THE DIAGNOSIS

of

TUMOURS OF THE LATERAL LOBE

of the

CEREBELLUM.

By

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There are few departments of medical knowledge in which more striking advances have been made within the last twenty years than in the localisation of intracranial lesions. It is, however, noteworthy that, while the localisation of cerebral diseases has already attained a high degree of accuracy and exactitude, cerebellar lesions have attracted much less attention. The reasons for this are not far to seek. In the first place, tumours of the cerebellum are numerically rarer than those of the cerebrum; for example, out of 300 cases collected by Starr —

178 were in the Cortex Cerebri
56 " " Centrum Ovale
141 " " Cerebellum.

Secondly, the functions of the cerebrum have been to a large extent elucidated, whilst those of the cerebellum are still obscure and disputed, despite the valuable experimental and pathological work done by various observers: Moreover, tumours of the cerebrum are more easily accessible to the surgeon than those of the cerebellum, and the numerous brilliant successes of cerebral surgery, in the hands of Macewen, Godlee, Horsley and others, contrast favourably with the gloomy
list of unsuccessful attempts to remove cerebellar
tumours, a record of failures unbroken, I believe, until
1895, when Mr. Annandale succeeded in removing a cere-
bellar tumour from a situation where I had been fortunate
enough to localise it.

The following paper is an attempt to clear away,
to some extent at least, the obscurity in which cere-
bellar tumours have hitherto been involved, by a closer
scrutiny of the clinical appearances in a number of
cases, some of which have been personally observed, the
others being gathered from a study of the contemporary
literature of the last few years on this subject.

References to cases of abscess in the cerebellum
have been purposely omitted, since the association of
the latter, in the vast majority of instances, with
middle ear disease renders their diagnosis less diffi-
cult.

The observations of most authorities have hitherto
been concerned mainly with the middle lobe, or vermiform
process, of the cerebellum, and with the middle peduncles
and it is the prevailing opinion that the localization
of a cerebellar lesion to one or other lateral lobe is
impossible. "Such a lesion"—to quote Gowers—"seems
per se to cause no symptoms by which it can be recognised."
Tumours of the lateral lobes, however, are precisely those which, if recognised, would be par excellence the ones most amenable to surgical treatment: It is quite otherwise with tumours of the middle lobe which is so inaccessible and so near to the vital centres in the region of the fourth ventricle that it is not likely that a tumour in such a situation could be attacked successfully by the surgeon, even if correctly localized, except perhaps in a few cases of cyst of the middle lobe in which it is conceivable that the contents might be evacuated, or in cases where the extreme posterior end of the vermis was alone affected.

I propose in the following pages to relate the clinical history of several cases which it has been my good fortune to observe and to adduce other cases which I have been able to collect from a study of the contemporary literature of the last few years.

Case A: (Edinburgh Hospital Reports: vol.iii.1895:).

The patient, a married woman, aged 25, was admitted to Ward 25 of the Royal Infirmary of Edinburgh on 8th April 1895, under the care of Sir Thomas Graham Stewart. In his absence, Dr. Gibson was in charge of the ward.

She complained of headache, giddiness, and difficulty in walking. These symptoms had commenced ten months
before admission, and had steadily grown worse, in spite of treatment.

Her family history was satisfactory, there being no evidence either of tubercular or of inherited specific disease. She had been married for three and a half years, and had borne one child, which died from convulsions at the age of 8 months, four weeks before patient's admission to Hospital. When the child was 3 months old, it had on its face and body a rash the exact nature of which the mother could not describe. Patient never had any miscarriages. There was no history of syphilis, either primary or secondary. The health of patient's husband, who is a sailor, could not be ascertained.

Patient was examined on the day after admission, and the following conditions were found in the nervous system:

As regards the sensory functions, there were no subjective sensations of any sort, with the exception of a deep-seated headache, which patient described as feeling "like a sharp dagger," strictly localised to the frontal region, exactly over the left eye. This pain was not increased by firm pressure, nor by tapping over the painful area. There was no cutaneous anaesthesia anywhere, and the muscular sense was normal. On examination of the eyes, there was found constant marked
nystagmus, both in the horizontal and in the vertical meridians. The left pupil was larger than the right; both pupils reacted to light and to accommodation. On ophthalmoscopic examination, marked optic neuritis was found in both eyes. Although the external and middle ears were normal; yet patient was completely deaf in the right ear, both to external sounds, such as the ticking of a watch, and to a tuning-fork placed on the vertex. Taste and smell were normal.

As regards the motor functions, there was no motor paralysis or paresis, except in the soft palate, the functions of which seemed to be slightly impaired, as evidenced by the regurgitation of fluids through the nose during swallowing. Her voice was somewhat "bleating" in character, and she herself noticed that it had altered from its normal state. The larynx was not examined. The organic reflexes were normal, with the exception of deglutition, which was occasionally a little difficult, especially on attempting to drink large draughts of fluid. The skin reflexes were normal.

Both knee jerks were equally exaggerated, and occasional ankle clonus could be elicited on both sides. Patient's gait was very pitching and staggering in character; she reeled along, walking on a broad base, planting her feet widely apart, but neither stamping her heels nor scraping
her toes. She complained of distressing vertigo, but only when she moved in bed or tried to sit up or walk. So long as she lay still, there was no feeling of giddiness. Her gait was so unsteady that she tended to fall unless supported, and there seemed to be a slight tendency to fall to the right side. On making patient stand, with her eyes shut and feet together, the swaying was very marked, and here also she tended to fall to the right side.

There were no vasomotor or trophic changes. Patient's intelligence, attention, and memory were excellent. She slept badly, owing to the persistent headache, which was always worst at nights. There was no abnormality to be discovered on examination of the cranium and spine.

As regards the other systems, the alimentary system was normal, save for a slight tendency to constipation; the lungs and heart were quite sound. As to the integumentary system, there was a small patch of ichthyosis over each ligamentum patellae. With regard to the reproductive system, patient had amenorrhea of four months' standing. The urine contained no abnormal constituents.

Prior to admission, patient had not suffered from vomiting, but this symptom supervened a few days after she came into Hospital. This vomiting recurred at
intervals, at first, of several days, but later more frequently, and it was quite unassociated with the ingestion of food.

Such being the clinical facts, the question of diagnosis next arose. The presence of headache, vomiting, and double optic neuritis indicated some intracranial lesion. The fact that the headache was constantly worse at night, the history of a suspicious rash on patient's child, and the husband's occupation - that of a sailor, absent for protracted periods in distant parts of the globe - pointed to the possibility of the case being a syphilitic one. The absence of distinct motor paralysis, either of limbs, trunk, or face, combined with the presence of a staggering gait and distressing vertigo, pointed clearly to the cerebellum as the seat of the lesion.

The farther question, as to the exact part of the cerebellum affected, next presented itself for consideration.

The observations of most authorities have been concerned hitherto mainly with the vermiciform process and middle peduncles of the cerebellum, and that localising symptoms are found in lesions of these parts much more frequently than in lesions of the lateral
lobes, is quite to be expected, when we consider that the fundamental part of the cerebellum is its middle lobe, for, as we descend the animal scale, we find that the cerebellar hemispheres become relatively smaller and smaller, until in birds they entirely disappear, the whole cerebellum there corresponding to the middle lobe in man. The chief sign regarded as diagnostic of lesions of the middle lobe, namely, swaying of the body in some particular direction during locomotion, did not afford much assistance in this case, for the tendency to fall to the right side was not at all pronounced. The other signs and symptoms, therefore, came to be considered more carefully.

The most distressing symptom, and the one of which the patient most persistently complained, was a constant, deep-seated, "boring" headache, strictly localised to a small area in the left frontal region. A consideration of the anatomy of the cerebellum seemed to afford a feasible explanation of this.

Briefly, the main connections of the cerebellum are as follows:- The cerebellum has three sets of peduncles - inferior, middle, and superior. Of these, the inferior peduncles, or restiform bodies, connect the upper part of the middle lobe of the cerebellum with the nuclei of the posterior columns of the cord, some of the fibres
(the anterior-external arcuate fibres) decussating as we trace them downwards, others (the posterior-external arcuate fibres, and the fibres of the direct cerebellar tracts) remaining uncrossed. The middle peduncles of the cerebellum form the transverse fibres of the pons, which fibres were formerly considered to be mainly commissural. More recent observations, however, show that this is not so, but that the transverse fibres of the pons arise mostly in the cortex of the cerebellar hemispheres, and pass across the middle line to nerve cells in the pons, which nerve cells again are connected with the various lobes of the cerebrum. Each superior cerebellar peduncle arises mainly in the interior of one dentate nucleus, but also in part from the cortex of the cerebellum, and especially from the lower part of the lateral lobe. Its fibres, when traced upwards, are found to decussate with those of the opposite side, between the corpora quadrigemina. Most of the fibres pass to the red nucleus of the tegmentum of the opposite side, whence other neurons start and can be traced to the frontal lobe of the opposite cerebral hemisphere, thus constituting a fronto-cerebellar tract.

With these facts in view, the left frontal headache led one to think of the possibility of the superior
peduncular fibres being affected in this case, and the question next arose as to which part of the fronto-cerebellar tract might be involved. Other symptoms here assisted in the diagnosis. The labyrinthine deafness on the right side indicated a lesion of the auditory path on that side. The hitherto accepted view, as regards the course of that portion of the auditory path above the nucleus, is that it passes up from the auditory nucleus through the most superficial layer of the tegmentum. Meynert, however, thinks that it passes through the cerebellum, and Gowers admits that there are at present no facts inconsistent with this hypothesis. The labyrinthine deafness, then, would be consistent with a lesion either of an auditory path in the cerebellum, or in the auditory nucleus or nerve itself.

The motor paresis of the soft palate, as evidenced by the tendency of fluids to regurgitate through the nose during the act of swallowing, pointed to some implication of the bulbar part of the spinal accessory. This would, therefore, indicate that the tumour, if tumour it really were, was pressing on the medullary region, that is, it must be pretty low down in the cerebellum.
From a consideration of these facts, which, it will be noticed, are largely anatomical, the diagnosis was made that there was a tumour in the lower part of the right lateral lobe of the cerebellum. Whether the tumour was of the nature of a gumma, a new formation, or a tubercular mass, could not be determined.

With the view of eliminating as far as possible the chance of the lesion being a syphilitic one, the patient was at once placed under treatment by gradually increasing doses of iodide of potassium, until, on 20th April, she was taking 60 grains three times a day. In addition to these massive doses of iodide, inunction with blue ointment was applied every day to two parts of the head - over the right half of the cerebellum, and over the seat of pain in the frontal region. This treatment was continued until 30th April. So far from improving, the patient grew worse, all her symptoms became more aggravated, and more especially the vomiting became more frequent. On 30th April, therefore, she was transferred to Professor Annandale's ward, with a view to surgical interference. After her admission to Professor Annandale's ward, the vomiting increased still more in frequency, and the patient was evidently going from bad to worse.
On 3rd. May, Professor Annandale cut down over the right lobe of the cerebellum, trephined the skull, and discovered a tumour about \(\frac{1}{2}\) in. below the surface. The tumour was about the size of a pigeon's egg, and lay low down in the lateral lobe of the cerebellum, rather closer to the foramen magnum than to the outer wall of the skull. On opening into the mass, about a drachm of clear serous fluid escaped and was lost. Within the cyst was found a solid tumour, apparently encapsulated. This was removed piecemeal, and subsequent microscopic investigation showed it to be of the nature of a fibro-sarcoma.

Since the operation, the progress of the case has left nothing to be desired. When the patient recovered from the chloroform anaesthesia, the frontal headache had entirely disappeared and since then it has never returned: The sickness has also entirely ceased, the nystagmus has become much slower and of a peculiar character: (vide later) Optic neuritis is absent from both eyes. The feeling of giddiness has entirely disappeared but the labyrinthine deafness of the right ear still persists. Deglutition is again quite perfect even with fluids and the voice has lost its former tremulousness.

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The following are notes of the patient's condition at various dates after the operation:

July 4th. 1895. Nystagmus occurs now only when patient fixes her eyes on some object not directly in front of her: On moving the eyes in the vertical meridian, nystagmus occurs only on upward rotation. In the horizontal meridian the nystagmus is still well marked on rotation to the left, much slower and less marked on rotation to the right. Both knee-jerks are still lively, especially on the right side, but there is no ankle-clonus. Her gait is no longer typically cerebellar: she now walks very well, with just the slightest suspicion of a lurch now and then: There is no difficulty in turning round rapidly, nor is there any swaying on standing with the eyes shut and the feet together.

December 12th. 1895: Patient gave birth some six weeks ago to a healthy child after an easy and natural labour. She made a good recovery and is still nursing her baby in part, but the supply of milk is very inadequate. The gait and nystagmus remain much the same as when last examined.

Jan. 31st. 1896: On examination to-day, patient's gait is found to be much the same: she can walk along a straight line very well, but at every 7th. or 8th.
step she gives a slight lurch and these lurches appear to occur towards each side alternately. Both knee-jerks are lively, the right being still slightly more marked than the left: there is no ankle-clonus: The palate is normal, both during rest and on phonation. The pupils are equal and normal: and the fundi are normal. Nystagmus as before, i.e. most marked on rotation upwards and to the left. Over the site of the operation wound there is a soft, slightly pulsatile swelling, collapsing somewhat on firm pressure: it is painless except on very firm pressure: Patient's weight is 10 stones 6 1/4 lbs:

Such, then, is the record of this unique case. Let us consider what are the conclusions that may fairly be deduced from it.

The tumour was diagnosed and successfully removed from the right lateral lobe of the cerebellum, a region which has hitherto by most authorities been regarded as devoid of symptoms or signs by which it can be diagnosed. "The diagnosis of a tumour of the cerebellum," says Starr, "is easy when the tumour lies near the median line, but is impossible when it lies near the surface in the lateral portion of the hemispheres." Such a con-
clusion is in complete accordance with the views of Flourens who in 1824, after a series of classical experiments on birds and mammals, arrived at the opinion that the middle lobe is the only essential part of the cerebellum: This view has been endorsed by all the clinical writers up to the present day who, without a single exception, so far as I can find, hold that tumours of the lateral lobe only produce symptoms indirectly, by pressure upon the middle lobe, pons and medulla.

Recent work, however, by Ferrier and especially by Risien Russell, shows that experimental destruction of one lateral lobe of the cerebellum often produces signs which are quite characteristic and recognisable. To these we shall return later.

Observe, then, that the tumour in this case was in the very situation stated by most authorities to be par excellence the site which is devoid of pathognomonic signs or symptoms:

From a study of this clinical case, let us now endeavour to select the unilateral as distinguished from the bilateral or general phenomena. In our case the following symptoms and signs were undoubtedly unilateral:
1. Crossed "fronto-cerebellar" headache on the left side.
2. Labyrinthine deafness, on the right side.
3. Exaggeration of the right knee-jerk.
4. Nystagmus on rotation upwards and to the left:

All of these still persist, with the exception of the headache, and the last three obviously cannot be due to pressure upon the middle lobe, pons, or medulla, since the tumour has been removed. Let us consider these four phenomena seriatim:

**Crossed Fronto-Cerebellar headache:**

This, I believe, was first called attention to by myself and in the above case it was one of the chief factors in determining the diagnosis. It will be observed that the headache was on the opposite side of the head from the lesion and a possible anatomical explanation of this fact has been offered above. The value of this symptom can only be determined by clinical observation in other cases (see later, Cases B. & C.) since its presence cannot be ascertained experimentally in the lower animals.

**Labyrinthine Deafness on the side of the lesion:**

This has been already discussed. When present, it is of great value as indicating the side of the brain affected.
(see also Cases B. & C.) but cannot apparently be held to have especial reference to the cerebellum.

Exaggeration of the knee-jerk on the side of the lesion: This has been present ever since the operation and the usual explanation of it, viz:—that it is due merely to pressure on the middle lobe, cannot be the correct one, since this sign is still present although the pressure on the middle lobe of the cerebellum has presumably been removed. Moreover its pressure harmonises in a remarkable way with the results obtained experimentally by Risien Russell after destruction of one lateral lobe of the cerebellum, where, again, the middle lobe was left untouched. Nor can it be explained as due merely to pressure of the opposite pyramidal tract against the floor of the skull, since it still persists.

Nystagmus on Rotation of the Eyes to the opposite side from the lesion. This has been repeatedly observed and verified in the above case ever since the operation, and it is still present: This sign I am also inclined to attribute to the destructive lesion in the right lateral lobe of the cerebellum and it is interesting to note that a somewhat similar nystagmus has also been observed by Risien Russell in cases of experimental ablation of one lateral lobe of the cerebellum: I am not yet prepared to offer any exact explanation of this phenomenon.
CASE B: (unpublished.)

This patient, a woman forty-seven years of age, was admitted to the Chalmers Hospital, Edinburgh, on 2nd November 1893, complaining of severe headache, somewhat paroxysmal in character, which had been present for about eight or nine months before admission: The pain was situated in the right frontal region: She had also suffered occasionally from attacks of vomiting which had been regarded as hepatic in origin. On several occasions before admission she had general convulsions, said to have been without any loss of consciousness, and there was a vague and indistinct history of these twitchings having on one occasion started in the left arm: The convulsions were said to have been clonic, not preceded by any cry and not followed by stupor: She had severe giddiness but she could not say that she ever fell or inclined to fall to one side more than another.

On admission, she had severe right frontal headache and there seemed also some tenderness on tapping over this area. The patient could not walk and had been unable to do so for two months. When supported on each side, her gait was dragging and distinctly paraplegic, both sides being equally affected. Ankle-clonus and
exaggerated knee-jerks were present on both sides, more markedly on the left side. The muscles of the lower limbs were flabby, particularly on the left side.

There were no sensory changes in cutaneous or mucous surfaces: Hearing was markedly impaired in the left ear.

The field of vision was contracted in both eyes and there was well-marked double optic neuritis. The pupils were sluggish, but otherwise normal: There were no indications of affection of any of the ocular muscles.

After admission, the patient was placed under treatment with potassium iodide and potassium bromide. After a week the attacks of vomiting ceased.

The patient remained much in the same state until November 20th, when some atony was noticed in the right side of the face, the left palpebral fissure being narrower than the right, and the angles of the mouth being not quite symmetrical. The tongue was protruded straight. The patient was drowsy and in addition to the frontal headache she had now some occipital pain with retraction of the neck and a degree of rigidity of the cervical muscles. She was irritable and greatly resented being moved in bed. The temperature was sub-
normal. The pulse was weak and about 74 per minute.

As the patient was evidently sinking, it was decided to operate and on Nov. 22nd. Dr. P. Heron Watson trephined over the right motor area. The fissure of Rolando was exposed in nearly its whole length. The dura mater was found natural, not bulging, and pulsating very slightly. A hypodermic needle passed through the dura mater yielded blood only: The wound was then closed.

Immediately after the operation, the patient seemed neither better nor worse. The headache, frontal and occipital, persisted, the temperature rose to 101°F and a degree of cardiac failure supervened, the pulse being for some hours imperceptible at the wrist: Digitalis, whisky and nutrient enemata supported life for two days, when the patient died without any convulsion or farther access of paralysis.

A post-mortem examination was made with the following result:—The operation wound was quite healthy and the subjacent brain was normal. There was a considerable effusion of fluid at the base of the brain: On incising the tentorium cerebelli on the left side, there was at once noticed to be something abnormal about the cerebellum: There was a tumour, about the size of a
walnut, lying in relation to the left lateral lobe of the cerebellum, apparently having its origin from the pia mater. Its anterior end lay in a deep sulcus on the posterior surface of the petrous temporal bone, in relation to the internal auditory meatus and in close proximity to the facial and auditory nerves. It was also connected with the pia mater between the cerebellum and the temporo-sphenoidal lobe of the left side and pressed distinctly against the left side of the pons and medulla. The left 6th nerve lay along the inner side of the tumour (during life there had been no evidence of pressure on this nerve) No other cranial nerves were involved in the growth: The tumour itself was firm, rounded, slightly lobulated and well defined. No trace of haemorrhage, softening or caseation could be seen: Around it there was evidence of recent meningeal inflammation, extending in between the cerebellum and the temporo-sphenoidal lobe of the cerebrum. Microscopically the growth was found to be a fibro-sarcoma.

The above case is of great interest when compared with Case "A", since in both cases the fronto-cerebellar headache was equally well marked. In Case "B", the tumour (it should be observed) was in the region of the
left lateral lobe of the cerebellum whilst the greatest pain was referred to the right frontal region. There can be no doubt of the peculiar site of the headache in this case, since the operator was thereby led to trephine over the seat of maximum pain, but with a negative result. Nor could any blame be attached to the surgeon in this case, since the existence of "crossed fronto-cerebellar" headache had not yet been called attention to by anyone: In this latter case I never saw the patient during life and I only obtained the full notes of her case after the publication of my own paper in 1895.

Again, it should be observed that in Case "B", just as in Case "A", the knee-jerk was exaggerated on the side of the lesion. There is no history of any nystagmus in Case "B" but the tumour was somewhat farther forward in the lateral lobe than it was in Case "A" and this possibly may be the cause of the presence of nystagmus in the one case and not in the other:

There was also in this case, just as in Case "A", deafness on the same side as the lesion, but this was explained by the direct implication of the left auditory nerve in the growth.

Case "B", then, corroborates Case "A" in several particulars, and notably in the presence of "crossed
fronto-cerebellar headache" in both. Both cases agree also with experimental observations on the lower animals inasmuch as the knee-jerk in each case was exaggerated on the side of the lesion.

CASE "C". (unpublished.)

This patient, a boy aged 10 years, was admitted to the National Hospital, Queen Square, London, on June 25th, 1895, complaining of headache, vomiting and staggering gait. The staggering had been observed for about three years. He was noticed to drag his right leg a little and to have some weakness of the right arm and shortly afterwards the headache and vomiting had appeared.

Seven years ago the patient suffered from a convergent squint for which he had been operated on, but with only partial success.

On admission he was found to be a well-nourished, healthy-looking boy, of exceptional intelligence. He had obvious internal strabismus of the right eye. His temperature was normal.

He complained of occasional paroxysms of pain which he localised to a spot exactly over the left eyebrow.
He said that the pain started at this spot and spread inwards to the middle line, where it stopped. He also suffered from attacks of giddiness in which everything seemed to be turning upside down. There was no history of any convulsive attack.

On examination, with the exception of marked double optic neuritis, all the cranial nerves were found to be normal: The internal strabismus of the right eye has already been alluded to.

There was no loss whatever of any form of sensation. His gait was staggering and when he stood still he tended to fall backwards. On the day of admission he seemed to fall somewhat to the right, a fortnight later he tended to fall to the left. All movements of the arms, legs and trunk could be executed normally, there being no muscular weakness anywhere. All the superficial reflexes could be elicited normally, save the scapular. The knee-jerks on admission were difficult to obtain, but a fortnight after admission they were exaggerated, the right more so than the left and there was a tendency to ankle-clonus on the right side. No elbow jerks were obtained but the jaw-jerk was present. The organic reflexes were normal. Speech and articulation were quite good. The chest, abdomen and urine were examined
and found to be normal.

The patient remained in much the same condition, with occasional attacks of vomiting, but the increase in the right knee-jerk became more distinct and his spinal muscles appeared to contract better on the right than on the left side when sitting up.

The diagnosis of a cerebellar tumour was made, but the precise locality within the cerebellum was left undecided.

On July 20th. Mr. Horsley trephined over both lobes of the cerebellum and, by enlarging the openings with bone-forceps, connected the two trephine openings across the middle line, the posterior margin of the foramen magnum being cut away. When this had been done, the dura mater, being exposed, was then observed to bulge much more on the right side than on the left.

The dura mater was not opened at this stage, the scalp being replaced and stitched in position. Three days later, the second stage of the operation was performed. The dura mater being incised over the swelling on the right side, cerebellar tissue at once bulged out until a mass the size of a walnut protruded, when suddenly a cyst within ruptured and about an ounce of clear fluid gushed out through a rent in the cerebellar sub-
stance. The remainder of the right lateral lobe of the cerebellum was then felt to be infiltrated by a soft growth which could not be shelled out.

The patient recovered well from the operation. A week later, some nystagmus was observed for the first time on lateral deviation: Later, patient developed occasional tremors of the right hand and forearm, which were found to be distinctly weaker than the left. This tremor was most marked on voluntary effort such as picking up a pin, touching his nose - etc. The nystagmus gradually diminished and disappeared, persisting longest on voluntary deviation to the left side.

When patient was discharged on Oct. 9th, eleven weeks after operation, he could walk quite well, but when his eyes were shut for several minutes he tended to fall backwards. The right knee-jerk could be obtained only by Jendrassik's method, the left not at all. The optic discs were somewhat pale, and the swelling had quite subsided.

I examined the patient on March 1st, 1897, a year and eight months after the operation and found his general condition excellent. There was no headache or giddiness: and there had been no sickness since his discharge from hospital. His intelligence and memory
were excellent. The pupils were equal and reacted normally to light and accommodation. The eye movements were good, but there was still some weakness of conjugate deviation to the right, and on looking to the extreme left a few slight nystagmoid jerks could be detected. The discs were pale: Vision in the right eye was $6/6$, in the left $6/15$. The tongue and palate were normal. A watch could be heard ticking at a distance of two feet from either ear. Co-ordination of the arms and legs was perfect and no motor weakness could be detected. The grasp of the right hand was 18, that of the left 16. (with a stiff dynamometer.) His gait was quite devoid of unsteadiness, but on walking slowly he planted his feet somewhat wider apart than normal. He could turn round promptly without any difficulty and did not tend to fall with the eyes shut and the feet together.

The right knee-jerk was brisk - the left absent, even with Jendrassik's method: There was no ankle clonus. Both plantar reflexes were absent.

There was a large pulsatile swelling in the sub-occipital region, projecting about an inch beyond the level of the skull. It was slightly collapsible on firm pressure, but not tender.

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This case in several points closely resembles the two cases previously related. Let us briefly recall the chief signs and symptoms in this case which may fairly be held to be unilateral.

(1) Crossed fronto-cerebellar headache.

(2) Inequality of the knee-jerks, that on the side of the lesion being greater than the opposite one. There was, moreover, at one period of the disease a tendency to ankle clonus on the side of the lesion.

(3) Apparent more vigorous action of the spinal muscles on the side of the lesion - when sitting up.

(4) During convalescence, nystagmus, especially on conjugate deviation of the eyes away from the side of the lesion.

(5) Weakness of the arm and leg on the side of the lesion.

In this case the crossed fronto-cerebellar headache is the exact counterpart of that observed in Case "A". and, as in Case "A", it disappeared after the operation: Its significance appears to be considerable, since here also it was the only pain complained of by the patient.
The exaggeration of the knee-jerk on the side of the lesion agrees exactly not only with both the two previous cases: but also with the results obtained experimentally by Risien Russell on removal of one lateral lobe of the cerebellum.

The apparent more vigorous contraction of the spinal muscles on the side of the lesion, I am inclined to think, was really due to a degree of weakness in these muscles, causing the patient to throw them more violently into contraction in order to maintain his balance: Experimental and clinical evidence (cp. Hughlings Jackson, Risien Russell, Niemeyer, &c.) goes to show conclusively that the lateral lobe of the cerebellum influences the corresponding side of the spinal cord and that in diseases of the cerebellum the spinal muscles are proportionably much more weakened than those of the limbs: Hughlings Jackson indeed goes so far as to suggest that "the cerebellar reel is to be accounted for on the view that the erratic movements of the legs are attempts on their part to run after and prop up the trunk in its immoderate inclinings resulting from the weakness of the spinal muscles."

This view I am also inclined to support owing to some experiments which I have made on several cases of
cerebellar disease in which I caused the patient during walking to be supported under both axillae, thereby taking the weight of the trunk off the legs: In the cases in which I tried this, the patient's gait at once lost its reeling character and the subjective feeling of giddiness for the time entirely disappeared.

The peculiar nystagmus which was observed in Case "C" during convalescence is almost the exact counterpart of that noted in Case "A" and it therefore seems to be of some localising significance.

The weakness of the arm and leg on the side of the lesion corresponds exactly with the experimental results of Risien Russell in dogs.

At this stage it will be well to recapitulate shortly the signs observed after experimental ablation of one lateral lobe of the cerebellum: These are:-

(1) Increased excitability of the cerebral cortex on the opposite side as tested electrically or by the production of absinthe convulsions.

(2) Rotation and reeling to the opposite side apparently due, according to Risien Russell, to over-action of muscles attempting to compensate for the weakness of the same side.
(3) Motor weakness affecting both extremities on the side of the lesion and also the posterior extremity of the opposite side.

(4) Slight anaesthesia and analgesia in the weak limbs.

(5) Rigidity, incoordination and increase of tendon reflexes, chiefly in the limbs of the same side.

(6) The eye of the opposite side is deviated outwards and downwards: the eye of the same side being little, if at all, affected.

(7) Lateral jerks of both globes towards the side of the lesion.

When we compare these results with the three clinical cases above recorded, it is remarkable to observe how closely the experimental results are corroborated by clinical facts.

Thus Case A. still shows increase of the knee-jerk on the side of the lesion and also the characteristic nystagmus. The fact that both these signs have persisted now for so long a time after the removal of the tumour points to their existence as being due to a destructive change in the cerebellum.
Case B. showed weakness of both lower limbs, most marked on the side of the lesion. With this there was a degree of rigidity and the knee-jerks were exaggerated, especially that on the side of the lesion. Also, the convulsions which were said to have started on one occasion in the arm of the same side, corroborate, so far as they go, the observations of Risien Russell as to the greater excitability of the opposite cerebral hemisphere.

Case C. showed increase of the knee-jerk on the side of the lesion with weakness of the arm and leg on the same side: It also exhibited for a time the characteristic nystagmus noted in Case A.

I have purposely devoted careful attention to the details of these three cases, on the principle that a few cases completely studied are of more value than a large number of cases carelessly reported.

Let us, however, now turn to the contemporary literature of the last few years on the subject of tumours of the lateral lobes of the cerebellum, and let us note how far it corroborates or supplements the
conclusions drawn from our own three cases.

A considerable amount of experimental work upon the lateral lobe of the cerebellum has also been done of late years, by numerous observers, notably by Luciani, Marchi, Ferrier and Turner and by Risien Russell. The results obtained by these observers are of value chiefly in two ways:

(1) As showing the paths of degeneration following cerebellar lesions in certain of the lower animals, (dog, monkey, etc.)

(2) As affording objective signs of cerebellar disease, as, for example, in the condition of the knee-jerks, etc.

But the conclusions of these various observers differ materially in several points and this variability in their results should remind us that, after all, the crucial test of experimental results is provided by clinical and pathological observations on the human subject.

In this paper it is therefore unnecessary to discuss at length the experimental results of different observers (references to which are found in the bibliography appended.)
Moreover, some important symptoms such as headache, etc, cannot be observed with certainty in the lower animals, whilst other symptoms, such as vertigo, can only be surmised from the animal's gait: hence the great value of a close study of cases in the human subject together with the pathological reports in cases which have been so examined.

On a careful search through the contemporary literature of cases of tumour of the lateral lobe of the cerebellum, it is surprising how few have been recorded, and how, of those which are recorded, still fewer have been examined with any degree of accuracy. Thus of 17 cases which I have been able to collect, in no fewer than 4 the observer has omitted to state whether optic neuritis was present or not. In the remainder it was present in 12 and absent in one case. If the 3 cases which I have recorded in this paper be added (in all of which it was present) this shows optic neuritis to be present in 15 cases out of 16, i.e. in 93.7 per cent of cases. This is in complete agreement with the statistics of Edmunds and Lawford, who in 23 cases of cerebellar tumour found optic neuritis to be present in 20 cases, i.e. in 86.9%: Their statistics also show that cerebellar tumours are more frequently associated with optic
neuritis than any other class of intracranial growths:

Certain other cranial nerves are sometimes affected, varying apparently with the position of the lesion in the lateral lobe: If the appended table of 20 cases be studied, it will be observed that the 5th. cranial nerve was only involved in 2 cases, in both of which the pons was probably directly implicated as well: The 6th. nerve on one or both sides, is not infrequently paralysed, (in 5 cases out of 16 where it was looked for). The facial nerve was involved in 7 cases, and the auditory nerve on the side of the lesion in 10 cases out of 16. The involvement of the 6th. nerve cannot apparently be referred directly to the cerebellar lesion in all cases, being probably not infrequently caused by the general increase of intra cranial pressure, especially in cases where both 6th. nerves were involved.

Those cases in which the facial nerve was involved seem to have been mostly cases in which the tumour implicated the lateral basal meninges of the posterior cerebral fossa:

Impairment of hearing on the side of the tumour is still more common and apparently this cannot be referred invariably to the implication of the auditory nerve itself in the growth. The significance of the implica-
tion of this nerve seems to be greater than that of any other cranial nerve as regards cerebellar growths, since in some cases where labyrinthine deafness was present, there could be little doubt that the tumour, being far back, did not directly implicate the nerve at or near its exit from the skull.

Affection of the lower bulbar nerves is probably a secondary effect of pressure downwards upon the medulla oblongata.

As to the growths which are most commonly found in the lateral lobes of the cerebellum, out of 20 cases I find one gumma, 2 tubercular and 17 neoplasms, (chiefly glioma and sarcoma.) The proportion of tubercular masses would probably be considerably higher, were we to take into consideration cases in which the middle lobe was also affected, but the table appended to this paper only applies to cases affecting one lateral lobe alone.

As to the site of headache, out of 14 cases where it was recorded, it was chiefly or entirely frontal in 6, frontal and occipital in 3, occipital alone in 4, and absent altogether in one case, that of a patient of 89 suffering from dementia.

In 4 cases the knee-jerks of the two sides were compared, and in every such case there was a difference, the knee-jerk on the side of the lesion being the greater.
Convulsions were recorded in 8 cases, occurring, for the most part, late in the disease and in every such case when the brain was subsequently examined, the ventricles of the brain were found distended. They may therefore be ascribed to the condition of internal hydrocephalus, compressing the cortex cerebri against the cranium and thereby irritating it to motor discharges.
SUMMARY.

The following seem to be the signs and symptoms most frequently observed in cases of tumour of the lateral lobe of the cerebellum.

I. General Signs and Symptoms of Intra-Cranial Disease.
   1. Headache.
   2. Vomiting.
   3. Double Optic Neuritis.
   the latter being especially common in cerebellar tumours and frequently going on to atrophy and total blindness.

II. Signs and Symptoms common to Disease in any part of the Cerebellum.
   1. Ataxic Gait.
   2. Vertigo.

   The latter being frequently relieved by supporting the patient's axillae.

   The direction towards which the patient falls, (in cases of lateral lobe tumour, at least) does not seem to possess much localising significance, since the patient in some cases falls towards the side of the lesion, whilst in others he falls to the opposite side.
III. Signs and Symptoms referable to a Tumour of one Lateral Lobe of the Cerebellum.

1. Inequality of the knee-jerks, that on the side of the lesion being the greater.

2. Crossed "Fronto-Cerebellar" Headache.

3. Localised Occipital Headache on the side of the lesion: this being commonest apparently in cases of tumour affecting the meninges.

4. Nystagmus on deviation of the eyes to the opposite side from the lesion.

5. Labyrinthine deafness, on the side of the lesion, in some cases.

IV. Late Symptoms due to pressure on adjacent parts of the brain:

1. Paralysis of one or more of the following cranial nerves: 6th. 7th. 8th. 9th. 10th. 11th. 12th.

2. Convulsions, apparently due to distension of the ventricles of the brain.

The late stages of cerebellar disease, when the ventricles of the brain have become distended, are indistinguishable from other conditions causing a similar increase in the intra-ventricular pressure:

In conclusion it is to be remembered that all the signs and symptoms enumerated in the above list are not
to be expected to be invariably present in every case. The precise significance of each symptom, moreover, is as yet not fully understood and it is only by a close observation of future cases that we can hope to elucidate the numerous obscure points in this problem of cerebellar disease.
<table>
<thead>
<tr>
<th>Observer</th>
<th>Age of Patient</th>
<th>Lateral Lobe Affected</th>
<th>Nature of Growth</th>
<th>Headache and Its Site</th>
<th>Vomiting</th>
<th>Failure of Sight</th>
<th>Optic Neuritis</th>
<th>Other Cranial Nerves Affected</th>
<th>Exposure</th>
<th>Conclusions</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. ASHBY</td>
<td>2½</td>
<td>R</td>
<td>Sarcoma</td>
<td>R. Occip.</td>
<td>+ + +</td>
<td>6th &amp; 7th</td>
<td></td>
<td></td>
<td>Increased</td>
<td>Tumour compressed medulla, pushing it across middle line; Ventricles dilated; Hydrocephalus.</td>
<td></td>
</tr>
<tr>
<td>2. ASHBY</td>
<td>10</td>
<td>L</td>
<td>Myxo-Sarcoma</td>
<td>Frontal &amp; Occipital.</td>
<td>+ +</td>
<td>6th.</td>
<td></td>
<td></td>
<td>Increased</td>
<td>At end Ventricles much dilated.</td>
<td></td>
</tr>
<tr>
<td>3. ASHBY</td>
<td>6</td>
<td>R</td>
<td>Sarcoma</td>
<td>R. Occip.</td>
<td>+ + +</td>
<td>6th &amp; 7th</td>
<td></td>
<td></td>
<td>Increased</td>
<td>Ventricles dilated; Hydrocephalus.</td>
<td></td>
</tr>
<tr>
<td>5. BRUCE</td>
<td>28</td>
<td>L</td>
<td>Gumma</td>
<td>+</td>
<td></td>
<td>Swallowing articulation.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. DANA</td>
<td>42</td>
<td>R</td>
<td>Sarcoma</td>
<td>Occipital</td>
<td>+ +</td>
<td></td>
<td></td>
<td></td>
<td>Increased</td>
<td>Towards end Recent meningitis as well.</td>
<td></td>
</tr>
<tr>
<td>7. ESKRIDGE</td>
<td>11</td>
<td>L</td>
<td>Glioma</td>
<td>Occipital &amp; Frontal.</td>
<td>+ +</td>
<td>&quot;Slight&quot; Early</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. FISHER</td>
<td>R</td>
<td>Glioma</td>
<td>Frontal</td>
<td>+</td>
<td>7th &amp; 8th</td>
<td>Present.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. GULLIVER</td>
<td>36</td>
<td>R</td>
<td>&quot;Simple Cyst&quot;</td>
<td>+</td>
<td>6th &amp; 8th</td>
<td>Increased then Absent Towards end.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. HADDEN</td>
<td>14</td>
<td>R</td>
<td>&quot;Cyst&quot;</td>
<td>+ + +</td>
<td>6th &amp; 8th</td>
<td>Towards end.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. JALLAND</td>
<td>R</td>
<td>Gliosarcoma</td>
<td>Frontal</td>
<td>+</td>
<td>7th, 8th lth.</td>
<td>Absent. R. side of modullia compressed.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12. MURR</td>
<td>17</td>
<td>L</td>
<td>Infiltrating Tumour</td>
<td>Chieflly Frontal also.</td>
<td>5th, 7th, 8th &amp; 11th</td>
<td>Increased L &gt; R Tumour implicated pons also.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13. MACDONALD</td>
<td>89</td>
<td>L</td>
<td>Sarcoma</td>
<td>+</td>
<td>8th.</td>
<td>Diminished.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. PRITCHARD</td>
<td>9</td>
<td>R</td>
<td>Tubercular</td>
<td>Chieflly occipital.</td>
<td>+ + +</td>
<td>Tumour extended into Forn and pressed on L 8th. 7th, &amp; 8th nerves. Operation in R. occipital region. Death from septic meningitis.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16. STARR</td>
<td>L</td>
<td>Gliosarcoma</td>
<td>Frontal &amp; L.</td>
<td>+ + +</td>
<td>8th, 13th</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18. CASE &quot;A&quot;</td>
<td>25</td>
<td>R</td>
<td>Fibro Sarcoma</td>
<td>L. Frontal.</td>
<td>+ + +</td>
<td>Increased towards R &gt; L. Tumour at base, implicating 7th &amp; 8th nerves.</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>19. CASE &quot;B&quot;</td>
<td>47</td>
<td>L</td>
<td>Fibro Sarcoma</td>
<td>R. Frontal.</td>
<td>+ + +</td>
<td>Increased towards R &gt; L. Tumour partly removed; Cure of symptoms.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20. CASE &quot;C&quot;</td>
<td>10</td>
<td>R</td>
<td>Cystic Sarcoma</td>
<td>L. Frontal.</td>
<td>+ + +</td>
<td></td>
<td></td>
<td></td>
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EXPERIMENTAL OBSERVATIONS

on the

CROSSED ADDUCTOR JERK.

by

J. PURVES STEWART, M.A., M.B., C.M.,
DIAGRAM to illustrate
ADDUCTOR JERK EXPERIMENT

Pat. Tend.
Knee Jerk.
Adductor
Chronograph.

X X X = Contacts which are broken when levers move
I have recently had the opportunity of observing a patient who exhibited a peculiarity in the deep reflexes which, although described by various observers as occurring in certain of the lower animals, is somewhat rare in man. On tapping one patellar tendon in the usual way, this patient showed not merely the ordinary knee-jerk on that side, but in addition a crossed knee-jerk, or more accurately, - a crossed adductor jerk, was also evoked. Thus, for example, if the right patellar tendon was tapped, two jerks occurred, the one being that of the right quadriceps extensor, the other that of the left adductor muscles. Conversely, if the left patellar tendon was tapped, the knee-jerk occurred on the left side and the adductor jerk on the right. Moreover, the left adductor jerk was only elicited by tapping the right patellar tendon and the right adductor jerk only by tapping the left patellar tendon.

To the naked eye, these two jerks which occurred when one patellar tendon was tapped, seemed to be practically simultaneous, but the case seemed to me to be worthy of experimental observation by more delicate methods, in order to determine some points in the comparative physiology of the knee-jerk & of the adductor jerk respectively.

The only experiments, with which I am familiar, which have been done on the human subject on the comparative
time-relations of the knee-jerk and of the crossed jerk are those made by Dr. Glynn of Liverpool. (Journal of Physiology 1396 p330) In Dr. Glynn's case, the crossed reaction was apparently due to the vastus internus of the opposite side and not to the adductor muscles as in my own case. Glynn's observations are of extreme interest, but their value as accurate time-records is impaired by the fact that the measurements were made by means of Marey's tambours, in which a long column of air has to be set into vibration before moving the drum of the recording tambour. There was thus a considerable time-loss due to the apparatus employed. But in spite of this, Dr. Glynn's results showed, clearly enough, that the crossed jerk in his case occurred after an interval, roughly speaking, four times as long as that occupied by the period from the tap on the tendon until the commencement of the knee-jerk.

In order to avoid these and other fallacies, I devised the following experiment, for the carrying out of which Mr. Victor Horsley kindly placed his laboratory at University College, London, at my disposal and moreover had the kindness to have the necessary apparatus made for me.

The patient was seated upon a mattress with his back resting against a vertical support, the hips being slightly abducted, the knees semi-flexed and the feet resting
comfortably against a foot-piece. In this way the quadriceps tendon of each knee was kept moderately stretched, so that the slightest tap on the patellar tendon evoked the knee-jerk of the same side and the adductor jerk of the opposite side.

Three long light platinum levers were arranged to record the three events under observation, viz:—

(1) The moment at which the patellar tendon was tapped.
(2) " " " " knee-jerk occurred.
(3) " " " " crossed adductor-jerk occurred.

1. A lever of platinum was used, about 3 inches long, \( \frac{1}{2} \) inch broad, and about as thick as a piece of stiff writing-paper, thus combining lightness with rigidity. The axle of this lever was so placed as to leave a long end of 6 inches and a short end of 2 inches. To the extremity of the long end was affixed a small platinum needle at right angles to the long axis of the lever and in the same plane as the sharp edge of the lever: A small platinum contact was arranged to touch this needle and a wire was led from the platinum contact, through a Grenet cell, to a small electromagnet signal and thence back again to the axle of the lever. The short end of the lever was twisted on its own long axis through a right angle so that its flat surface could be accurately laid upon and adjusted to the surface of the patellar tendon, to which it was firmly fixed by means of
sticking-plaster. In this way a tap upon the short end of the lever, i.e. a tap on the patellar tendon, caused the long end of the lever to fly up and open the galvanic circuit thus causing the electromagnet signal to be depressed at the same instant and thereby recording the exact moment at which the tap on the tendon occurred.

2. Another lever, similarly provided with a projecting needle at its long end touching a platinum contact, had its long end strapped by means of sticking-plaster to the skin covering the quadriceps extensor but with the narrow edge of the lever resting on the skin. In this way, the instant that the quadriceps began to contract, the long end of the lever was thrown up and the moment of occurrence of the knee-jerk was recorded, by means of another electromagnet signal which fell at the instant when the galvanic circuit was opened. A small wooden counterpoise was fixed to the short end of the lever, this short end hanging free.

3. Another counterpoised lever, similar to No.2, with a needle touching a platinum contact and arranged in connection with an electromagnet signal, was strapped in a similar manner so that its narrow edge rested on the inner aspect of the opposite thigh so as to be moved by the slightest contraction of the adductor muscles.
The three signals in connection with these levers were all arranged so as to write in the same vertical plane upon a smoked glass plate, measuring 20 inches long x 7\frac{1}{2} inches broad. This glass plate was mounted in a solid frame which was shot with great velocity horizontally past the writing points by pulling a trigger which released a strong spiral spring. (Smith's "Shooter")

4. A tuning-fork, vibrating 250 times per second, driven by a Grenet cell, was also arranged so as to write below the three signals above described and in the same vertical plane with them.

Each experiment was done as follows: - An assistant pulled the trigger of the "shooter" (Dr. Donald Armour of Toronto kindly did this part for me) and at the same time gave a signal to the experimenter who at once tapped the patellar tendon: In this way, whilst the glass plate was shooting past the writing points, the time at which the patellar tendon was tapped was recorded, together with the time of occurrence of the knee-jerk and of the crossed adductor jerk.

It will be observed that the above is a more accurate method of recording the time at which each of the three events occurred than the method employed by Dr. Glynn, who used a system of tambours and elastic tubes containing air
to be set in motion. But my method is also a much more
difficult and delicate one to manage, inasmuch as the opening
of a current was used as the record of the movement of the
lever. It would have been easier to have made the long end
of each lever to close a circuit, but in that case there
would still have been a slight time-loss in the recording
apparatus, inasmuch as the electromagnet signal would not
have begun to move until the circuit was completed and the
galvanic current had had time to establish the magnetism of
the electromagnet: This would have caused a slight but
appreciable delay. In these experiments, however, the levers
were all arranged so as to open circuits which had already
been established, so that no time corrections of any sort
were necessary. Both time and patience, however, were
required in order to see that all three circuits were actually
closed by apposition of the levers with the platinum contacts
at the moment the tap was delivered on the tendon: A large
number of experiments were done but only a small proportion
of them were successful, owing to the frequent accident that
some one of the three circuits was not actually closed at
the time, in which case, of course, the circuit being
already open, the corresponding electromagnet signal did
not move and only two events were recorded, for example
either the patellar tap and the knee-jerk without the crossed
adductor jerk, or the patellar tap and the adductor jerk without the knee-jerk.

Photographs of three successful tracings are shown in illustration of this paper. They show clearly enough that the crossed adductor jerk occurs at an interval distinctly later than the knee-jerk. Thus in Plate No.1, the knee-jerk occurred in 19.5 vibrations, the crossed adductor jerk not until 34 vibrations after the tap on the patellar tendon had been delivered. In Plate No.2 the knee-jerk occurred in 14.5 and the crossed adductor jerk in 27.5 vibrations, whilst in Plate No.3, the knee-jerk occurred in 19.5 and the crossed adductor jerk came in 33 vibrations after the stimulus had been applied. The average delay between the occurrence of the knee-jerk and the crossed adductor jerk in these three experiments is therefore about 14 vibrations i.e. .056 sec. or 56 "millisecs," (to adopt the phraseology of Professor Rutherford) This interval is considerably shorter than the average difference between the two sides in Dr. Glynn's case. He found the average difference to be from 30 to 90 millisecs. This is all the more remarkable inasmuch as the average time taken for the knee-jerk to occur in my case was 69 millisecs (53 millisecs being the minimum) as compared with 25 to 30 millisecs in Dr. Glynn's case: whilst the average time taken for the crossed jerk to occur in my case was 126 millisecs.
as compared with 110 to 120 milliseconds in Dr. Glynn's patient (the results in the case of the crossed jerks being thus almost identical).

I am not inclined in the meantime, from my own experiments, to attempt to draw any conclusion as to the average absolute time necessary for the production of the knee-jerk or crossed adductor-jerk, for the reason that my experiments have not yet been sufficiently numerous to justify any generalisations on those points. I hope, however, at some future date to perform another series of experiments whenever I find another patient exhibiting a similar abnormality. Meanwhile it is worthy of note that the time relations in experiments done in the manner here described are obviously less liable to fallacies inherent in the apparatus than are the results obtained by some other observers.

Let us now endeavour to summarise the salient points in our present knowledge of the knee-jerk and crossed adductor-jerk respectively.

By the work of Westphal, Waller, Gotch and many others, it has already been demonstrated conclusively that the knee-jerk is a direct muscular jerk produced by sudden stretching of the muscle: It is not a true tendon reflex, since it occurs after an interval too short for an ordinary reflex action. But it depends for its occurrence upon the integrity
of the reflex arc, which, by causing a reflex muscular "tone," permits the muscular twitch to be evoked.

Opinions, however, have hitherto been divided as to the nature of the crossed adductor-jerk, some authorities (for example, Gotch) holding that it is a true reflex, whilst others, such as Waller, hold that it is, like the knee-jerk, a direct muscular jerk produced by suddenly stretching the adductor muscles. Those who hold the latter view would explain the occurrence of the adductor-jerk, in such a case as I have mentioned, as being due to the "jar" of the pelvis by the tap on the patellar tendon thus causing the adductor muscles to be suddenly stretched, just in the same way as the knee-jerk is evoked by the sudden stretching of the quadriceps tendon. This view, however, appears to me to be erroneous and for two reasons:—firstly, because a tap on any of the bones in the region of the knee (patella, femur, or tibia) although it was equally likely to "jar" the pelvis, did not evoke the adductor-jerk, which it ought to have done, had the exciting cause been a mere "jar" of the pelvis: and secondly, because only one adductor-jerk was evoked and that by a tap on the opposite patellar tendon, whereas if it were a mere "jar" communicated to the pelvis, it would excite both adductor jerks equally. The view held by others again, that the adductor-jerk is due to a sudden mechanical shock
to the spinal cord appears for the same reason to be erroneous, since a shock to the cord would elicit jerks on both sides, not merely on one and that the opposite side to the tendon which was tapped.

From a consideration of the experiments here described it may, I think, be fairly concluded.

1. That the crossed adductor-jerk is not due to direct stretching of the adductor muscles by a shock communicated to the pelvis.

2. That the crossed adductor-jerk is not due to a shock mechanically transmitted to the spinal cord.

3. That the crossed adductor jerk is a true reflex, occurring at a period distinctly later than the ordinary knee-jerk.

4. That the average time required for the appearance of the crossed adductor jerk is about \(126\) second from the time at which the opposite patellar tendon is tapped.

In conclusion, I beg to state that this investigation is obviously capable of farther work and I hope to supplement what I have already described on some future occasion when a suitable opportunity affords itself.