THE MECHANISM OF SUSPENSION

IN THE

TREATMENT OF LOCOMOTOR ATAXY.

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Received December 6th, 1889—Read January 14th, 1890.

THE treatment of locomotor ataxy by suspension has engaged so much attention of late, and has been advocated and attacked with so much energy on either side, that a serious effort to assign it a rational basis would have been at any time a welcome contribution to the discussion. It does not appear, however, that such an effort has been made hitherto ; and this is the more strange because the dangers to which the proceeding is open are very generally admitted, while at the same time the benefit with which it is occasionally attended is supported by ample testimony.

Thus it happens that the matter is invested with a double interest, and from either point of view it is highly important to attain to a right understanding of it.

If, moreover, it could be shown that the danger of the operation is not inseparable from its admitted advantages, but rather that the latter can be better ensured by eliminating the element of risk, a practical conclusion of some

consequence will result. To establish such a conclusion is the object of this paper. It further pretends to show the methods of reasoning and observation by which the writer has been compelled to dissent from the views of others more competent to judge than he is, but perhaps in some cases without the same opportunities of testing the truth of their convictions.

It cannot be said that the suspension treatment is without its theory. Charcot in France, and de Watteville in England, to whom belongs the credit of its adoption in their respective countries, left the matter open. Charcot suggested that the effect might be due to a stretching of the spinal cord, or of the nerve-roots, but he thought it possible also that it might be caused by changes in the spinal blood-supply. A stretching of the cord, however, would seem to be the condition aimed at in practice. The origin of the treatment is known to everyone. The physician of Odessa who first resorted to it did so on the grounds of an apparent cure in the case of a patient who, in addition to tabes, had caries of the spine; and in that case no doubt the cord, or rather its membranes, were stretched in the process. There is no need to point out that for the purpose in hand the analogy fails, in an important particular, between those instances where caries of the vertebræ exists and those where it does not. Perhaps it is this coincidence which has biassed men's minds and made the assumption very general of a fact which is far from self-evident. That the assumption is general appears sufficiently from the reports of cases, where considerable elongation of the vertebral column is recorded, and improvement or disaster accounted for thereby. From those who reject the procedure little is heard of the formidable danger of dislocation, and a great deal of hidden menace from tampering with the cord. By its supporters the prospect of a cure is openly or tacitly referred to the same indefinite agency. The theory was boldly enunciated in England by Dr. Althaus. Writing in the 'Lancet' April 13th, 1889, he says: "Part of the

influence of suspension *by which the cord is efficiently stretched* is owing to the breaking down of adhesions due to chronic meningitis;" and again: "by the process of *stretching the spinal cord*, the overgrown and unduly hardened neuroglia may be loosened and broken down." This theory was endorsed by Prof. McCall Anderson; speaking at Glasgow in October, he referred to it as the best yet announced.

We need not pause to ask whether the symptoms of locomotor ataxy may be held to depend in any degree upon meningitis, or whether the most powerful stretching would be adequate to change the character of a sclerosis; but does the needful stretching occur, or is it not rather a *deus ex machinâ*? To answer this question it will be necessary to consider the evidence upon which the belief may be thought to rest. The writer knows of no other than certain measurements made during life. Some of these partake of the marvellous. Thus Dr. Bianchetti, of Padua, by suspending certain heavy men extended the vertebral column (by which, of course, the line of the spines is meant) as much as 4 centimetres (nearly 1½ inches). At the same time, in three cases out of eight amaurosis was induced, and this leaven of mischief amidst much good was ascribed to an extension of the cord in some degree comparable to the above-mentioned elongation behind it.

The reputed fact and the inference are not in logical sequence, but we are concerned now with the statement. Taken for what it implies—an absolute elongation of the column to that extent—it is incredible. The vertebral column is not straight, but deflected in curves (Fig. 1), and the first effect of the force represented by the weight of the body is to straighten out these curves. Not till straightening has occurred will any considerable elongation of a convexity take place. Now the dorsal curve is much the largest, and its convexity is behind, where measurement has to be taken. To obtain so much as 4 centimetres, therefore, would be needed either a formidable extensibility

of the powerful ligaments which knit together the spines, laminae, and transverse processes in the cervical region,

FIG. 1. To show the vertebral curves with the spinal canals exposed.
(Drawn from the skeleton.)

or such a hiatus between the bodies of the dorsal vertebræ anteriorly as the imagination fails to supply.

Very little experience suffices to show the direction from which misconceptions of this kind arise. During life the vertebral column can be measured only along the summits of the spinous processes. How far an inference is warranted from such a measurement to the condition of the cord will be considered presently. The limitations of the process of measurement itself demand some notice now.

In flexion of the head the spines from the first to the seventh cervical are separated, so that a tape placed along their summits will measure upwards of eight inches. When the head is thrown back the spines and laminæ overlap, so that the same points are approached within three inches. Similarly in stooping the dorsal spines will spread over an area exceeding by three or four inches their extent when approximated by muscular action. Again, extension and depression of the occiput will cause a notable difference. It is always extremely difficult to ascertain differences due to muscular tension, and consequently to place the body in a position in this respect similar to that which it assumes when suspended. When an effort is made the decision must be in any event purely arbitrary. The difficulty described must have been appreciated by everyone who has conscientiously endeavoured to obtain the measurements required, and he will have satisfied himself that an error of more than two inches can be accounted for in this way. After much experience, I am convinced that comparative measurements of this kind taken on the living body are but little reliable. There is great difficulty in ascertaining the points chosen; and the time during which suspension is tolerated, at any rate where the patient is not supported from the axillæ, hardly suffices to make sure of them. In the statistics which I have prepared I have done what I could to obviate this defect. I have secured the assistance of skilled anatomists, considered with them every chance of fallacy, and controlled the results by others derived from observation on the dead body. Proceeding in this way I have come to the conclusion that in the living subject there is a decrease in the length

measured along the spines from the second cervical to the last lumbar vertebra of less than one third of an inch ; that the portion of the column which is occupied by the dorsal curve is contracted by about half an inch, and that consequently the apparent lengthening takes place entirely in the neck. Apparent lengthening is said, because it is impossible to be sure that in the original estimate the proper state of muscular equilibrium has been maintained.

The patient is instructed to stand erect, with the chin and occiput inclined in a suitable manner. The observer then measures with a tape the entire length of the vertebral column, following the prominence of the spines. This is noted. The spine of the axis is then made out, and the distance from its lower border to that of the fifth lumbar is measured and written down. The same points are taken while the patient is suspended. The process is somewhat tedious, and in the last case is apt to be hurried, which itself adds an element of ambiguity. Some of the results obtained by me are appended. In no case were marks on the skin trusted to, but the bony point aimed at was determined by the finger on each occasion.

The results obtained in this way are so much at variance with others reported elsewhere that I feel called upon to point out the probable sources of error. Allusion has already been made to that which depends upon muscular action. Measurements of the neck, which is so much more freely movable than the back, are especially open to fallacy of this kind—so much so indeed that figures connected with it are but little trustworthy. On the living body my estimate, conjointly with that of others, has varied in successive experiments on the same person. Accordingly I attach but little importance to the result of observations on this part. I hope, however, to make it appear that variations in the length of the neck are of minor consequence, and I have endeavoured to attain securer data by experiments upon the dissected subject.

The objection indicated does not apply with equal force to careful measurements of the dorsal and lumbar curves,

but neither are these devoid of difficulty. Thus it is not always easy to determine the points chosen. In the statistics produced here the lower border of the spine of the first dorsal vertebra was invariably chosen as a fixed point, because that spine is the most prominent. But here, even in persons in whom the bony points stand out well, an error is very apt to arise. In such persons the observer has satisfied himself that his finger tip was on the extreme border, and when the patient was told to flex his back the true point proved to be a quarter of an inch lower down. When the body is suspended the point in question is most prominent. The difficulty then occurs in the preliminary measurement, and it can be surmounted with care. It depends upon the obliquity of the spinous processes. The posture assumed with the body erect is practically the same under all circumstances, so far as the dorsal curve is concerned. Consequently it is possible, though not easy, to secure absolute certainty in measuring that region. The same is true of the lumbar curve. But it appears that an error of a quarter of an inch may occur in determining one fixed point and as much in determining the other, not to speak of grosser mistakes, such as taking the first lumbar for the last dorsal spine, or the fourth for the fifth; and, since variations in the length of the dorsal and lumbar regions together seldom exceed half an inch, the need of accuracy will be appreciated. In order to supply this we have controlled our observations on the living body by dissections of the dead. The results are appended of only six cases chosen from amongst many, because they were judged to be most nearly correct, and because they were obtained with the assistance of others.

October 30th, 1889. *Regent's Park Hospital.*

CASES 1 and 2.—Dr. Cagney suspended by Mr. Roughton.

Posterior measurements :

			Suspended.		
			(a) Standing.	(b) Occip.—chin.	(c) Occip.—axillæ
i. 2 C. to 4 L. (spines) ...	(22) $22\frac{3}{8}$ in.	...	$22\frac{1}{4}$ in.	...	22 in.
ii. 2 C. to 1 D. „ ...	$3\frac{1}{2}$	...	$4\frac{1}{2}$	...	$4\frac{1}{2}$
iii. 1 D. to 4 L. „ ...	(18 $\frac{3}{8}$) $18\frac{3}{4}$	...	$17\frac{3}{4}$	...	$17\frac{1}{2}$

Analysis.—Questionable decrease on the whole in (b) and (c). Absolute increase of about 1 in. in cervical region, similar diminution in dorsal. The dorsal region was still more shortened in (c), where the axillæ were supported.

CASE 3.—Mr. Roughton suspended by Dr. Cagney.

Posterior measurements :

	(a) Standing.	(b) Suspended from occip. and chin.
i. 2 C. to 4 L. (spines) ...	(22 $\frac{1}{4}$) 21 $\frac{3}{4}$ in.	... 21 $\frac{5}{8}$ in.
ii. 2 C. to 1 D. „ ...	3 $\frac{3}{8}$	... 3 $\frac{5}{8}$
iii. 1 D. to 4 L. „ ...	18 $\frac{1}{4}$	... 18

Analysis.—Total diminution of $\frac{1}{8}$ in. Increase of $\frac{1}{4}$ in. (?) in cervical, diminution of $\frac{1}{4}$ in. in dorso-lumbar curves. Mr. Roughton fainted when taken down.

CASE 4.—Wm. B—, æt. 47. *Tabes.* Often suspended before. Reports having fainted first time. Has a considerable lateral curvature.

Posterior measurements :

		Standing.	Suspended (occip.—axill
i. 2 C. to 1 D. (spines)	...	3½ in.	... 3½ in.
ii. 1 D. to 4 L. „	...	17½	... 17¼
iii. 2 C. to 4 L. „	...	20¼	... 20⅝

Analysis.—Total elongation of $\frac{3}{8}$ in. Increase of $\frac{3}{8}$ in. (?) in cervical, $\frac{1}{8}$ in. in lumbo-dorsal region.

This is the only instance met with in which the dorsal region was stretched, and it is remarkable that the patient had curvature of the spine.

November 5th.

CASE 5.—Wm. D—, æt. 40, cook. Paræsthesia of trunk. First suspension.

Posterior measurements :

	(a) Standing before suspension.	(b) Suspended.
i. 2 C. to 1 D. (spines)	... 4½ in.	... 4½ in.
ii. 1 D. to 5 L. „	... 15½	... 15½

Analysis.—Increase in cervical region of $\frac{3}{8}$ in. (?), diminution in dorsal of $\frac{1}{4}$ in. Total increase of $\frac{1}{8}$ in. (?).

CASE 6.—Ch. H—, ataxic. Fourth suspension.

Posterior measurements.

	(a) Standing before suspension.	(b) Suspended.
i. 2 C. to 1 D. (spines)	... 4 in.	... 3½ in.
ii. 1 D. to 5 L. „	... 16½	... 16½ (?)

Analysis.—Diminution of $\frac{1}{2}$ in. in cervical region and total diminution of $\frac{1}{2}$ in. Dorsal measurements somewhat doubtful.

Reference has been made to the uncertainty of measurements of the neck during life. It is illustrated here by the alternative figures quoted in two cases. Both sets were thought to indicate the distance along the spines with the head as erect as possible. The difference is so great that no conclusions can be drawn from the figures, and they have been retained because they seemed the most nearly accurate that could be found, and also because they tally with others more reliable derived from the dead body. Read in connection with these, certain inferences may be based upon them.

The measurements of the dorsal and lumbar regions may be regarded as quite exact in all but one case.

The subjects of experiments were in some cases healthy, in others they suffered from spinal disease.

In every instance except one there was a *contraction* in the dorso-lumbar region, *not an elongation*. In this excep-

tional instance it was noted beforehand that the patient (a tabetic) had an extensive lateral curvature. The elongation in this case did not exceed $\frac{1}{8}$ in. In another case the dorso-lumbar measurement was invariable, $16\frac{1}{2}$ in. from the first dorsal to the fifth lumbar spine both before and during suspension. The greatest contraction occurred in the writer's own case when he was suspended, and the notes were made by his colleague, Mr. Edmund Roughton, Demonstrator of Anatomy at St. Mary's. The tape indicated a diminution of 1 in. distance from the first dorsal to the fourth lumbar spine when suspended from the occiput and chin alone, and there was a further decrease of $\frac{1}{4}$ in. in this region when support from the axillæ was added. The latter fact is very significant, and it agrees entirely both with what may be seen on the dead body, and with the views on the subject of muscular action, which shall be stated presently. Mr. Roughton was well satisfied of the accuracy of the figures.

It is difficult to obtain a subject sufficiently tolerant of the position to allow good measurements to be taken while suspended from the occiput and chin, and there remain the data in but one other case, that in which the writer suspended a colleague. There occurred then a contraction in the dorso-lumbar curve of $\frac{1}{4}$ in., an increase in the cervical apparently of less than $\frac{1}{4}$ in., and a total contraction of $\frac{1}{8}$ in. In the writer's own case, when suspended by the head alone, the total length of the column was unaltered, an elongation of 1 in. in the cervical compensating for a similar contraction in the dorsal district. When again suspended both from the head and axillæ the dorsal shortening was $\frac{1}{4}$ in. more, while the length of the neck remained the same, *a total shortening then in this instance of one quarter of an inch.* In these three cases, therefore, there was a total shortening throughout the column of $\frac{1}{8}$ in. to $\frac{1}{4}$ in. *A shortening of the dorso-lumbar curve was invariable, ranging from $\frac{1}{4}$ to $1\frac{1}{4}$ in., and averaging nearly 1 in.* It was judged, moreover, that the lumbar curve was in all cases unaffected. The result of the re-

maining three cases was generally the same. In all the dorso-lumbar line was shortened, with the single exception alluded to. In all except this instance a shortening of the whole column was found. In only one case was there apparent shortening of the neck. But it has been said that no positive statement can ever be made upon that point. One fact only has been ascertained beyond doubt, namely, that the neck is less elongated by the process in those who have been several times suspended than in those who are submitted to the operation for the first time.

The uncertainty of this class of measurement impressed me so strongly that I determined to make others under like conditions in the dissecting room, and on the dead body. These were necessarily quite accurate. The muscles were removed from the back—the bony points cleaned and exposed to view—and ample time was available to carry out the experiment with precision. The measurements obtained in this way tallied remarkably with the average of those taken during life. Where they differed the discrepancy was referable to the uncertainty already alluded to as to what position of flexion or extension should be given to the head in the original estimate. The results are instructive in many particulars, and they are appended.

*Dissecting room, St. Mary's Hospital, October 26th,
1889.*

CASE 7.—Body suspended. The limbs had been removed, and the thorax and abdomen dissected. The dorsal muscles were carefully cleaned off, all the ligaments remaining. The body was then suspended from the chin and occiput and the first series of measurements along the spines was taken. Three heavy bricks (17 lbs.) were then attached to the pelvis while the body hung, and the spines were measured a second time.

a. Before adding weights.

- i. Upper border of 2 C. to lower border of 1 D. = $4\frac{1}{8}$ in.
- ii. Lower border of 1 D. to lower border of 1 L. = $10\frac{1}{4}$ in.

b. After weights were added.

- i. As before = $4\frac{7}{16}$ in.
- ii. As before = $9\frac{15}{16}$ in.

Therefore there was a stretching in the cervical region of $\frac{5}{16}$ in., and a contraction in the dorsal of $\frac{1}{4}$ in.; a total stretching of $\frac{1}{16}$ in.

The anterior measurements were not taken, but it was apparent that the anterior common ligament was greatly extended. The cervical and dorsal curves were nearly abolished. The splanchnic nerves were stretched like fiddle-strings.

An incision was made separating the anterior common ligament and detaching the intervertebral disc beneath the third cervical vertebra. The aperture did not gape, though the weights remained on.

The body was then taken down and the laminæ and pedicles removed, while the body was supported on the table by a block under the thorax. As disclosed in this position, the cord and nerve-roots were stretched tense. The body was then hung up as before with weights. The cord enclosed in dura mater then bulged out towards the back, being very loose and relaxed. The dura mater was wrinkled transversely. The course of the nerve-roots from their origin to the intervertebral foramina was much shortened, and they were in sinuous curves. This effect was equally pronounced in every region. In the cervical region, as elsewhere, the apparent origin of each nerve was well above its point of exit from the spinal canal.

Dissecting Room, St. Mary's Hospital, November 6th.

CASES 8 and 9.—Body suspended. The lower limbs were attached, but the feet had been removed. The arms were off. The brain was removed. The thorax and

abdomen were dissected. The dorsal muscles were cleaned off and the spines and laminæ exposed. Anterior and posterior measurements were taken along the bodies and spines—(1) with the body on the table; (2) suspended by occiput and chin; (3) two heavy bricks ($11\frac{1}{4}$ lbs.) being attached in the latter case.

I.—A. Anterior measurement (body lying on its back on the table and extended to the utmost) :

- (1) i. From basilar pr. to lower border of 1 D. . . = $7\frac{1}{8}$ in.
- ii. From lower border of 1 D. to lower border of 5 L. = $16\frac{1}{8}$ in.

B. Posteriorly (on table) :

- (1) i. From tubercle on atlas to lower border of 1 D. = 6 in.
- ii. Dorso-lumbar as before . . . = $18\frac{1}{4}$ in.

II.—A. Anteriorly :

		(2) Simply suspended.		(3) Weights added.
i. As before	...	$5\frac{3}{4}$ in.	...	6 in.
ii. As before	...	$16\frac{1}{2}$ in.	...	17 in.

B. Posteriorly :

i. As before	...	$5\frac{3}{4}$ in.	...	$5\frac{3}{4}$ in.
ii. As before	...	$18\frac{1}{2}$ in.	...	$18\frac{1}{4}$ in.

Analysis.—Anteriorly : The discrepancy of $1\frac{3}{8}$ in. between the first and second measurements shows that a suitable position of the neck had not been obtained, and indeed, this can never be made certain of. Dorsal stretching $\frac{3}{8}$ in. The addition of heavy weights stretched the cervical region only $\frac{1}{4}$ in., and the dorsal $\frac{1}{2}$ in. more. Posteriorly : Cervical region contracted $\frac{1}{4}$ in. when suspended first, and this underwent no change when weights were added. Dorso-lumbar first stretched $\frac{1}{4}$ in., and again contracted to previous length.

(a) Body suspended simply :

Cervical ?	} anteriorly.
Dorsal extension $\frac{3}{8}$ in.	
Cervical contraction $\frac{1}{4}$ in.	} posteriorly.
Dorsal extension, $\frac{1}{4}$ in.	

(b) Weights added :

Cervical extension $\frac{1}{4}$ in.	} anteriorly.
Dorsal extension $\frac{1}{2}$ in.	
Cervical unaffected	} posteriorly.
Dorsal contraction $\frac{1}{4}$ in.	

The value of these experiments depends on the fact that they were done under conditions which entirely got rid of muscular tension. They represent the effect of suspension on the osseo-ligamentous skeleton stripped of its coverings. The bony points were exposed, and measurements were made under the most favorable circumstances. The same uncertainty as before attaches to figures which deal with the posterior surface of the neck, but in a less degree. Those taken in the dorsal and lumbar region are absolute and reliable.

In the first experiment (Case 7) the addition of weights to the body already suspended caused a shortening along the summit of the dorsal and lumbar spines—a shortening in this case of $\frac{1}{4}$ in. Under the same circumstances the cervical spines were separated by a total distance of $\frac{5}{16}$ in., the length of the column remaining unaltered. The measurement of the cervical region in this case, being made under like circumstances before and after the addition of weights, is presumably correct. At the same time the movements of the vertebræ amongst themselves could be watched. The cervical and the dorsal curves straightened out by extension of the posterior ligaments above, and of the anterior ligaments below, and by separation of the bodies below. The appearance of the dura mater when the spinal canal was opened under these circumstances will be referred to later.

In the second experiment (Cases 8 and 9) the anterior measurements were taken as well as the posterior. The results of the latter were in the main those obtained under all other conditions, but modified in a very interesting manner. The line along the dorsal and lumbar spines was stretched $\frac{1}{4}$ in. when the truncated and eviscerated body was simply suspended. When, however, a

FIG. 2. Compounded from two photographs of dissected and dried specimen (exhibited). The specimen was suspended first simply and afterwards with 18 lbs. added below. Two strings were stretched horizontally in front of the specimen. In the first photograph the strings crossed the points A A, in the second the points B B. B B is a greater distance than A A. This shows a slight relaxation of the spinal cord which is exposed. The specimen is from the museum of St. Bartholomew's Hospital, and it was dissected by Mr. Roughton.

weight of $11\frac{1}{4}$ lbs. was added, the line contracted to its original length. There was thus no elongation, but rather, perhaps, a shortening. The $\frac{1}{4}$ in. gained on suspending the body is very likely the expression of an error due to the fact that the unsupported vertebral column collapsed a little when laid on the table, its curves straightening and the spinous processes in the dorsal region approaching one another in a somewhat concentric manner. This probably explains another anomaly—the apparent shortening of the spinous surface in the neck, which stretched again to its original length when weight was added. The collapse of the curve in the cervical region when the body lay on the table would have the effect of expanding the spines in a fan-like manner. The weight of the body was sufficient to overcome this malposition, and the further weight of $10\frac{3}{4}$ lbs. acted not by stretching the posterior ligaments, as was the case with the body prone, but by compression of the intervertebral discs anteriorly. This is a fact of great importance, and will be referred to again. The total result was to leave the spinous surface unaffected when the light body was suspended and a subsequent contraction of $\frac{1}{4}$ in. when weight was added. All this contraction, as before, occurred in the dorsal region.

The results of the anterior measurement are very suggestive. The basilar process having been taken as the upper fixed point for the cervical region makes one series of figures unreliable. Uncertainty as to the proper degree of flexion of the head is the cause, and the doubt is illustrated by so great a discrepancy between the length along the vertebræ when the body was on the table and when it was simply suspended—a discrepancy of $1\frac{3}{8}$ in. The comparison in this case, therefore, does not hold. When weight was added to the suspended body the cervical curve expanded $\frac{1}{4}$ in. In the dorsal and lumbar regions together the effect of suspension was to stretch the anterior surface of the column $\frac{3}{8}$ in., and when weights were added a further stretching of $\frac{1}{2}$ in. took place, a total elongation of this aspect in the weighted body of $\frac{7}{8}$ in. This appeared

to come exclusively from the dorsal curve. If it be remembered now that the line of the spines at the same time shortened, it will appear that the effect of suspending the weighted body was to straighten out the dorsal curve by a movement of the vertebræ each around an axis which corresponds to the situation of the posterior border of the bodies. The anterior common ligament was stretched, the

FIG. 3. The lower part of the thoracic curve, with spinal canal exposed. The left-hand figure is drawn from the skeleton, the right-hand figure from a specimen which was forcibly straightened.

ligaments of the post-neural segments were relaxed, and the spinal canal, since it lies behind the axes of rotation, must have been shortened. At the same time the intervertebral foramina are approximated.¹ From both facts it follows that the spinal cord would be relaxed, and most on

¹ See the writer's paper on "The Disposition of the Vertebral Column in Hanging and Swinging Postures," 'Journ. of Anat. and Physiol.,' 1890.

its dorsal surface (Fig. 3); the nerve-roots would be relaxed with it, and still more so by the approximation of the intervertebral foramina by which they leave the spinal canal.

The cervical curve was stretched anteriorly $\frac{1}{4}$ in. and probably about as much between the spines. The curve tended to straighten by overlapping of the laminae in front. It would seem probable that so slight a change does not in any way affect the cervical portion of the cord, which besides is disposed to accommodate itself to the freest range of movement. The changes that occur are to some extent compensatory; for while the absolute elongation of $\frac{1}{4}$ in. on both back and front would tend to render the dura mater, if not the cord, tense, straightening of the curve will act in the opposite direction, since the cord lies in its concavity. My own belief is that it is impossible in this way to stretch the dura mater without dislocating the neck. This view is strongly confirmed by observation of the cord *in situ* with the spines and laminae removed.

The absence of the soft parts would obviously modify the conditions of extension or relaxation. Here, therefore, are tabulated the measurements in two cases taken in the post-mortem room without dissection.

November 12th, 1889. *Post-mortem Room, St. Mary's Hospital.*

CASE 10.—Body of a man, æt. 35, who died of Bright's disease.

1. Anterior measurements :

	Lying prone after long suspension, about 2 hours.			Suspended.
i. 2 C. to 1 D.	...	5 $\frac{1}{4}$ in.	...	5 $\frac{1}{2}$ in.
ii. 1 D. to 12 D.	...	9 $\frac{1}{2}$ in.	...	10 in.
iii. 12 D. to 5 L.	...	7 $\frac{1}{4}$ in.	...	6 $\frac{3}{4}$ in.

2. Posterior measurements :

	Prone before suspension.			Suspended.
i. 2 C. to 1 D.	...	3 $\frac{3}{4}$ in. (5)	...	3 $\frac{1}{2}$ in.
ii. 1 D. to 12 D.	...	11 $\frac{1}{8}$ in. (12)	...	10 $\frac{1}{2}$ in.
iii. 12 D. to 5 L.	...	4 $\frac{3}{4}$ in. (4 $\frac{3}{4}$)	...	4 $\frac{3}{4}$ in.

The figures in brackets indicate measurements taken when a block was under the thorax. The others give results without the block. This body was suspended without the viscera ; and the cranium had not been opened. While suspended the spinal arteries were injected from the following trunks : abdominal aorta in two places, above and below the coeliac axis ; right vertebral, left vertebral, and left ascending cervical. It was cut down after two hours and the entire cord removed. This is specimen marked Cord A.

Analysis.

Anteriorly :

Cervical	.	.	.	stretched $\frac{1}{4}$ in.
Dorsal	.	.	.	„ $\frac{1}{2}$ in.
Lumbar	.	.	.	contracted $\frac{1}{2}$ in. ¹

Posteriorly :

Cervical	.	.	.	stretched $\frac{1}{8}$ in.
Dorsal	.	.	.	contracted $\frac{3}{8}$ in.
Lumbar	.	.	.	unaffected.

The significance of these tables is modified by the fact that the first measurements (anteriorly) were taken after two hours' suspension. They indicate that a certain resilience will occur after death. As an indication of the effect of suspension the difference in the anterior measurements is probably too small.

Without making allowance for this, the gross result is :

Anteriorly :

Cervico-dorsal region	.	.	stretched $\frac{3}{4}$ in.
Lumbar „	.	.	contracted $\frac{1}{2}$ in.

Posteriorly :

Cervico-dorsal region	.	.	contracted $\frac{1}{2}$ in.
Dorsal region alone	.	.	„ $\frac{3}{8}$ in.

¹ This was repeatedly verified. The fact is very significant.

November 12th. *Post-mortem Room.*

CASE 11.—Body of a boy, æt. 15, who died of typhoid fever.

1. Anterior measurements :

	(a) Lying prone on table.	(b) Suspended.
i. 2 C. to 1 D. ...	$4\frac{1}{8}$ in. ...	$4\frac{1}{8}$ in.
ii. 1 D. to 12 D. ...	$8\frac{3}{4}$ in. ...	$9\frac{1}{4}$ in.
iii. 12 D. to 5 L. ...	$6\frac{1}{2}$ in. ...	$6\frac{1}{2}$ in.

2. Posterior measurements :

i. 2 C. to 1 D. ...	$4\frac{1}{8}$ in. ...	$3\frac{1}{2}$ in.
ii. 1 D. to 12 D. ...	$9\frac{3}{4}$ in. ...	$9\frac{1}{2}$ in.
iii. 12 D. to 5 L. ...	$5\frac{1}{8}$ in. ...	$5\frac{1}{8}$ in.

In measuring the cervical region the head was supported in a position judged to be the same as that assumed in suspension, and it was drawn outwards. This body had the brain and viscera removed before suspension. The weight was supplied by attaching 11 lbs. to the legs.

Analysis.

Anteriorly :

Cervical region unaltered	} stretching $\frac{1}{2}$ in.
Dorsal „ stretched $\frac{1}{2}$ in.	
Lumbar „ unaltered	

Posteriorly :

Cervical region ?	} contraction $\frac{1}{4}$ in.
Dorsal „ contracted $\frac{1}{4}$ in.	
Lumbar „ unaffected.	

The experiments, of which a detailed account has been given, appeared to furnish collectively all the available data. They comprise measurements taken under three classes of circumstances : namely, those upon the living body, those upon the dead body with the bony points and ligaments exposed, and those upon the dead body undissected. Each of the series is instructive in its way, and each tends to illustrate the others. One fact stands prominently forward. So far from finding the great elongation of the dorsal region of the spine reported by others, I have only once, either in the living body or in the dead,

met with any lengthening at all, and that was in a case of lateral curvature. The remarkable consistency amongst the results in this particular goes to prove that the same forces are at work upon the vertebral column, alike in the living and the dead body. In the former case there are other forces added, *e. g.* the effect of muscular tension, which remains to be considered. The posterior measurement, that along the summits of the spines, is the only one which can be obtained under all conditions.

An analysis of the eleven experiments recorded would show *that the result of suspension is to cause an average extension posteriorly in the cervical region of $\frac{1}{16}$ in., a contraction in the dorsal region of more than $\frac{1}{3}$ in., no effect upon the length of the lumbar curve, and a total contraction of rather less than $\frac{1}{8}$ in., throughout.* Anterior measurements can be had only on the dead body. Averages compiled from the tables show an *increase of $\frac{1}{8}$ in. in the cervical region, of $\frac{1\frac{3}{8}}{16}$ in. in the dorsal, and of $\frac{4\frac{7}{8}}{8}$ or 1 in. in the two taken together.* At the same time there is a diminution of $\frac{1}{4}$ in. in the lumbar curve.

Something has already been said of the manner in which these effects are produced, but they need a little further consideration. The statistics show that the chief result of suspension on the dead body, is a straightening out of the cervical and the dorsal curves. But in the two districts this takes place in a different way. In the dorsal region, where the convexity lies behind, straightening takes place by lengthening of the anterior surface (Fig. 3). The anterior common ligament and the marginal attachment of the intervertebral discs give way, and the bodies separate to the extent, on an average, of $\frac{1\frac{3}{8}}{16}$ in. At the same time the spines approach one another. There is consequently a point of rotation somewhere between. This is doubtless in the situation of the posterior border of the bodies of the vertebræ, which are thicker there than in front. In the cervical curve the case is different. Not one or two, but several strong ligaments are present to resist the stretch-

ing of the concavity which occurs readily enough lower down.¹ On the other hand, the bodies of the vertebræ are not thicker towards the convexity in front, but the intervertebral discs are thick in that situation, and indefinite compression is possible. It is probable that it takes place, and that the curve tends to straighten out at the expense of its anterior surface—the convexity—which actually shortens. The difficulty of making accurate measurements in the neck renders it impossible to show this point in figures, but in addition to the anatomical facts mentioned, there are others which support the view: the remarkable lip-like projection on the lower border of each body appears calculated to guide the upper border of the body below in the direction required, and finally some such appearance is presented when the dissected body is suspended. Again, the fact recorded in one of the dissecting-room experiments, when the anterior common ligament was separated and the incision did not gape, lends countenance to the view. Beyond this, however, there is the fact that actual shortening of $\frac{1}{4}$ in. to $\frac{1}{2}$ in. does occur in the lumbar region in which the curve is similarly situated, and there also it must be by compression of the intervertebral discs in front. In the cervical region the spinal cord occupies the concavity of the curve. If, then, this straightens out without separation of its extremities, the cord is relaxed thereby. The process which we have traced in the dorsal region is obviously attended with shortening of the spinal canal and consequently relaxation of the cord in that situation. At the same time the approximation of the intervertebral foramina still further shortens the nerve-roots. This, I believe, is the process in the dead body.

It remains to consider the effect of muscular tension, —and first where the body is suspended from the axillæ in the usual manner. Suspension from the axillæ, in so far as it is effective, is suspension from the scapulæ and clavicles, and ultimately from the muscles which

¹ Op. cit., 'Journ. of Anat. and Physiol.,' 1890.

connect those bones with the trunk. These muscles may be divided into two classes: first, those (the trapezius and rhomboids) which take origin from spinous processes; secondly, those (serratus magnus, and pectorals) which arise from the ribs or some part in front of the vertebræ.

Muscles of the first class tend to approximate the spines directly, and so aid the action of gravity as seen in the dead body (Fig. 4, B). Again, the muscles which arise from ribs do so too, because they raise the ribs which are firmly attached to the transverse processes by the costo-transverse ligaments, while they are free to move on the articulation

FIG. 4. To show the axis of rotation and the point of application of muscular force in the dorsal region.

- A. The dotted line indicates the axis of rotation under the influence of muscular action.
- B. *a*. The direction in which the muscles act which are attached to the ribs; *b*. The direction of muscles attached to spinous processes; *c*. The axis of rotation.

of their heads with the bodies of the vertebræ. They constitute, therefore, a set of levers of the second order, the weight being at the transverse processes. Since, however, the transverse processes are situated behind the axes of rotation mentioned above (Fig. 4, A), muscular tension in this case also acts in the same direction as gravity, and with it helps to relax the spinal cord by shortening the spinal

canal. This view is further supported by figures. When the writer was suspended from the head by Mr. Roughton there was a contraction of 1 in. posteriorly in the dorsal region, and when support was given from the axilla a further contraction of $\frac{1}{4}$ in. ensued.

The question of muscular tension in the neck is more complicated, and that of forced muscular action still more so. When a patient is first suspended, especially if it be by the head alone, he commonly hangs with the body thrown back, so that the legs are well behind the plumb-line from the point of support. At the same time the back is curved in the direction of *opisthotonos*. This is an effect of muscular action, and it originates in an involuntary effort to resist straightening of the cervical curve. For this purpose the muscles of the neck contract powerfully. So do the *erectores spinæ* and their continuations in the back. Under these circumstances the maximum of posterior shortening occurs, and doubtless also the greatest possible elongation along the bodies of the *vertebræ* in front. It is then that syncope, vomiting, and diarrhœa have followed suspension. These may find their explanation in the stretching of the splanchnic nerves, which I have repeatedly seen on the dead body. Whether this be so or not, I am convinced that the splanchnics are the only nerve-structures which *are* stretched.

It appears, at all events, that the spinal cord and its nerve-roots are not stretched but relaxed. This conclusion results alike from measurements, from *a priori* anatomical considerations, and from actual demonstration on the dead body with the spines and *laminæ* removed.

Is it possible to attribute to this relaxation any of the curative effect of suspension? Doubtless it is. Those who have assumed that stretching of the cord might be competent to break down adhesions and overgrown neuroglia have forgotten important facts of anatomy. The *dura mater* is a highly inextensible membrane; it is connected to the bony walls which enclose it, not only above and below, but also by means of strong processes

to each pair of intervertebral foramina. Any movement which it admits is checked in this way, and it cannot be extended indefinitely from one segment to another. The most effectual way to stretch the dura mater is to bend, not to straighten, the spine, as can be shown when the cord is exposed *in situ*. Again the movements of the cord within the dura mater are controlled both by the connection of the nerve-roots with the latter at the intervertebral foramina, and by the processes of the ligamentum denticulatum. Finally the vertebral column is admirably constructed to defend the cord from the action of excessive force such as it has been attempted to exert. But how would extension of the cord, if it were possible, affect a patch of sclerosis? Injuriously if at all. Tension on a rope does not tend to loosen its fibres; but active relaxation, as by doubling up the rope, does. The white matter of the cord is formed of strands of nerve-fibres derived from the nerve-roots. In sclerosis, these are shrunken, compressed, and cemented together. Adhesions amongst the fibres will be broken down, if indeed they can be broken down mechanically—best by relaxation, such as it is contended occurs. This may be a part of the *modus medendi*, but far more efficacious must be the concomitant effect on the spinal blood-vessels and lymphatics. Sclerosis is associated with and maintained by mal-nutrition. The vessels are thickened and choked by pressure from the contraction of surrounding fibrous tissue. If this be opened up and relaxed, more blood will enter. The posterior columns will be flushed. There is a possibility that, with freer circulation, morbid products will be removed, regeneration of tissue promoted, and suspended function restored. I have injected spinal cords while the body was suspended. The naked-eye appearances favour the view stated here and it is hoped that microscopical sections will throw further light on the subject. Some of these are now in course of preparation and others are exhibited. It must not be forgotten, however, that there remains the possibility that vital changes, not demonstrable

on the dead body, have their share in the result. Allusion has been made to the stretching of the splanchnics. When this is excessive, as it most probably is in those cases where the body is curved backwards, stretching may cause a temporary paralytic lesion, whence possibly arises pain in the epigastrium, syncope, vomiting, diarrhœa, and, it may be, death. A slighter degree of extension might constitute an irritative lesion, and it is conceivable that such would have its rôle in the therapeutics of suspension.

The conclusions to which I have been led may be briefly summed up.

1st. A stretching of the cord would give no rational explanation of the effects sought, but this stretching does not occur.

2nd. A considerable and effective relaxation, both of the cord and its nerve-roots does occur in suspension. Relaxation is competent to account for the benefit sought. It takes place to the greatest extent in the dorsal curve, where also the tabetic lesion is always and chiefly situated, and more in the posterior than in the anterior columns of the cord.

3rd. This effect is produced by the weight of the body alone, and is aided by muscular tension when the body is suspended from the axillæ.

4th. Muscular tension, like the force of gravity, acts beneficially most, if not only, in the dorsal region. *Relaxation of the cord in the neck is impossible, and cervico-occipital suspension is not only dangerous and unpleasant, but unscientific and inoperative.*

5th. It follows, therefore, that measures should be directed towards the dorsal region alone. For the old and infirm, the present method of suspension from the axillæ, but from the axillæ alone, will probably remain the best. No strain should ever be put upon the head. If relaxation of the cervical portion of the cord be aimed at, this can be obtained in no way better than by poising the head upon the vertebral column in the natural position of ease. If these views are correct, the best plan of all,

where it can be adopted—as in younger men—would be found in a judicious course of gymnastics, which should have for their object a moderate and associated contraction of the muscles of the back combined with tension of those which connect the scapula and clavicle with the trunk. Simply to hang by the arms from a point above the head for a short time would probably be attended with better consequences than are attained by the use of the cumbrous apparatus at present in vogue.

(Since writing the last paragraph I have made trial of this plan, and in two cases I have obtained results not less remarkable than those published elsewhere.)

(For report of the discussion on this paper, see ‘Proceedings of the Royal Medical and Chirurgical Society,’ Third Series, vol. ii, p. 53.)