at a rate of about four per second, if kept initially below the threshold for a flexor response, gave rise to an ipsilateral extensor response. If the initial pricks were too hard, however, a flexor reflex developed.

Deep pressure by a pressure algesiometer also gave rise to ipsilateral flexor and extensor responses. Here again, a sudden increase in the degree of pressure gave rise to a flexor reflex, whereas if the pressure was slowly increased over a period of five to ten seconds, an ipsilateral extensor reflex followed.

Electrical stimulation was also tried, both galvanic and faradic currents being used: the latter was the more satisfactory. If the intensity of the faradic current was kept low, ipsilateral extensor reflexes were readily produced, and if a continual faradic current was applied, repeated ipsilateral extensor reflexes continued indefinitely. An increase in the intensity of the current produced a flexor reflex, as with the other types of stimulation.

All these stimuli could reasonably be described as nocuous, but the nocuous aspect of the stimulus was not indispensable. In some patients with well-developed flexor reflexes blowing on the sole of the foot was sufficient to produce a flexor reflex. Ipsilateral extensor reflexes were not obtained with such a minimal degree of stimulation. The crossed extensor reflex was never produced alone, but was an accompaniment of a flexor or extensor reflex in the opposite leg. The stimulus had to be a little more intense than that required to produce the ipsilateral flexor or extensor reflex.

Ipsilateral flexion of the hip and knee with extension of the foot was produced by a stimulus which, in intensity and duration, was midway between that required for a flexor reflex and that for an ipsilateral extensor reflex. Thus a prolonged mild stimulus might cause an ipsilateral extensor reflex: shortening and intensifying the stimulus caused the hip and knee to flex while the foot continued to extend: shortening and intensifying the stimulus even more produced a pure flexor reflex.

The crossed flexor reflex required the most intense stimulus of all. A stimulus which caused a flexor reflex with a crossed extensor reflex, when intensified, often caused the crossed reflex response to become flexor.
It was apparent, therefore, that the type of reflex elicited depended largely on the nature of the stimulus applied. The reflex response from one skin area could often be varied at will by altering the nature of the stimulus.

Receptive field of the various reflexes.—In order to compare the fields of the various reflexes the lower limb was divided into arbitrary areas, to which stimuli of different intensities and duration were applied. The sole of the foot was one area; in the leg three areas were delineated, antero-lateral, medial and posterior; in the thigh four areas were marked out, anterior, posterior, medial and lateral: the perineum and anterior abdominal wall made two more areas. The incidence of the various reflexes in these areas is shown in Table I.

<table>
<thead>
<tr>
<th></th>
<th>Flexor</th>
<th>Ipsilateral flexor with extended foot</th>
<th>Crossed flexor</th>
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<tbody>
<tr>
<td>Sole</td>
<td>88</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Leg</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td>ant.-lat.</td>
<td>69</td>
<td>14</td>
<td>3</td>
</tr>
<tr>
<td>med.</td>
<td>66</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>post.</td>
<td>63</td>
<td>10</td>
<td>1</td>
</tr>
<tr>
<td>Thigh</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ant.</td>
<td>46</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>med.</td>
<td>43</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>lat.</td>
<td>37</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td>post.</td>
<td>37</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td>Perineum</td>
<td>13</td>
<td>19</td>
<td>3</td>
</tr>
<tr>
<td>Ant. abdomen</td>
<td>16</td>
<td>16</td>
<td>2</td>
</tr>
</tbody>
</table>

The flexor reflex was best elicited from the periphery of the limb; the more proximal the area the less easy it was to obtain a flexor reflex. Within each limb segment, however, there was no significant difference in the incidence of the flexor reflex elicited from the skin overlying the flexor as against the extensor muscles. The crossed extensor reflex had much the same field as the co-existing flexor reflex, except that it did not extend quite so far proximally as that of the flexor reflex.

The ipsilateral extensor reflex by contrast was best elicited from the proximal parts of the limb. It was also obtained frequently from the leg, but never from the sole of the foot. As with the flexor reflex there was no clear evidence that the extensor reflex was more easily elicited from skin overlying extensor muscles than from flexor surfaces.

The ipsilateral flexor reflex with extension of the foot was also more
commonly obtained from the proximal part of the limb, but on three occasions the field extended to include the sole of the foot.

The crossed flexor reflex like the ipsilateral flexor reflex was best elicited from the periphery of the limb, especially from the sole of the foot, though the field on occasion covered the whole of the limb.

A wide field for the flexor reflex was not of necessity associated with a restricted field for the ipsilateral extensor reflex and vice versa. Thus in one patient the field for the flexor reflex extended from the sole up to the groin, while that for the ipsilateral extensor reflex spread from the eleventh thoracic dermatome down to and including the medial and posterior aspects of the leg. The same skin area was frequently a part of the field of flexor and extensor reflexes, the particular reflex elicited depending on the strength of the stimulus.

When the faradic method of stimulation was used and the active electrode applied to the skin over the quadriceps femoris muscle, the possibility that the muscle was being stimulated directly and giving rise to reflex activation of other extensor muscles arose. The opportunity to examine this point was provided by a patient in whom the anterior nerve roots from the second, third, fourth lumbar segments had been divided for severe flexor spasms. When a faradic current was applied to the skin over the anterior part of the thigh with the indifferent electrode on the arm, no contraction occurred in the quadriceps femoris muscle, but flexion or extension of the foot was produced by varying strength of the stimulus. This indicated clearly that the sensory field for the reflexes was cutaneous.

**Incidence of the various reflexes.**—The observations on the nature of the stimulus and the fields for the various reflexes enabled a systematic exploration of the reflexes to be made, and an estimate of their incidence and interrelations to be formed; the results are given in Table II.

<table>
<thead>
<tr>
<th></th>
<th>Flexor</th>
<th>Crossed extensor</th>
<th>Ipsilateral extensor</th>
<th>Ipsilateral flexor with extended foot</th>
<th>Crossed flexor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flexor</td>
<td>—</td>
<td>41</td>
<td>35</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Crossed extensor</td>
<td>41</td>
<td>—</td>
<td>33</td>
<td>21</td>
<td>11</td>
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<tr>
<td>Ipsilateral extensor</td>
<td>35</td>
<td>33</td>
<td>—</td>
<td>17</td>
<td>7</td>
</tr>
<tr>
<td>Ipsilateral flexor with extended foot</td>
<td>21</td>
<td>21</td>
<td>17</td>
<td>—</td>
<td>3</td>
</tr>
<tr>
<td>Crossed flexor</td>
<td>12</td>
<td>11</td>
<td>7</td>
<td>3</td>
<td>—</td>
</tr>
</tbody>
</table>
In all 44 patients a flexor reflex could be obtained by suitable stimulation at some point on the limb, and in 41 instances it was accompanied by a crossed extensor reflex. The absence of a crossed extensor reflex in 3 patients was surprising. In 1 patient the field for the flexor reflex extended up to the tenth thoracic dermatome, and a crossed flexor reflex was elicited as well. This suggested that the flexor synergy was too great to permit a crossed extensor reflex to appear. But in the other two instances a crossed flexor reflex was not present, and in 11 other patients crossed extensor and crossed flexor reflexes could both be obtained. In the second patient there were strong extensor spasms yet a crossed extensor reflex could not be obtained. In the third, the field for the flexor reflex was restricted to below the knee. There was thus no one explanation for the failure to obtain a crossed extensor reflex except, perhaps, lack of persistence on the part of the observer.

In contrast to expectation the ipsilateral extensor reflex was elicited in no less than 35 of the 44 patients, an incidence of 80 per cent. This reflex was elicited with ease by suitable adjustment of the stimulus even in patients in whom the field for the flexor reflex was extensive. In 26 patients (59 per cent) the ipsilateral extensor reflex was obtained from the lower half of the thigh or more peripherally. It should also be noted that the ipsilateral extensor reflex was obtained in 7 patients in whom the crossed flexor reflex was well developed.

Ipsilateral flexion of hip and knee with extension of the ankle and toes was seen in 21 instances in all. In 17 of these it was obtained in a limb from which an ipsilateral extensor reflex had been obtained. Thus all gradations were seen in the same patient from a pure flexor reflex, through flexion of the hip and knee with extension of the foot, to pure extension of the whole limb. In some instances these three reflexes were obtained from the same skin area by adjusting the strength of the stimulus, while in other instances they were obtained from different areas on the same limb.

A word must be said about the status of this phenomenon of flexion of the hip and knee with extension of the toe or foot. Walshe (1914) dismissed this as an artefact, believing it occurred because of contractures, or, in the case where the ankle dorsiflexed and the toe plantar-flexed, because of passive pull on the muscles of the toes. Care was taken, therefore, to avoid patients with contractures of the toes; and in cases where the toe alone extended, the ankle was held rigid, as recommended by Walshe, but extension of the toe still occurred. Moreover, in many of the patients both toe and ankle extended, excluding any possibility of passive pull on
the muscles being caused by flexion of the ankle. This showed clearly that the extension of the toe was an active movement.

Walshe's other explanation of this phenomenon was that it constituted an abortive flexor reflex, and he published recordings showing the initial extension of the toe being followed by flexion. Fig. 3 demonstrates that suitable adjustment of the stimulus gives pure extension not followed by flexion. It seems, moreover, that following Sherrington's (1910a) definition of a reflex as a reaction, "in which there follows on an initiating reaction an end-effect reached through the mediation of a conductor," this extension of toe and foot, without subsequent flexion, must be considered a true reflex. The fact that a more severe stimulus may cause initial extension to be followed by flexion, does not alter the fact that a milder stimulus will produce pure extension of the foot followed by a return to the neutral position. Moreover, increasing the stimulus to one skin area produced first ipsilateral extension, then ipsilateral flexion with extension of the foot, and finally pure flexion, suggesting that ipsilateral flexion with extension of the foot is a transition phase, in which neither flexor nor extensor dominance is established.

The crossed flexor reflex was the least common of the reflexes obtained, occurring in 12 patients. In 11 of these it occurred as an alternative to the crossed extensor reflex. The ipsilateral flexor reflex with which the crossed flexor reflex was associated was usually elicited from a very wide field, but only a restricted part of that field gave the crossed flexor reflex. In 1 patient, however, the crossed flexor reflex was obtained from the whole of the lower limb.

An illustration of the occurrence of the different reflexes in the same patient is shown in figs. 4, 5 and 6. Fig. 4 shows the flexor reflex accompanied by the crossed extensor reflex following stimulation of the sole of the foot. Intensifying the stimulus to the sole of the foot changed the crossed response from an extensor to a flexor reflex as shown in fig. 5. In fig. 6 stimulation of the lower half of the lateral side of the thigh caused extension of the knee and plantar flexion of the ankle and toes in the ipsilateral extensor reflex. Fig. 7 which was taken from another patient
Fig. 4.—The flexor reflex accompanied by the crossed extensor reflex in response to stimulation of the sole.

Fig. 5.—The flexor reflex accompanied by the crossed flexor reflex with strong stimulation of the sole, in the same patient as fig. 4.

Fig. 6.—Stimulation of the thigh causing extension of the knee and plantar flexion of the ankle and foot in the same patient as fig. 4.
Fig. 7.—A double exposure showing the extension of the ankle and toes in response to stimulation of the lateral side of the leg in the ipsilateral extensor reflex.

shows clearly the active extension of the toes and foot in the ipsilateral extensor reflex following stimulation of the lateral aspect of the leg. There can be no doubt, therefore, that these various cutaneous reflexes can be obtained from the same patient at one time, and cannot, therefore, be indicative of continuity or disruption of the spinal cord.

The relationship between tonus and reflexes.—5 patients in this series had so great an increase of tone in the extensor muscles of the lower limbs that they were held rigidly, and it required tremendous force exerted for 30 seconds or more to bend the knees in order to seat the patient in a chair. This great increase in extensor tone, however, was not accompanied by a similar preponderance of the ipsilateral extensor reflexes. In 2 of the patients these reflexes were completely absent; in 2 others they were restricted to one limb, although the extensor hypertonus affected both; and in 1 patient ipsilateral extensor reflexes were obtained bilaterally, but the field was restricted to the anterior aspect of the thighs. The ipsilateral flexor reflex in these patients, on the other hand, arose from a wide area extending in 2 on to the abdomen, and in 2 others up to the groin. In 3 of the patients the crossed flexor reflex was also obtained. There was thus no correlation between the degree of extensor tonus and the facility with which ipsilateral extensor reflexes were elicited, or with the depression of flexor reflexes. There was, on the other hand, a positive correlation between the presence of extensor spasms and well-developed ipsilateral extensor reflexes. 3 patients had extensor spasms, and in all 3 the ipsilateral extensor reflexes were readily elicitable.
The occurrence of extensor thrust.—Only 12 of the patients were examined for the extensor thrust reflex, but in 4 of these it was found. The best method of eliciting this reflex was to dorsiflex slowly and steadily the second, third and fourth toes by pressing up against the pads, until eventually the foot was being dorsiflexed as well. It was difficult to be certain if dorsiflexion restricted to the toes would give the reflex, though the impression was that it did. As the pressure was exerted the extensors of the knee and ankle became active and thrust the leg out rigidly with the foot strongly extended (plantar-flexed). All 4 patients showed ipsilateral extensor reflexes as well, though not from a wide field. The field for the flexor reflex was restricted in 2 patients to the skin below the knee, but extended in the other 2 up to the groin.

Discussion

The observations reported in this paper lend no support to the view that spastic paraplegia can be clearly divided into two groups on the basis of the reflexes obtainable from the lower limbs. Study of the various reflexes obtained in these patients showed that all possible combinations of flexor and extensor reflexes occurred. Thus, ipsilateral flexor and extensor reflexes were frequently obtained from the same limb by applying different stimuli. A crossed extensor reflex, believed only to occur in paraplegia-in-extension, co-existed with a crossed flexor reflex, said to be typical of extreme paraplegia-in-flexion (Walshe, 1914), in no less than one-fourth of the patients. No division could, therefore, be made on the basis of the type of reflex obtainable from the limb.

Charting the fields of the various reflexes also failed to show a clear division of the cases into two groups. Thus the same skin area gave flexor and extensor reflexes with ease, depending entirely on the type of stimulation used. Likewise, a widening of the field for the ipsilateral extensor reflex was not of necessity accompanied by a corresponding reduction in the flexor field.

The factors of pre-eminent importance in determining the type of reflex obtained were the intensity and duration of the stimulus used to elicit it. A noxious stimulus, mild in degree and prolonged in duration, was the appropriate stimulus for the ipsilateral extensor reflex, whereas a severe stimulus of short duration almost invariably gave rise to an ipsilateral flexor reflex response.

Though an exclusive distinction between the types of reflex obtained, or their fields, was not observed, it must not be thought that a pattern was completely absent. The flexor reflexes, both ipsilateral and crossed, were undoubtedly most easily obtained from the periphery of the limb,
whereas the ipsilateral extensor reflex was best elicited from the proximal part of the limb. Thus, though the overlapping territory of these reflexes spread from groin to ankle, their foci, or points of maximum incidence, were at opposite ends of the limb.

No difficulty was experienced in obtaining the extensor reflexes by cutaneous stimulation, in contrast to the observation of Kuhn (1951). 2 patients who had shown no motor, sensory or sphincter activity for over four years gave flexor and extensor reflexes in response to cutaneous stimulation with ease. Similarly faradic stimulation of the skin overlying muscle incapable of a motor response, gave flexor and extensor reflexes. A predisposition of the skin over flexor muscles to give flexor reflexes and over extensor muscles to give extensor reflexes, as seen by Hagbarth (1952) in the cat, was not observed. This may well be a reflection of the fact that it is not possible to test patients with the same exhaustive thoroughness as can be done with the experimental animal. Though every effort was made to test each skin area systematically on several different occasions, the limitations imposed by the clinical situation enjoins that conclusions should be drawn only tentatively from negative results, and the main emphasis placed on the positive findings.

This demonstration of flexor and extensor reflexes co-existing in the same patient is not an abandonment of the physiological teaching of Sherrington, but rather a return to it, for the teaching of clinical neurology in this field appears to have been based on one aspect of Sherrington's views only, and to have ignored other aspects of his work, and the work of Graham Brown. Writing of the spinal dog Sherrington (1910b) states "the attitude thus exhibited undoubtedly amounts to standing and is sometimes maintained for minutes at a time." And though he goes on to say that, "Spinal standing is not fully equivalent to the standing of the decerebrate preparation" he clearly recognized the existence of extensor activity in the completely isolated spinal cord. The concept of a continuum existing between the dominance of flexor reflexes on the one hand and of extensor reflexes on the other was always present in physiological teaching; and the notion that the presence or absence of extensor reflexes indicated, respectively, continuity or complete disruption of spinal pathways was foreign to it.

Paraplegia-in-flexion and paraplegia-in-extension remain, therefore, as clinical entities dependent on the group of muscles in which tone predominates. The more severe the lesion the more will the tone of the flexor muscles exceed that of the extensors and vice versa. With this predominance of tone, however, there does not go an equal predominance of the type of reflex response obtained. As Riddoch observed, both flexor and
extensor reflexes may be present when tone predominates in one group of muscles; and this study would go further by demonstrating that the opposing reflexes may be elicited from the same receptive field by suitable adjustment of the stimulus irrespective of the distribution of tone in the muscles.

The observations made here are in agreement with those of observers of traumatic paraplegia since the 1939-45 war. The excitation of flexor or extensor reflexes from the skin does not depend on whether the cord is in isolation or not, for both can be elicited at one and the same time from the same patient. The determining factors as to whether flexor or ipsilateral extensor reflexes are obtained are the intensity and duration of the stimulus applied and to a lesser degree the site of its application.

SUMMARY

The cutaneous reflexes obtainable from the lower limbs of 44 patients with spastic paraplegia due to disease of the spinal cord, together with their receptive fields and their adequate stimuli have been systematically studied.

Division of these reflexes into two distinct groups was not found, for all reflexes were present in many patients. The determining factor as to which reflexes are obtained is not the predominance of flexor or extensor tone, but the nature of the stimulus used to elicit the reflex, and to a lesser degree its site of application.

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