Original Communications.

THE SYMPTOMS OF ACUTE CEREBELLAR INJURIES
AS OBSERVED IN WARFARE.

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The functional defects which are produced by injury or disease of the cerebellum have been described by many physiologists and clinicians, and almost innumerable attempts have been made to analyse and solve their significance and thereby determine the normal functions of this organ. But there is still a remarkable divergence between the symptoms attributed to lesions of the cerebellum in man in various text-books and monographs and the phenomena which physiologists have observed after its injury or ablation in animals. It is, however, obvious that a close correspondence must be established between them before clinical experience can contribute to the solution of the physiological significance of the cerebellum, and before we can determine the part which this plays in the human nervous mechanism.

The opportunity of making uncomplicated clinical observations is rare in civil life, since acute lesions of the cerebellum, comparable with those produced by physiologists, are uncommon; tumours and abscesses which develop in it are very liable to compress or to influence the functions of other parts; softenings and haemorrhages are rarely wholly limited to it, and the degenerative and atrophic diseases which involve it practically never affect it alone. In warfare, on the other hand, wounds limited to the cerebellum and injuries of it of different extent and localization can be frequently observed. During the present War I have been able to examine over forty men in whom it had been injured, but as wounds of this region of the head are notoriously serious a certain number died early, in others the symptoms were only slight or transient, and many were of

33
The Symptoms of Acute Cerebellar Injuries

necessity evacuated to England within a short time of the infliction of the injury. Twenty-one patients in whom the symptoms were pronounced remained; however, under observation sufficiently long to permit repeated examination and investigation. In several of these the wounds had healed and they were able to leave bed and walk before they were transferred; some of the more serious cases in fact remained under observation for two to three months.

My investigations have been consequently made chiefly in the early and acute stages of injuries of the cerebellum, but in many cases the recovery of function, or "compensation," could be also studied. I was particularly fortunate in being able to examine, before this paper was completed, two men in whom the lesions were of much longer standing. One, in an attempt to commit suicide eight years previously, had shot himself through his mouth and produced extensive destruction of one lateral lobe of the cerebellum, in which fragments of metal still remained. The other had been wounded by a fragment of shell-casing twenty months previously and had been trephined over one lateral lobe. Both patients still presented symptoms of cerebellar disturbance, but unfortunately the second man had developed signs of disseminated sclerosis. In a third case, which also came under my observation, the characteristic symptoms of a very severe unilateral cerebellar lesion had come on suddenly while he was under heavy gun fire. I have not included these three cases in my series, but I have been able to control many observations made in acute cases on them. My observations have been made, therefore, on injuries which resemble closely those on which the classical physiological descriptions are based, and it will consequently not be surprising that a close similarity exists between them. The chief divergencies probably depend on the position of the subject in the phylogenetic scale, and on the relative importance or subordination of the cerebellum in the nervous system of different animals.

In the subsequent pages it will be my aim to describe those disturbances of function which constitute the symptoms of recent cerebellar lesions as objectively as possible, and to attempt to analyse complex symptoms into their simpler components. Names and terms applied to symptoms will be employed as rarely as possible, and as the defects of function can be often most easily understood by observing abnormalities in the ordinary or spontaneous activities of the affected parts, clinical tests have been made use of only sparingly or have been supplemented by further observations.

It is, however, impossible to deal with this subject without relying largely on Babinski's masterly analysis of, cerebellar symptoms and on the careful descriptive work of other neurologists, especially André-Thomas, who has also attempted a valuable correlation of these clinical symptoms with the disturbances that occur in animals after experimental injury. If
the references to their work are incomplete it must be attributed to the circumstances under which this contribution has been written.

In the majority of my patients who survived, the lesions were unilateral and involved only, or chiefly, one lateral lobe of the cerebellum; the descriptions of the resulting symptoms will be consequentially based largely on these cases. Certain patients with extensive bilateral lesions were, however, also observed.

UNILATERAL LESIONS OF THE CEREBELLUM.

(1) Disturbance of Tone.

The effects of cerebellar injuries fall almost exclusively upon the motor system, and in the early stages of an acute lesion one of the most prominent symptoms is loss or diminution of tone in the muscles of the limbs, and to a less extent in those of the trunk, of the same side.

If a case in which there is an extensive unilateral lesion be examined within the first week or two, one of the most striking features is the flabbiness of the muscles of the homolateral arm to palpation; as compared with those of the opposite side they are more easily compressed and displaced transversely, and they can be stretched or elongated to a greater extent without any discomfort to the patient. This is obviously the reason why the limbs often assume unnatural attitudes or are placed in postures which the patient would tend to avoid, in a normal limb. Not infrequently, for instance, the hand may be observed lying for long periods prone on the bed with the fingers fully straightened out or even hyperextended, although this unnatural attitude can be easily corrected; and this is probably the explanation of the fact, that on attempting to rise into the sitting position in bed the patients occasionally help themselves by throwing their weight on the dorsum of the affected hand, so that the fingers and wrist are overflexed to an extent that would be uncomfortable or even painful in the normal limb. An officer, for instance, who was dull and restless for a few days afterwards complained that the knuckles and the wrist of his affected hand were sore, owing to the fact that in attempting to sit up in bed he usually placed this hand under him in the flexed position. This phenomenon cannot be attributed to loss of sensation, since repeated examinations have failed to reveal alteration in any of its modalities; it is analogous to the failure to correct instantly unnatural attitudes of the limbs, which Luciani has described after partial or total ablation of the cerebellum in animals.

If in such a patient both forearms are held vertically by the observer the wrist of the affected side usually falls passively into a position of extreme flexion, while in the normal limb the wrist is not allowed to become more than semiflexed owing to the tone of its extensor muscles (fig. 1). Similarly, if as the patient lies in bed his arms are fully abducted and rotated out-
The Symptoms of Acute Cerebellar Injuries

wards so that his hands lie behind his head, the affected wrist is more fully extended by its own weight than is its fellow, and the arm is often excessively rotated too.

When such a limb is handled and moved about passively it is at once obvious that there is loss of that slight but definite resistance that normal muscles offer to stretching. Further, if either the arms or the legs are seized and shaken it is found that the more distal segments of the affected limbs flop and swing about in an unnatural inert manner like the arm of a flail. This can be easily seen, but the abrupt jar which the arrest of the freely swinging segments communicates to the observer’s hand is often even more unmistakable. Another striking feature brought out by this manoeuvre is, that while the oscillations of the distal segments of the normal limb are limited by the elastic tension of the muscles that are stretched, those of the other limb can be felt to swing till the joints “lock,” and their bony and ligamentous structures prevent their further movement. This “locking” of the joints can be most easily felt at the wrist, elbow, and the ankle. There is never, however, any evidence of articular or ligamentous relaxation which permits a greater range of absolute movement, such as occurs in tabes dorsalis.

The same phenomena may be observed by rotating or otherwise suddenly displacing the patient’s whole body when he can stand erect, for the affected arm swings about inertly as though it were only tied to the shoulder by a string. (André-Thomas.)

In rapid voluntary movement, too, an excessive passive swing at certain joints not directly concerned in the action can be often observed. When for instance the patient is asked to flex and extend his supported elbows as quickly as possible, as in testing for adiadochokinesia, the affected wrist
Gordon Holmes

is successively overflexed and overextended owing to the momentum of the movement, so that the hand is flung against the shoulder or towards the bed. The fact that in this test the affected elbow is often raised from its support by the momentum of the flexing forearm is also due to deficient tension in those muscles that should fix the shoulder-joint.

And if the forearms are seized by the observer, and suddenly flipped as if he were cracking a whip, the wrists flex passively, but while the normal hand is immediately extended again owing to the elasticity of its extensors, the affected one remains flexed or only swings inertly. This may be seen at the ankle too if the relaxed leg is similarly jerked and arrested abruptly. Finally, if a patient in this stage holds his two arms horizontally outstretched and the normal limb is gently tapped by the observer's fingers, it is but little displaced and immediately regains its original position, but the affected arm swings more widely as a result of each blow, offers less resistance to displacement, is arrested less abruptly, and is slower in its return (André-Thomas). In this test the displacement is generally due to movement at the shoulder, but if the hand is more forcibly tapped the wrist and the elbow often flex too.

This diminution in elastic resistance of muscles to stretching can be often observed directly. If the fingers are seized and passively extended at the same time as the wrist they can be easily, and without the observer experiencing any resistance, bent back till further movement becomes impossible owing to the conformation of the joints and the tension on their ligaments; and even in this position the patient does not experience the dull pain or discomfort in the overstretched flexor muscles which he suffers when the unaffected wrist and fingers are forcibly extended to the same degree. This may be also observed at the elbow, shoulder, and in the joints of the lower limb. The affected heel can be for instance easily brought into apposition with the buttock, or the thigh can be so fully flexed that the knee touches the chest (fig. 2). Consequently, though the maximum possible range of passive movement may not be increased, the normal resistance offered to it by the muscles when they are passively elongated is deficient, and definite resistance is felt only when the rigid ligaments or the apposed bones restrict the movements. As a rule this diminished elasticity of the muscles becomes more obvious about five to ten days after the infliction of the wound, and in cases of severe injury it may persist for several weeks at least.

We therefore find on palpation, passive movement, shaking and tapping of the affected limbs, that their muscles are soft and flabby, and that their tension, which normally tends to oppose passive movement and prevent that unrestricted swinging under the influence of gravity or displacement of their different segments, such as occurs in a hinged skeleton, is diminished. In other words, there is loss of that active tension which
The Symptoms of Acute Cerebellar Injuries

distinguishes normal muscles and is independent of their length, that is known as tone.

This flabby hypotonic state of the muscles suggested the examination of their reaction to direct percussion. This was done in several cases but no definite difference could be detected.

When an extensive unilateral lesion of the cerebellum exists this state of hypotonia is always limited to the same side, but it is usually more pronounced, or at least more easily demonstrated, in the upper than in the lower limb. Distal and proximal muscles are involved to relatively the same degree. It is less easy to demonstrate in the trunk muscles, but here too the stretching of those of the side of the lesion offers less resistance, as the patient sits or stands, than those of the unaffected side. It does not produce any appreciable asymmetry or other change in the face. In smaller lesions it is generally demonstrable in both the upper and lower limbs, but it is less pronounced, especially in the latter.

Its distribution, especially in slight cases, is a question of considerable importance in view of the conclusions arrived at by André-Thomas and Durupt from experimental work, which Thomas attempts to support by certain clinical observations. These authors have described as a result of small limited lesions of the cerebellum an affection of the tone of certain

Fig. 2.—A case of severe injury of the right lateral lobe and of the right side of the vermis, ten weeks after the infliction of the wound. The right thigh can be fully flexed on to the trunk, the heel placed on the buttock, and the foot much dorsiflexed with the exertion of very little power.
Gordon Holmes

muscles or groups of muscles only, so that a condition of anisosthenia or loss of tone in some muscles and relative hypertonicity of their antagonists, results. It is to this disturbance that André-Thomas attributes many of the symptoms of cerebellar lesions which occur in man.

Though I have carefully searched for this condition in the majority of my patients, I have been unable to find any support for his observations. In the early stages of extensive lesions the atonia is certainly uniform, no matter what method is relied upon for its demonstration; and even during recovery, as well as in cases of circumscribed injuries, I have been unable to discover that it is ever limited to certain muscles. In my notes of one case, it is true, it is recorded that on the twenty-seventh day "there is perhaps relative hypertonicity of the adductors and inward rotators of the shoulder, and of the supinators," but in both the earlier and later notes it is emphasized that the hypotonia was general and uniform in the affected limbs. If such anisosthenia existed commonly it would probably be most obvious in cases with local and restricted lesions of the cerebellum; but though I have seen many of these I could find no evidence of it.

The one common symptom that might be advanced in support of Thomas's thesis is the tendency to deviation of the unsupported limbs, and the frequent error in projection revealed by Bárány's pointing test; but these signs will be dealt with later.

In cases which remained under observation for some time the hypotonia diminished gradually and uniformly, but in all it persisted and was easily demonstrable till the patients were transferred to England. In three cases it was still pronounced seventy-one, seventy-eight, and ninety days respectively after the infliction of the wound. Even in the case in which the injury dated from eight years previously the homolateral arm and leg swung about more inertly, and the patient, who was an educated man, described them as "floppier" than his normal limbs.

(2) Voluntary Movement.

(A) Strength.—The flabby toneless limbs of the affected side give an unmistakable impression of feebleness when they are handled or examined, and many patients have spontaneously complained that they are "weaker" or "more useless," or that they "have not nearly so much power in them," as they formerly had, or as those of the opposite side still possess. This impression is, however, not wholly borne out by examination, for the degree of paresis is always moderate. But there can be no doubt that during the earlier stages of every extensive injury of one side of the cerebellum the strength of all the movements of the limbs of this side is definitely reduced, even when concomitant lesions of the cerebrum and of the chief motor paths can be excluded with certainty. Both the proximal and the distal muscles are affected and as a rule the former
The Symptoms of Acute Cerebellar Injuries

appear on the whole relatively weaker. The feebleness is always more pronounced in the arm than in the leg.

This feebleness is usually obvious even when the patient attempts any movement that requires the exertion of power, since more effort is apparently necessary to perform it. This may be seen when he is asked to hold his arms horizontally outstretched or when he tries to raise an object of moderate weight, and the longer the attempt is prolonged the more striking is his difficulty.

When in such cases the strength of various movements, as grasping, flexion and extension of the elbow, flexion of the hip, etc., is tested and compared with that of the corresponding muscles of the opposite side, the difference is usually definite and is approximately proportional in all movements of one limb. This can be easily demonstrated by dynamometric readings. With Dr. Castex's dynamometric apparatus, which he kindly lent me, I obtained the following measurements of the maximal force of several movements of the two sides, in two cases of severe unilateral injury.

<table>
<thead>
<tr>
<th>Movement</th>
<th>Case 1 (thirty days)</th>
<th>Case 2 (seventeen days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Unaffected side (R.)</td>
<td>Affected side (L.)</td>
</tr>
<tr>
<td>Grasp</td>
<td>12'4</td>
<td>15'3</td>
</tr>
<tr>
<td>Flexion of elbow</td>
<td>11'8</td>
<td>15'2</td>
</tr>
<tr>
<td>Extension of elbow</td>
<td>10</td>
<td>5'2</td>
</tr>
<tr>
<td>Supination</td>
<td>29'8</td>
<td>15'2</td>
</tr>
<tr>
<td>Pronation</td>
<td>17</td>
<td>15</td>
</tr>
<tr>
<td>Extension of ankle</td>
<td>17</td>
<td>15</td>
</tr>
</tbody>
</table>

In Case 1 there was a penetrating wound, from which a piece of shell casing was removed, over the middle of the left lobus gracilis; a considerable amount of softened cerebellar tissue escaped at the operation, and it is probable that the nucleus dentatus was involved. Healing occurred rapidly without any hernia formation.

In Case 2 a large fragment of metal entered over the lateral third of the right lobus gracilis and was removed from the mesial portion of this lateral lobe. There was considerable destruction of cerebellum and a hernia developed, but the patient eventually recovered.

These figures represent the average of several readings for each movement. Case 1 was examined on the thirtieth, Case 2 on the seventeenth day after the infliction of the wound.

The lower records on the affected side may be partly attributed to the difficulty and awkwardness of this hand in holding the instrument; this may be a factor especially when the power of grasping is tested by the ordinary dynamometer, but it can have little influence in estimating the power of other movements by Dr. Castex's apparatus.

When a series of records is made it is also found that the affected limbs tire more quickly than their fellows, and the power exerted by
the contracting muscles then diminishes considerably. It is often obvious too, that when the patient is asked to grasp the observer’s hand as strongly as possible, the grasp of the affected limb is less continuous and less well maintained than of the other; but this is not always so. It can be even more easily demonstrated when the patient attempts to depress the observer’s hand with his extended arm; the exertion of power can be felt to be jerky and more or less intermittent. In other movements, too, a similar irregularity in the exertion of power can be often detected, and if the lesion is severe the contraction of the muscles in every action against resistance may be less well maintained.

The sudden unexpected relaxations of contracting muscles that sometimes occur are closely allied to this; in standing, for instance, the leg of the affected side occasionally gives way under the patient, and some men complained that they were afraid to use the affected hand in taking food and in similar actions, as any object they grasp by it is liable to fall suddenly from it. But even when a limb is definitely weak in active movements its static strength—that is, the resistance it can offer to displacements which the patient attempts to resist voluntarily—is generally unaffected. If, for instance, he attempts to keep his elbows or his fingers flexed when the observer tries to extend them, the power necessary to overcome his resistance is approximately the same on the two sides.

Another feature, which is often very striking when the cerebellar injury is severe, is the apparent reluctance of the patient to move the affected arm. This may be frequently seen to lie for long periods in the same attitude, and though he may frequently bring the opposite hand to his face, arrange the bedclothes with it, etc., he more rarely employs the affected one. And when food or any object is offered to him it is almost always with the unaffected limb that he takes it. This may be partly due to the patient’s knowledge that he cannot use the affected limb as efficiently or as safely as the other; but it is impossible to observe a patient with a recent cerebellar injury for any time without coming to the conclusion that there is an inherent reluctance to move the limb unless it is necessary. Even if his two hands are pricked by a pin the patient withdraws the affected limb less readily and less briskly than the normal. I could, however, never observe any difference between the reflex withdrawal of the limbs of the two sides from a noxious or painful stimulus. In two cases it was noticed that during the early stage of chloroform anesthesia the patient in struggling moved only or chiefly his normal limbs.

Further, in the early stages of a cerebellar injury there is almost always a marked slowness of the movements of the affected limbs, and especially of the arm, as compared with that of the other side. If a rod is held in front of the patient equally distant from his two hands and he is asked to take hold of it with both, it is found that the movement starts
more slowly on the affected side, and that this limb seizes the rod an appreciable time after its fellow. Undoubtedly the slowness in reaching the object is partly due to the irregularity of voluntary movement which is generally known as "ataxia," but this is certainly not its only cause. This may be seen when the observer's hands are placed in the patient's, and he is asked to grasp them firmly at a given signal; the slowness of the affected limb in starting the action and in developing full power is often unmistakable. It matters not whether the patient attempts such simultaneous actions of the two limbs at the rate he chooses, or whether he is asked to do them as quickly as possible, the affected limb lags behind the other. In the early stages of severe injuries it is in fact difficult to make him hurry in movements of the affected limb.

**Fig. 3.**—From a case of moderately severe injury to the right lateral lobe ten days after the infliction of the wound. The patient was asked to grasp simultaneously with his two hands against two equal springs. 1 and 1' represent the simultaneous ordinates, A and A' the lines traced on a rapidly revolving drum. The drum was allowed to complete one revolution and a signal to relax was then given; 2 and 2' represent the simultaneous ordinates, and B and B' the curves traced by the released springs. Time by a tuning-fork of 128 vibrations per second.

Even in cases of less severe injury in which there was no obvious loss of power, this slowness in movement is also apparent. It may be partly attributed to the fact that experience has taught the patient that the more rapidly he attempts to make a movement the less well can he control it; but that this is not the whole explanation can be easily seen by the investigation of simple movements, especially by the graphic method. Fig. 3 reproduces the tracings obtained when a patient with a right-sided lesion was asked to grasp simultaneously on a given signal against two carefully graded and equal steel balance springs. With his left hand, A, he started immediately on the signal being given (1 and 1') and attained full power.
in about five-tenths of a second; but in his right hand, A', there was a delay of two-tenths of a second in starting the contraction, and the exertion of power did not attain its maximum till one second later. Further, the power exerted was little more than one-half that developed by the left hand.

When the signal to relax was given (2 and 2'), his left hand opened at once and the tracing, B, quickly reached the base line, but on the right side relaxation did not commence till about one-seventh of a second later, and the fall of the tracing to the base line was much more gradual even though the extension of the fingers was aided by the tension of the extended spring. The same features may be seen in the tracing reproduced in fig. 4; here the right hand, which was affected, was less slow in initiating contraction, but the full power of grasp was only attained after six-tenths of a second, and its strength was only half that of the left hand. There was also an appreciable delay in commencing relaxation and a definite slowness in its completion.

In fig. 5 the same condition is seen when a third patient with a right-sided lesion attempted to flex his elbows simultaneously against resistance, and later relax on a given signal; in this case delay in initiating, and slowness in effecting, relaxation were the most prominent features.

The same facts may be easily observed in other movements of the
The Symptoms of Acute Cerebellar Injuries

affected limbs in the majority of, if not in all, patients with severe and moderate unilateral injuries. When, however, corresponding muscles of the two limbs are stimulated simultaneously by a faradic current no slowness in either their contractions or relaxations can be detected (fig. 6);

![Diagram](image)

**Fig. 5.**—From a case of injury of the right lateral lobe and probably also of the vermis of the cerebellum, six weeks after the infliction of the wound. Tracings, A and A', of an attempt to flex his two elbows simultaneously against the resistance of two equal springs, and later to relax them simultaneously on a given signal B and B'. 1 and 1' and 2 and 2' represent the simultaneous ordinates.

![Diagram](image)

**Fig. 6.**—Tracings obtained from tambours placed on the tendons of the flexors of the fingers of the right and left hands when these were stimulated simultaneously by a faradic current, in a patient with an extensive right-sided cerebellar injury. There was in this patient a considerable delay in the initiation of both voluntary contraction and relaxation of these muscles. A and A' represent the corresponding ordinates. Time in fifths of a second. Read from left to right.

nor is there any difference in the latent periods of their contractions when these are excited reflexly.

We consequently find that (1) a delay in initiating muscular contractions; (2) a slowness in attaining the exertion of full power; (3) a delay
in commencing relaxation; and (4) a slowness in effecting relaxation, are among the symptoms produced by cerebellar lesions. As a rule, there is delay and slowness in both contraction and relaxation, but occasionally only contraction, or more commonly relaxation, is slower than it is in the normal limb; a slowness in relaxation is probably the most common.

The affected limb also tires more rapidly than the normal, especially in movements that demand power and in those made against resistance.

![Diagram](Right Left)

**Fig. 7.**—From a case with an extensive right-sided lesion five weeks after the onset. The patient was asked to compress and release a strong spring as quickly as he could with his left and his right hands in succession; the movements of the spring were recorded in a slowly revolving drum. The tracing obtained from the left hand shows only evidence of fatigue; that from the right hand is very irregular and frequently did not reach the abscissa, owing to the patient commencing to flex his fingers again before he had fully relaxed his grasp.

This can be well seen if the patient is made to hold his arms outstretched horizontally in front of him, or to keep his legs elevated from the bed. At first the affected limb is usually held very steadily, but it tires rapidly, and then a coarse jerky tremor often appears, owing chiefly to his voluntary attempts to regain the position from which the tired limb gradually falls away. The tendency of the affected limbs to tire more rapidly can be seen in most ergographic tracings. In these the range of movement is also generally smaller and more irregular,
The Symptoms of Acute Cerebellar Injuries

while its rate is slower. Occasionally, however, as in fig. 7, the most striking feature is due to the fact that when the patient attempted to perform such movements against resistance as quickly as he could a second contraction often occurs before the previous relaxation was complete, and consequently in many excursions the tracing did not reach the base line. In this patient there was an obvious delay and slowness in starting and in completing the relaxation of contracting muscles.

The weakness of the limbs of the affected side is always most evident in the early stages of the cerebellar injury and diminishes gradually. In several of the cases in which the lesion was small or moderate in size no difference could be detected in the power of the homologous limbs after two to three weeks, but in more severe injuries the paresis is more persistent. In the two cases referred to above in which dynamometric readings were made, it was still obvious in each upper limb eighty and seventy days respectively after the infliction of the wound, but the lower limbs were then equally strong. Even when their strength had recovered the affected limbs still remained appreciably slower in movement than the normal.

This form of weakness due to cerebellar wounds is distinguished from that produced by lesions of the cortical motor area or of the cortico-spinal tracts by its homolaterality, by its uniformity and the approximately equal affection of all groups of muscles, by the fact that though all voluntary movements are weak none are limited in range, by the absence of the characteristic alterations in the reflexes, and by the fact that there is no tendency for rigidity or contractures to develop. The term asthenia introduced by Luciani is consequently more suitable for it than paresis.

(B) Ataxia.—But the most obvious sign of cerebellar disease is that irregularity in voluntary movement which is generally loosely described under the term "ataxia," though physiologists and certain clinicians have tried to analyse it into simpler components.

This disturbance of voluntary movement may be most easily studied separately, as it occurs in the early and in the later stages of extensive lesions, since in the latter period the effects of cerebellar deficiency are complicated by the results of "compensation" by other parts of the nervous system, and by the voluntary efforts by which the patient attempts to control his disability.

In the early stages all movements of the limbs are affected, but the disturbance is more striking in the upper than in the lower extremity, and in complex than in simple movements. It must be emphasized that the control of movements by vision has no influence on their regularity, and that they are quite as "ataxic" when the patient's eyes are open as when they are closed.
Let us assume we have a patient with a recent severe lesion of the right half of his cerebellum. When he is asked to touch an object with his left forefinger he does so promptly and accurately, and to reach it moves his hand in the most direct line practicable from the position in which it lay. He raises his right hand from the bed less promptly, and as soon as the limb is unsupported it sways unnecessarily and aimlessly at its more prominent joints, and during the movement his finger deviates from the direct course by which it could most easily reach its aim. Further, he rarely succeeds in touching the object at once, but usually brings his index to one or other side of it, and projects it too far or more rarely stops the movement too soon. Errors consequently occur in both the direction and in the range of its movement. If his elbow is fixed so that it is necessary for him to move only his forearm and hand, the irregularity and inaccuracy of the movement is less pronounced. Similarly, if when his arm is extended vertically or held outstretched in front of him, he is asked to bring his index finger to his nose, it is seen that his finger does not take the direct and shortest course, and instead of coming accurately to his nose it often strikes his chest, chin or forehead. Further, it is often brought to his face with undue force.

If an attempt is made to obtain from the patient his explanation of this irregularity of his movements he merely describes, if he happens to be intelligent, that which the observer has already noticed. One patient said: "I don't seem to have the power to do what I want to with my hand, though if I take hold of anything with it I can grip it all right. If I want to bring it to my mouth I only hit my eye with it; it is drunk; it won't go straight." Another man described his disability by the statement: "I don't feel that I can get the right direction with this arm"; while a third patient when examined in a later stage (ten weeks after the infliction of the injury) complained that he "could not pull the arm up quickly enough," and therefore brought his finger beyond any point he wished to touch.

This irregularity in direction and range is always more marked in rapid than in slow movements; in fact when the patient is asked to execute the movement slowly, or is urged not to hurry, there may be little or no obvious disturbance. Further, simple actions which require movement at one joint only may be fairly accurately performed, though complex actions are irregular and ataxic; the patient can succeed much better in touching with either his finger or toe an object that he can reach with the limb extended than when movements at the elbow, knee or other joints are also necessary.

The movements of all segments of the limbs are generally affected, and those of the distal joints are in fact usually the most seriously disturbed. If, when the patient's eyes are closed, an unknown object is placed in his
The Symptoms of Acute Cerebellar Injuries

hands and he is asked to identify it, it may be seen that he handles it and moves his fingers over it irregularly and awkwardly; often he only grasps it firmly and rubs it between his finger and thumb. The affection of his fingers is better demonstrated and more easily analysed if he is asked to bring the tip of each finger in succession to the top of his thumb; then he frequently fails to place finger and thumb in correct apposition, the finger often slides along the side of his thumb, and the relative degree of movement at the different joints of the finger are not so regular or appropriate as in the normal hand; sometimes only the metacarpophalangeal joint is flexed, or the bending of the interphalangeal joints may be excessive. The rate of movement, too, is not uniform, but is often jerky and intermittent. Further, while in the normal hand each finger is flexed separately, on the affected side all fingers are frequently flexed at the same time, though he wishes to bring one finger only to his thumb.

When this disturbance of movement is more carefully examined several factors can be distinguished in it. These may be most easily considered separately, though the relative prominence of each may vary in different cases and even in different stages of the one case.

(i) Decomposition of Movement.—If we again ask the patient as he lies in bed to extend his arm vertically over his face and then bring his forefinger to his nose, it is seen that instead of depressing his arm and flexing his elbow simultaneously, he first brings his elbow towards the bed and only when it is there or near it does he approach his finger to his nose by flexing his elbow. In other words, he "decomposes" the movement into its separate elements (Babinski). This may be seen in various other actions of both the upper and lower limbs. One patient, for instance, when asked to place the heel of his affected side on his opposite knee always dragged the heel along the bed till it reached the knee and then only raised it to the proper height; other patients on the contrary have raised the heel unnecessarily before beginning to flex the knee. Or if the patient be asked, as he lies on his back, to bring his heel to his buttock, he may do it in two stages: first flexing his hip and only later flexing his knee. Similarly, if when able to leave bed he attempts to place his foot on a chair, he frequently raises the foot too high by flexion of his hip before he bends his knee.

In other words, the patient tends to perform the separate movements that constitute an act "by numbers," as in a gymnasium or in military drill. This is the condition which Babinski has termed asynergia; he has defined it as "the inability to accomplish simultaneously the various movements that constitute an act."

The question arises whether this decomposition of movement is voluntary or not. I know of no test that can settle this point directly, but the fact that it may be observed in its extremest form when the
patient, still in a dull and stupid state on recovering from the early general effects of a wound, or after an operation which has entailed further damage of the cerebellum, first makes purposive movements, suggests strongly that it is not always a willed device by which he attempts to diminish the inaccuracy of his limbs.

(ii) Asynergia.—The term asynergia can be more correctly restricted to the absence or disturbance of that proper synergic association in the contraction of agonists, antagonists and fixating muscles, which assures that the different components of an act follow in proper sequence, at the proper moment and are of the proper degree, so that the act is executed accurately and with the least possible expenditure of energy.

When the fingers are flexed the extensors of the wrist normally contract synergically with appropriate force in order to prevent simultaneous flexion of the wrist, but when a patient with a cerebellar lesion grasps a small object quickly it often happens that the wrist of the affected side is extended excessively or too early, so that the hand is bent backwards when the fingers are but half flexed: the normal co-operation of the contracting muscles, on which the accuracy and precision of the action depends, is consequently disturbed. This can be often seen more definitely when the patient flexes and extends his fingers rapidly; then the wrist often flexes as he brings his fingers into his palm, or extends too much as he straightens them, or the finger movements and the synergic wrist movements may be partly dissociated or inaccurately combined in time or in degree.

A disturbance of synergia, which should keep the legs extended and thus bring the centre of gravity of the body as near the pelvis as possible, is also the explanation of the fact that in attempting to rise from the supine position by flexion of the trunk upon the hips the heel of the affected side often rises from the bed (Babinski). Frequently, however, only the knee is raised by flexion of the hip on the trunk and the heel remains in the bed owing to failure of the normally associated contraction of the quadriceps extensor. Babinski has also shown that the cerebellar patient, when standing, often falls when he throws his head backwards, owing to his failure to bring his centre of gravity over his base by flexing his knees, and I have observed this in several cases. When asked to sit down on a low bed or stool he is also liable to fall backwards, as he again fails to adjust his balance by flexing his trunk on his hips. Other examples are seen in walking, as the affected arm generally hangs inertly by his side and does not swing forwards when he advances his opposite foot; and in the failure of his head and eyes to move simultaneously when he looks to one or the other side.

In the majority of such movements the contracting muscles (agonists) have to displace the limb or some of its segments against gravity, and
472. The Symptoms of Acute Cerebellar Injuries

their antagonists only relax reciprocally; but in other actions, as when the elbow is fixed above his head and the patient brings his finger down to his nose, that is in the direction in which its weight would move it, the most important factor is the gradual relaxation of muscles which are the antagonists of the flexors of the elbow. The disturbance in the co-ordinated activity of agonists and antagonists suggested comparison of movements executed with and those performed against gravity, but though this was investigated in certain cases, as by making the patient bring his finger successively up to and down to his nose by merely bending his elbow, no significant difference could be detected.

(iii) Dysmetria.—Another striking abnormality in the affected limbs is the fact that the range and the force of their movements are not correctly adapted or proportioned to their aim; they are ill-measured or dysmetric (Luciani). In attempting to touch a point, for instance, the finger-tip often shoots past it, or more rarely the movement is arrested before it reaches it. And in bringing his finger to his nose, the patient may either strike his face too forcibly, or arrest the movement momentarily before he reaches it. Similarly, when asked to grasp an object, he throws his arm forward with excessive force, opens his hand unnecessarily widely, and finally seizes it too roughly and too forcibly. In other words, neither the range nor the force of the movement is accurately adapted to its aim.

This is particularly prominent in quick movements; when the movement is slow, and can be closely watched by the patient, it is more correctly graded, but even in slow and deliberate actions, as in carrying out Bárány's pointing test, dysmetria may be seen. Often, too, as he makes a deliberate attempt to touch his nose, he allows his affected hand to flop heavily against his face, as though he were too lazy or careless to pull it up.

It is noteworthy that as has been pointed out by other observers (Babinski, André-Thomas), the range of movement is most commonly excessive, but in the early stages of acute cerebellar lesions it happens frequently that the movement is arrested or slowed down before the point the patient wishes to attain is reached, and the hand or foot is then brought to it by a series of slow deliberate jerks. In a few cases the most striking abnormality when the patient tried to take hold of an object was the tendency of the affected hand to stop short of it, pause for a moment, and then swoop down on it with excessive force. In other actions, too, when he tries to bring the tips of his fingers successively to the top of his thumb, the range of movement is often too small rather than excessive.

This dysmetria is particularly pronounced in the attempts to perform accurate movements against resistance, as when he tries to raise a moderate weight, or to release his finger from the observer's grasp and bring it directly to the tip of his nose. It is under such conditions that
the difficulty in arresting a movement that was correctly initiated is most obvious. These facts suggest that dysmetria bears a close relation to the symptoms described under the "rebound phenomena."

(iv) \textit{Tremor}.—Voluntary movement is also often complicated and disturbed by the occurrence of tremor in the moving limb, but this is not such a prominent factor in the early as it is in the later stages of a cerebellar lesion. In the notes on many of my more serious cases it is stated definitely that there was no tremor.

Frequently, however, and especially in quick movements, the finger or toe is approached at a fairly uniform rate to within a few inches of the point the patient wishes to touch, and is thence brought to it by a series of irregular brusque jerks, which to some degree resemble those of ordinary intention-tremor, though the pauses and interruptions of movement are usually less abrupt, and the projections more deliberate and larger in range. And even when the limb reaches the object for a time it is not held steadily in contact with it; after the patient has brought his finger to his nose, for instance, the tip of the latter is often intermittently depressed or displaced to one side or the other.

The coarser forms of tremor may be associated with dysmetria, the movement being arrested too soon, and the limb then approached to the object by a series of jerks; or it may be due to voluntary arrest of the primary movement and the subsequent attempts of the ataxic limb to reach its aim. It cannot be attributed wholly to these causes. When simple movements, as flexion or extension of the forearm or leg, are carefully observed, it may be often seen that the limb is moved in a series of irregular jerks, and that the tremulousness usually increases towards its completion when accuracy is most essential. It is occasionally possible by palpation of the muscles to detect an irregularity or discontinuity in their contractions. Occasionally, however, the movement seems to be interrupted by irregular intervention of the antagonists. Consequently, even from its commencement the movement is often irregular, and throughout its whole range it lacks the continuity and uniformity in rate which distinguish ordinary voluntary displacements of a limb.

(v) \textit{Deviations from the line of movement}.—It has been already stated that the irregularity of movement in the early stages of a cerebellar lesion are partly due to the fact that the limb deviates from the direct line, and is not moved along the shortest course that it should naturally take; but this symptom needs more emphasis, as it has been overlooked by many clinicians who have studied chiefly the later effects of cerebellar injuries, or the symptoms of atrophic or degenerative diseases of this organ.

This deviation in movement was observed by Grainger Stewart and myself after the removal of tumours and surgical damage of the cerebellum, and I have seen it frequently since in similar cases. It is equally obvious
The Symptoms of Acute Cerebellar Injuries

in recent gunshot injuries. In the early part of the movement the limb sways about in a purposeless manner as soon as it is raised from its support; during the movement it deviates from its proper course, and towards its completion it does not come straight to the object it should touch or seize; in trying to touch his nose, his finger, for instance, often comes to his cheek or eye. One patient declared that when he attempted to feed himself with the affected hand it was frequently to his ear that he brought the food, and another that he could not use this hand in smoking, as he was afraid of putting the cigarette into his eye. This error cannot be attributed to dysmetria, or to properly directed movements executed with ill-graded force, as the hand which the patient wishes to bring to his nose often comes to his cheek or eye even when it is moved from directly in front of his face.

The slow swaying at the commencement of the movement is most pronounced when the limb is atonic, and it seems to be directly associated with loss of tone in the muscles that should fix its proximal joints; it often suggests an asthenic or paretic condition. But the deviation from the direct course during the movement and the failure to bring his hand or foot to the correct point, must be attributed to disturbance in the regulation of the force and sequence of the contractions of the different muscles employed in the act. Decomposition of a movement naturally produces errors in its direction, and a similar disturbance in the co-operation of the various muscles, even though it does not cause obvious decomposition may lead to deviations from the correct direction.

It is an interesting point whether there is any constancy in the direction in which the limb deviates during and at the completion of the movement, and if so what its relation is to the direction in which it tends to deviate when unsupported and in Bárány's pointing test. No regularity in the direction of the deviation can, however, be observed in early cases, though later the frequent tendency to spontaneous deviation often influences the direction of the error. One man, twenty months after the infliction of a cerebellar wound but who now presented symptoms of disseminated sclerosis as well, in attempting to touch his nose when his eyes were closed always brought his forefinger to that side of it towards which his arm tended to deviate in Bárány's test, and the same fact was observed in another patient three months after he had been wounded. It is in such cases that Babinski rightly contrasts the failure of the cerebellar patient with that of the tabetic in attaining his aim.

After the first few weeks, according to the nature and the severity of the wound, these disturbances of voluntary movement begin to alter in character. When the patient raises his arm or leg the limb sways about less aimlessly, in movement its deviations from the correct direction are less obvious, and it generally reaches its aim more directly.
At the same time the tendency to decompose or "two-stage" movements is less common in simple actions, as in bringing his finger to his nose, though it can still be detected in more complex actions. The disturbances in the co-ordination of agonists, antagonists and synergic muscles also diminish; in closing his fingers quickly there is less tendency to over-extension or to flexion of the wrist, and the wrist and finger movements are more correctly associated when he rapidly extends or flexes the latter.

On the other hand, the deficient regulation of the range and force of movements, which has been described as dysmetria, persists or may be even more striking now. The arm is flung out from the shoulder and the hand tends to grasp every object with too much force. At this stage the range of movements is much more frequently excessive than short of its aim; dysmetria therefore generally takes the form of hypermetria. Movements consequently tend to be performed too abruptly and too forcibly, though they still start more slowly than those of the normal limb.

Now, however, voluntary correction begins to play a greater part; when the patient's movements and actions are carefully watched it may easily be seen that he tries to correct his errors. If on one occasion he overshoots his mark, in subsequent attempts he may stop short of it. The patient who stated that he could not pull up the affected arm quickly now began to arrest his finger short of his nose when he attempted to touch it, and then brought it in contact with it by a series of deliberate coarse jerks; and if the arm at first tended to strike his cheek or eye when the patient tried to bring his finger to his nose he now stops before he reaches his face and completes the action in the same intermittent, jerky fashion.

An irregularity in movement resembling intention-tremor is consequently a prominent feature at this stage. This cannot however be attributed wholly to the intervention of voluntary effort in order to control the errors, as even the jerks are irregular and inappropriate in range and force, though it is usually more pronounced the more rapidly the movement is performed and consequently the less opportunity the patient has to correct his errors voluntarily.

But in order to understand more fully these disturbances of voluntary movement it is necessary to investigate the symptoms included here in the rebound phenomenon, and to observe the affected limbs as the patient attempts to perform alternate movements rapidly with them.

(To be continued.)