THE CAUSATION AND PATHOLOGY

OF THE MORE COMMONLY OBSERVED FORMS OF

LATERAL CURVATURE OF THE SPINAL COLUMN.

BY

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IN this paper I hope to succeed in showing that the large proportion of the cases of lateral curvature which come under the observation of the surgeon are due to the habitual assumption of attitudes of rest by young subjects who are wanting in vigour. This group is produced in the same manner as are the simple deformities which develop in young life, namely, knock-knee, flat-foot, dorsal excruciation, &c. These I have discussed in previous papers.¹

There exists a larger proportion of cases of lateral curva-

¹ "The Causation, Pathology, and Physiology of several of the Deformities which develop during Young Life, including Simple Knock-knee, Flat-foot, Lateral Curvature, Dorsal Excurvation, Deformities of the Toes, a Form of Facial and Thoracic Deformity due to Large Tonsils, and Rickety Deformities of the Spinal Column, Pelvis, and Lower Extremities," 'Guy's Hospital Reports,' 1886, 1887. "A Brief Statement of the Causation of the several Simple and Rachitic Deformities that develop during Young Life," 'Brit. Med. Journal,' Jan. 26th. 1889.

ture which are not produced by the habitual retention of the column in the easy erect posture than of those other deformities, for the reason that asymmetry of this portion of the skeleton is of necessity brought about in carrying any load by one arm or by supporting a load upon one half of the thorax, and the habitual repetition of such an act soon renders the column permanently asymmetrical.

We know that the curves in an antero-posterior plane occupied by the bodies of the movable vertebræ are to a very great extent evolved during the lifetime of the individual in consequence of the assumption of attitudes of activity and rest, and that any interference with one of the curves in an antero-posterior plane, as in the case of caries, is followed by an alteration in the form of the other curves. In the active postures there is a constant tendency to the diminution of the several convexities, while in the easy attitudes the reverse is the case.

The result of the habitual exercise of the active erect posture is seen in those labourers who carry loads of only moderate weight upon the head. In such cases the curves in an antero-posterior plane are rendered much less convex than they are in the normal type.

In feeble old age, in which the trunk assumes only attitudes of rest, the reverse condition is seen to great advantage, the curves being rendered remarkably more convex.¹ The same exaggerated convexities are seen in the young subject who habitually retains the column symmetrically in an attitude of rest.

In infancy the form of the bodies of the vertebræ, of the fibro-cartilages, and of the curves which develop later does not exist. In the active erect posture the plane of the facet upon the upper surface of the sacrum is placed very obliquely, so that it looks forwards and upwards, and it is upon this inclined plane that the superjacent bodies of the vertebræ and fibro-cartilages are placed, and connected to them are the cranial, thoracic, and abdominal walls, con-

¹ "The Causation and Pathology of Rheumatic Arthritis and of Senile Changes," 'Trans. Path. Soc.,' 1886, and 'Guy's Hospital Reports,' 1886, 1887.

tents, and appendages, all of which exert upon the column a pressure in a downward direction in front of their transverse axes of rotation. The formation of the lumbar convexity is determined of necessity by the plane of the sacral facet, while the cervical and dorsal curves are also influenced by the presence of the thorax, &c., in their formation.

It is apparent that as the spinous processes and laminæ occupy a median position, and as they lie behind the transverse axis, around which each vertebra rotates, they can only serve to influence the amount of this rotation, or, in other words, to limit flexion and extension of the several portions of the spinal column.

As it not uncommonly happens that the lower extremities differ in length in the same subject to a considerable extent without any obvious reason, one would naturally expect that the lateral inclination of the plane of the sacral facet which must result from the rotation of the pelvis around an antero-posterior axis in the direction of the shorter limb must necessitate the formation by the vertebral discs and intervertebral fibro-cartilages of curves in a vertical transverse plane, the lower or lumbar curve forming a convexity directed to the shorter limb, the dorsal vertebrae presenting a convexity to the opposite side, and the cervical a convexity of the same direction as the lumbar. Yet in the vigorous child this is not the case. The advantage of retaining the column in an antero-posterior plane is obviously so great that as the child learns to walk, the powerful muscles inserted into the lumbar transverse processes and bodies drag the whole of the lumbar spine, which they retain fixed in an antero-posterior vertical plane, to one side upon the sacral facet, and so influence the growth of the last fibro-cartilage that it forms a wedge whose base is directed to the shorter limb. Should such a subject perform habitually such heavy labour as produces a rapid destruction of the greater portion of the fibro-cartilages in the lumbar region, the apparently necessary lateral curve is obviated by the conversion of the body of the last lumbar vertebra into a wedge shape, the base of

the wedge being, like the last fibro-cartilage which had been destroyed or reduced to a uniformly thin dense fibrous layer, directed to the shorter limb. Cases illustrating the energy with which the bodies of the lumbar vertebræ are retained in a vertical antero-posterior plane by the powerful muscles of the vigorous subject, even though the difference between the lengths of the lateral pelvic supports be considerable, are described in papers¹ in the 'Journal of Anatomy and Phpsiology.' I have illustrated these conditions diagrammatically in Figs. 1 and 2. I have also

FIG. 1.

FIG. 2.

FIG. 1 represents a vertical transverse section through the lower portion of the spinal column, showing the lateral deflection of the plane of the sacral facet, *s f*, consequent on a considerable congenital difference in the length of the legs.

FIG. 2 represents a similar section. In this case the individual had carried very heavy loads on his back, and the fibro-cartilages are shown to be much thinned and indurated. *IV* and *V* represent the 4'' and 5'' lumbar vertebræ.

shown in the 'Guy's Hospital Reports,' 1886, that the same is true for acquired shortening in the vigorous subject.

We are aware that even in the vigorous child the total

¹ "A Remarkable Example of the manner in which Pressure Changes in the Skeleton may reveal the Labour History of the Individual," 'Journal of Anat. and Phys.,' April, 1887. "The Causation of several Variations and Congenital Abnormalities in the Human Skeleton," 'Journal of Anat. and Phys.,' July, 1887. "Can the existence of a Tendency to Change in the Form of the Skeleton of the Parent result in the actuality of that Change in the Offspring?" 'Journal of Anat. and Phys.,' Jan., 1888.

thickness of the intervertebral discs is markedly less in the evening than in the morning, and that this difference is more noticeable in the feeble subject in whom the fibro-cartilages are more compressible and less resilient than in the robust; also that this difference can exist without the presence of any deviation of the bodies of the vertebræ from a vertical antero-posterior plane. In the young subject the total thickness of the fibro-cartilages bears a greater proportion to the total thickness of the bodies than it does in adult life, and in the feeble child this proportion is still greater.

Let us now analyse the condition of the spinal column and its appendages while the child assumes the easy erect posture, supporting the greater part of its weight on one leg. In this attitude the pelvis is fixed upon the thigh in a position of extreme extension. (In this case, for the convenience of description and because it is the one more commonly used, we will assume the supporting leg to be the right one.) In consequence of this rotation of the pelvis around a transverse axis the downward and forward inclination of the plane of the facet on the upper surface of the sacrum is altered so as to look much more directly upwards than it does in the active erect posture. As the pelvis is also fixed in a position of extreme adduction upon the supporting thigh and has in consequence rotated through a considerable angle around an antero-posterior axis, the plane of the sacral facet is inclined downwards and to the opposite side, its surface looking upwards and to the left. This considerable lateral inclination of the base upon which the superjacent column of bony and fibrous discs is placed determines of necessity the formation in a vertical transverse plane of a series of curves corresponding pretty accurately in their extent to the several curves in an antero-posterior plane. The convexity of the lateral lumbar curve is of course directed to the left.

Should this child have one of its legs longer than the other owing to some congenital condition or in consequence of some disease or injury, and should the longer leg be the

one on which he supports the trunk in this easy posture, the lateral inclination of the sacral facet to the opposite side will be much greater than in a subject whose legs are of equal length. Again the presence of a peculiarly formed and thick last fibro-cartilage will also serve to increase the convexity of the lateral lumbar curve.

It is therefore quite obvious that this temporary arrangement of the bony and fibrous discs in lateral curves during the retention of the body in this easy erect posture is dependent for its existence upon the same factors which determine firstly the temporary and subsequently the permanent arrangement of the antero-posterior curves and the characteristic forms of the several bony and fibro-cartilaginous discs, namely, the inclination of the sacral facet and the attachment of the several appendages.

I have already alluded to another factor which in this position assists in determining the formation of lateral curves. It is the rotation of the pelvis around a transverse axis, so that the plane of the sacral facet looks upwards rather than forwards and upwards, as it does in the active erect posture. This change in the direction of this surface causes a marked diminution in the anterior lumbar convexity. In fact it causes it to form a portion of a long single curve in an antero-posterior plane, the dorsal and cervical vertebræ entering into its construction. It is obvious therefore that if the spinal column is made to assume a resting attitude upon a symmetrically placed pelvis, as in all attitudes of repose, the bones and ligaments are made to perform the greatest possible share in supporting the body in such a posture, the expenditure of muscular energy being as small as possible. The resilient fibro-cartilaginous discs are sustaining very great pressure, and as this is much greater in their anterior segments than in the posterior, each cartilage forms a wedge whose base is directed backwards. I have attempted to indicate diagrammatically my meaning in Fig. 3. A indicates the bodies of the vertebræ, B the fibro-cartilages, C D the spinous processes, and E the inelastic supraspinous and

interspinous ligaments which are rendered extremely tense.

FIG. 3.

It is easy to understand that if the plane of the sacral facet be deflected laterally, the compressed and resilient fibro-cartilages by their elasticity immediately alter their form so that each forms a wedge whose base is directed towards the side to which the sacral facet is deflected. By this means the mass of the fibro-cartilage escapes the general compression to which it was subject when the column was symmetrical, while that portion of the fibro-

cartilage which corresponds to the concavity of the lateral curve experiences a compression which is even greater than that sustained by the anterior portion in the symmetrical column. This more local compression is increased still more by the increased shortening of the arc of the segment by the development of a second curve, and by the absence of such resistance to the extreme compression of the lateral segment of the fibro-cartilage in the lateral curve as is afforded by the leverage of the spinous processes and the resistance of the inelastic and powerful interspinous ligaments in the symmetrically flexed column.

Again, while in the symmetrically flexed column the posterior portion of the fibro-cartilage is forcibly compressed, in the lateral curve that portion of the fibro-cartilage which corresponds to the convexity of the curve is situated to one side of the antero-posterior axis, around which each vertebral disc rotates, so that instead of transmitting pressure its fibres are in a condition of tension. I have attempted to illustrate this diagrammatically in Fig. 4.

It is apparent from a careful consideration of the above-mentioned facts that the segment of the fibro-cartilage which in this resting attitude sustains the greatest amount of pressure is that corresponding to the junction of the antero-posterior and lateral curves. This in the case of a curve having its convexity to the left would be the right antero-lateral segment, and it would be at this point that temporary and later permanent changes would ensue in the thickness and density of the fibro-cartilage, and where still later the bony margins of the discs would form dense lips of bone, which may adhere to one another. Again, it is at these points that the rate of growth of the epiphysial lines would be diminished below the normal rate and extent, while in the same proportion would the rate of growth of the epiphysial line in the opposite segment be increased, since it is habitually exposed to strain in the permanent lateral curve, while in the large majority of the movements of the normal spine it sustains pressure equal to that on the opposite side.

We see then what an important factor is the resiliency and elasticity of the fibro-cartilages in determining the formation of the lateral as well as of the antero-posterior

FIG. 4 represents a vertical transverse section through the bodies of the lumbar vertebrae in a case of lateral curvature, *A B* indicating the lateral inclination of the plane of the sacral facet; *D* represents a body, and *E* a fibro-cartilage.

curves, and the greater breadth and thickness of the bodies and fibro-cartilages in the lumbar region renders its illustration still more apparent in that portion of the column. In symmetrical flexion of the column the bodies of the vertebrae rotate around a transverse axis.

Now, if the vertebrae and fibro-cartilages alone were arranged in a vertical line upon a sacral facet occupying a horizontal plane, the upper extremity of the column being retained in the same vertical plane, any lateral deflection of the sacral facet would result in the formation by the column of a lateral curve in a vertical transverse plane, each vertebral body rotating around an antero-posterior axis which passes through its centre, and the line formed by the

apices of the spinous process would occupy the same antero-posterior vertical plane as that formed by the centres of the bodies of the vertebræ.

Therefore when this erect posture of ease is assumed the bodies of the vertebræ rotate around an axis in a horizontal plane, the direction of this axis being between that of the transverse and of the antero-posterior axis, its exact direction depending upon the various degrees of inclination of the plane of the sacral facet laterally and antero-posteriorly. Roughly, we may consider the axis in an antero-posterior plane around which each vertebra rotates as occupying a varying position between the axes above referred to, and being directed obliquely forwards and outwards.

It is apparent, from an examination of the articulations of the articular processes of the several vertebræ, that they readily permit of a considerable amount of rotation of the body of each vertebra around an axis in a horizontal plane and having this oblique direction. This explanation of the mechanism of the movement seems to me to be both obvious and readily capable of demonstration. As the axis of rotation is directed forwards and outwards, it of necessity follows that in this resting posture the line formed by the apices of the spinous processes lies much nearer the median line of the body than does the line formed by the centres of the bodies of the vertebræ. This circumstance, namely, that these two lines are not in exactly the same antero-posterior plane in a lateral curve seems to have constituted a great stumbling-block in the way of those pathologists who have devoted any attention to the subject, and many hypotheses, both remarkably complex and obscure, have been put forward to explain a movement which, till it becomes permanent and forms a deformity, is normal and its mechanism physiological.

Having satisfied ourselves as to the mode in which the temporary and permanent lateral curves of the spinal column are brought about, let us consider the influence which the deviation of the bodies of the vertebræ from a

median plane exerts upon the structures connected to them. If we examine a young subject who is supporting himself in this erect attitude of rest upon his right thigh, we are able to make out a greater resistance to the left of the middle line. We find that the transverse axis of the thorax occupies an oblique position, being directed forwards and to the left. The left shoulder is displaced forwards and the right backwards, the outline of the right scapula being much more obvious than that of the left. At the same time the right half of the chest appears to be more expanded than the left, the intercostal spaces in the former being apparently wider than in the latter. This is all obviously consequent upon the existence of the lateral dorsal curve, and upon the mode of connection of the ribs to the spinal column.

Since this rotation of the thorax is produced by the leverage exerted upon each vertebra upon each pair of ribs, it is obvious that the resistance offered to this force by the ribs must be felt as strain chiefly at two points, namely, about the angles of the ribs which lie on the side of the convexity of the lateral curve, and about the anterior extremities of the ribs which are connected with its concavity. Therefore should this resting posture become fixed and subsequently exaggerated owing to its repeated and habitual assumption, it is at these points that we would expect to find, and do find in the young growing child, more or less marked projections which are formed by the more or less abrupt yieldings of the ribs under the influence of this pressure. The knowledge of the manner in which this attitude of rest in the erect position is brought about, and especially of the very important part played by the compressibility and resiliency of the fibro-cartilages, enables us to understand very readily the practically insuperable obstacles which oppose the removal of the deviation when it has become permanent and constitutes a deformity. As long as the condition remains a physiological one, that is, as long as the compression sustained chiefly by the antero-lateral segment is removed by rest in the horizontal posture

or by the retention of the column in the symmetrical position by the expenditure of muscular energy, it is only of interest to the anatomist as illustrating a portion of the somewhat complex physiology of the spinal column. But when this segment has sustained such prolonged pressure as to render it unable to recover its normal thickness by rest, we find that clinically we have no effectual mechanical means of restoring the bodies of the vertebræ to the median line. All we can do is to render the organism more vigorous and robust, and by that means, while improving the density of the osseous and ligamentous tissues generally, the powerful spinal muscles are made sufficiently powerful to prevent further rotation of the bodies of the vertebræ.

In the case of simple knock-knee in an early stage, we can readily open out the diminished external femoro-tibial angle by the pressure exerted by an outside splint, causing a more rapid growth of bone along the outer portions of the epiphysial line and diminishing the rate of growth along the inner portions. But here we have only to treat rotation around an antero-posterior plane, and we are able to apply pressure directly at an immense mechanical advantage.

To remedy the acquired asymmetry of the lumbar vertebræ in the same effectual manner, we would require to use some force which would cause a sufficient rotation of each vertebral body around the oblique axis in a direction the reverse of that in which it has rotated to assume its asymmetrical position, in order to expand the compressed segment of fibro-cartilage, and to shorten that which has been over-extended. It is at once apparent that we are unable to apply force in this manner. We can, by inclining sufficiently the plane of the sacral facet to the opposite side by such means as raising the level of the plane of the sole of the foot on the side of the convexity of the lumbar curve by a thick sole, tend to displace the lateral curve formed by the bodies of the lumbar vertebræ to the opposite side, yet it is apparent from an examination of Fig. 5 that even if we did succeed in doing this we would not succeed in so altering the conditions of pressure and tension in the

several segments as to effect this purpose. Such a method could only be of service in remedying conditions which are but slightly in excess of the physiological and normal.

FIG. 5.—E and L each represent a vertebra, A being the anterior and B the posterior surface. C D indicates the transverse axis around which each body rotates in flexion of the column in an antero-posterior vertical plane. E F indicates the antero-posterior axis around which each vertebra would rotate were the column formed solely of vertebrae and discs placed upon a horizontal sacral facet whose plane was deflected laterally. G H represents diagrammatically the oblique antero-posterior axis around which each vertebral body rotates in forming a right lateral curve, and I J the oblique axis around which each body rotates in forming a left lateral curve. M indicates the segment of intervening fibro-cartilage which sustains the greatest pressure, and L that which sustains the least. The segment of fibro-cartilage N sustains greater pressure than that marked O.

Since in many of the sedentary attitudes of rest which are so frequently assumed by the feeble young subject considerable lateral inclination of the sacral facet is very usually, in fact is always, associated with a very marked degree of flexion of the spine, especially in the lumbar region, it is easy to understand that the deformity which is first the fixation and subsequently the exaggeration of a normal physiological attitude may result as readily in these sedentary postures as we have seen it develop in the easy erect posture.

I do not intend to render this paper tediously long by

discussing the causation and pathology of the less frequently observed cases of lateral curvature, which are due to carrying loads asymmetrically upon the thorax or by means of one arm or shoulder, to the forcible approximation of the ribs on one side due to extensive pleural adhesions and fibroid change in the lung, to contraction of the sterno-mastoid, &c., as I have gone into them very thoroughly in previous papers.¹ In connection with this portion of the subject I would refer the reader to a very interesting experimental research by Dr. L. von Lesser.²

I have limited myself in this paper to attempting to explain briefly, and I trust clearly, the causation and pathology of the very large proportion of the cases of lateral curvature which come under the observation of the surgeon, and whose treatment of which, except in the very earliest stages of the deformity, can, unfortunately, not be more than palliative, by which I mean that he can only oppose the progress of the deformity, and to do that he must expend much patient skill and energy. He cannot hope to again render the column symmetrical.

¹ "Three Forms of Spinal Deformity," *Med.-Chir. Trans.*, 1884. "Some Points in the Physiology and Pathology of the Changes produced by Pressure in the Bony Skeleton of the Trunk and Shoulder Girdle," *Guy's Hospital Reports*, 1885, 1886. "Some Changes in the Form of the Acetabular Cavities, Spinal Column, and Joints of the Hand, illustrated by the Anatomy of the Charwoman," *Guy's Hospital Reports*, 1886, 1887, and other papers in the *Journal of Anatomy and Physiology*, &c.

² "Experimentelles und Klinisches über Skoliose," Virchow's *Archiv für pathologische Anatomie und Physiologie und für klinische Medizin*, 113 Band, 1888.

(For report of the discussion on this paper, see 'Proceedings of the Royal Medical and Chirurgical Society,' Third Series, vol. i, p. 107.)