SPONDYLOLISTHESIS.*

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DISPLACEMENT of the presacral spine forwards upon the sacrum has attracted a great deal of attention since the name of spondylolisthesis was applied to it by Kilian in 1854. In the latter half of the nineteenth century those chiefly interested were the obstetricians, who, stimulated by the work of Neugebauer, recognized the lesion as an occasional cause of difficult labour. With the advent of roentgenology fresh interest was aroused, and it has become apparent that this condition is at least as common in men as it is in women. A further development has been provided by improved lateral roentgenography of the spine, which has made possible the detection of lesions not seen in antero-posterior views. At the present time spinal lesions are being increasingly investigated because of the onslaught of the motor-car and of other mechanical devices. In view of its possible relation to trauma, the subject of spondylolisthesis occasionally provides material of medico-legal interest.

The present paper is based upon a study of 34 cases of spondylolisthesis, and of anatomical and roentgenological material, with special reference to the mechanics of the lesion and to its diagnosis. The main features of interest are summarized in the following table :—

	Cases
Males (53 per cent)	18
Females (47 per cent)	16
Under 25 years of age (youngest 11)	13
Between 25 and 50	15
Over 50 years of age (oldest 71)	6
Spondylolysis with displacement	23 ⎫
Forward displacement of entire 5th lumbar vertebra ..	6 ⎬ 34
Displacement of 5th, but of uncertain type	5 ⎭
Early cases—mild displacements	9
Spina bifida present	15
Sciatica prominent symptom	12
Severe injury to spine	3
Moderate injury to spine	6

Types.—There are two types of spondylolisthesis. The first is one that is often described in text-books and occasionally in journal articles, but is rare. In this practically the entire 5th lumbar vertebra slips forwards upon the sacrum and carries the rest of the spine with it. The second type, the one which is most frequently seen, and which was well recognized by Neugebauer as well as by most modern writers, consists in the separation (or spondylo-*lysis*) of the 5th lumbar vertebra into two portions by a solution of bony continuity in the laminæ posterior to the transverse processes, in such a way

that the part bearing the spinous process and inferior articular surfaces moves backwards and the rest of the vertebra slips forwards upon the sacrum. This is the condition discussed in this article.

Literature.—There have been written, up to the present time, about 250 articles upon this subject, a considerable number being of German or American origin. Until 1900 almost all of them were based upon descriptions of museum specimens, the pioneer work being carried out by Neugebauer. In England, Lane in 1885 discussed spondylolisthesis as one of the numerous changes found in the spine of labourers; but one of the best descriptions of pathological material was by Lawrence in 1900. The remarks by Blacker supplemental to Lawrence's paper are of importance, as he clearly appreciated that the site of bony defect was in the interarticular portion of the laminæ of the 5th lumbar vertebra. Of modern British clinical and roentgenological work, that by Brailsford is the most noteworthy. In America in 1912, following a description of a case, Fitch gave an important list of 161 references to the literature. In recent years Whitman, Albee, Kleinberg, and Willis have made valuable contributions. An article by Meyerding in 1931 reporting 121 cases is of great interest from the clinical point of view. In this series 62 per cent of the patients were males. In 1928 Faldini in Italy made an excellent contribution to the study of spondylolisthesis. He applied a different title to each of the two types of lesion : for the rare slip of the entire 5th lumbar vertebra he reserved the name ' spondylolisthesis '; for the commoner lesion he used the title ' spondylolysis '.

The Congenital Nature of the Basic Lesion of Spondylolisthesis.—Many writers have noted the congenital nature of the defect in the laminæ of the last lumbar vertebra. The most extensive investigation is by Willis, who has reported upon a series of over 700 skeletons, and finds such defects in the neural arch of 4·28 per cent of individuals. It has often been stated that the neural arch of the last presacral vertebra, instead of being developed from two primary centres of ossification, may have four, one for each pedicle and superior articular process and one for each lamina, and that it is failure of the latter to fuse with the former that permits the common form of spondylolisthesis to occur. Willis suggests that although such a congenital origin is probably the only satisfactory explanation of these lesions, yet the embryological evidence upon which this statement should be based is very weak.

What Part does Trauma take in the Development of Spondylolisthesis ?—Assuming the presence of a congenital defect, it cannot, however, be denied that trauma plays an important part in the further development of spondylolisthesis. Can this condition, on the other hand, develop as a purely traumatic lesion ? The answer is at present unsatisfactory, as a study of the literature reveals that no one has presented a case in which trauma has been proved to be the causal factor to the extent that, as the result of the injury, spondylolisthesis can be shown to have developed in a spine known by previous X-ray examination to have been normal. Furthermore, the majority of cases or specimens reported upon have been advanced lesions, and no demonstration has been made of the progression in the same patient from the pre-slip stage to a well-marked spondylolisthesis. Reports have,

however, been published of cases in which the deformity has occurred in spines previously stated to have been normal clinically (Kleinberg, Turner).

It is obvious, however, that mechanical strain must be of influence, and it is probable that the greatest part is played by the ordinary influences of gravity that everyone is subjected to, though a history of violent injury to the back is presented by some patients.

Emphasis has been placed upon the increased tilt of the sacrum towards the horizontal in the production of spondylolisthesis. In fact, Armitage Whitman has described several cases of pre-spondylolisthesis in which this was a prominent factor. While not denying the existence of this and of the consequent increase in the shearing stress exerted at the lumbosacral joint, I believe that certain other details must be borne in mind. At the inception of the condition lordosis may be absent. In support of this are the following facts : The commoner types of injury complained of by those patients in whom trauma is a prominent feature are : (1) The lifting of heavy weights ; (2) Falls to the ground upon the buttocks ; and (3) The fall of heavy weights on to the shoulders. In none of these is lordosis likely to occur ; in fact, in all of them it is an almost impossible position. In lifting a heavy weight, a man starts with his hips flexed and the lumbar spine arched backwards. Elevation of the load is largely carried out by use of the gluteus maximus muscles with extension of the hips. Thus the sacrum is actively tilted backwards and forced against the laminæ of the 5th lumbar vertebra. When an individual is forced to sit suddenly on the ground, the lumbar spine becomes flexed so that the normal curve is obliterated. If a load is suddenly forced on to the shoulders or upper back, the patient 'caves in' forwards ; in other words, he collapses with the lumbar spine again held in extreme flexion. So - called traumatic spondylolisthesis usually occurs in men, in whom lordosis in extreme form is not so commonly found as in women. In the examination of the early cases in young adults where slipping has scarcely commenced, I have been impressed by the absence of lordosis. In late cases the lordosis present is, I feel, secondary to the displacement at the lumbosacral joint, and
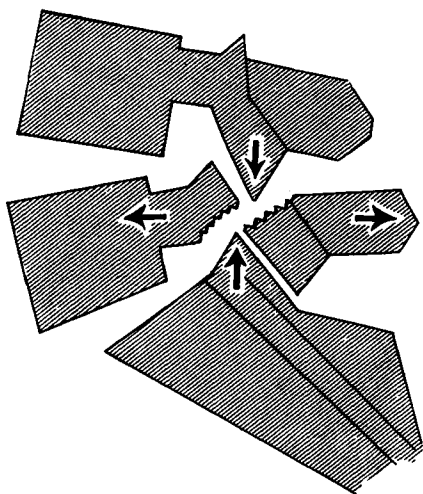

FIG. 282.—Diagrammatic lateral view of lower spine to show the influence of sacral and lumbar wedges upon the last lumbar vertebra.

is of a peculiar kind in that the sacrum, instead of being nearly horizontal, is rotated into the vertical position and carries with it the spinous process of the 5th lumbar vertebra (*see Fig.* 289).

An important factor that I think has been overlooked is the wedge-like influence provided by the upper and posterior borders of the sacrum (*Fig.* 282). The apex of the wedge is formed by the articular facets of the sacrum,

and this is driven upwards and splits the 5th lumbar vertebra into two portions at the site of congenital non-union. Thus is initiated spondylo*lysis*, and 'spondylo*listhesis*', or slipping, follows through the continuance of the two influences of wedge action and shearing stress.

In the lumbar spine, because of the direction of its curve, weight transmission tends to be displaced posteriorly from the bodies to the laminæ and articular facets, and the laminæ of the 5th will thus tend to be nipped between the sacrum and

FIG. 284.—Tracing of lateral skiagram of cervical spine in a patient with fracture of the atlas and axis showing analogous splitting of vertebræ. (*By courtesy of Dr. F. J. Hodges.*)

FIG. 283.—Tracing of lateral skiagram of a case of tuberculosis of the thoracico-lumbar junction. Demonstration of tensile and compression stresses and early spondylolisthesis.
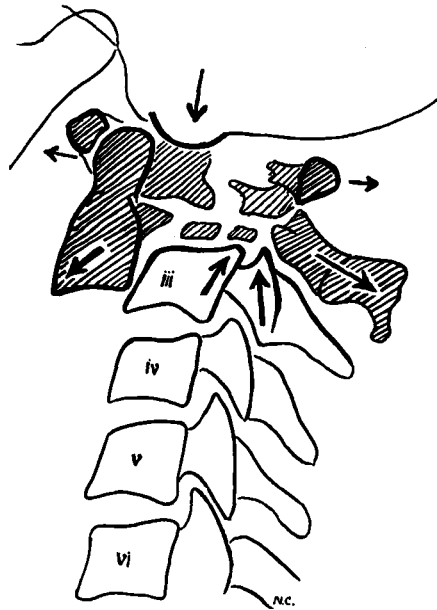
an upper wedge provided by the lower articular processes of the 4th lumbar vertebra. Such conditions are difficult of demonstration in the resting spine. I am fortunate therefore in being able to present an X-ray (*Fig.* 283) of a lumbar spine where these factors can be studied in a stationary form. The patient had had a long-standing tuberculosis of the upper lumbar vertebræ with severe collapse anteriorly. At the lumbosacral joint a mild spondylolisthesis has commenced. Examination of the illustration, in which the chief lines of

force have been indicated by arrows, will reveal how splitting of the 5th lumbar vertebra has probably occurred.

As a demonstration of a somewhat similar wedge action elsewhere in the spine, the case illustrated in *Fig.* 284 is of great interest. In this the 1st and 2nd cervical vertebræ have been split each into two halves at points analogous to the site of the lesion in spondylolisthesis. The apices of the wedges involved are here provided by the condyles of the occiput on the one hand and the anterior edges of the superior articular surfaces of the 3rd cervical vertebra on the other. The cause of this lesion was a motor-car accident.

Spina Bifida.—With one morphological defect, it would not be surprising to find other similar anomalies, and this in fact is true of spina bifida and the
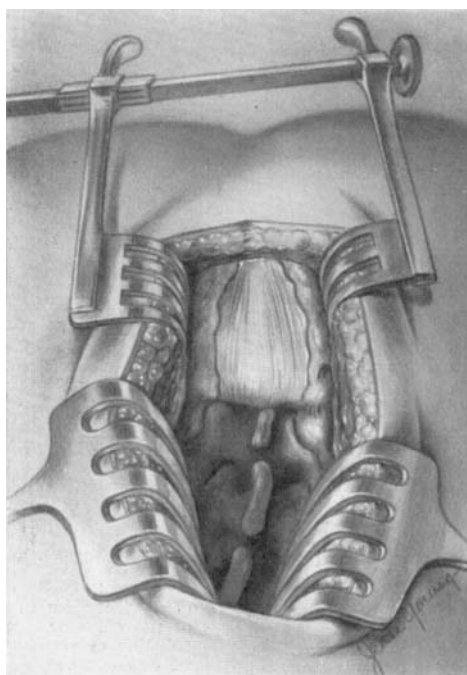

Fig. 285.—View of lumbosacral spine at operation in a case of severe spondylolisthesis, showing wide bony defect in the sacrum.

interarticular defect that is present in spondylolisthesis. While I do not believe that spina bifida bears any causal relation to spondylolisthesis, I find that those cases having wide gaps in the laminæ of the 5th lumbar vertebra or sacrum do show much more severe forward displacement. In *Fig.* 285 is illustrated the type of sacral defect found in two very severe cases of displacement operated upon by the writer.

Rotato-scoliosis.—In spondylolisthesis the amount of displacement is often not symmetrical because the laminal defect may be present on one side only.

In such cases rotato-scoliosis results (*Fig.* 286). This is of great interest, as the lumbar spine is commonly supposed to possess little power of rotation on account of the situation in relation to the sagittal plane of the articular facets. The usual reasoning regarding lumbar rotation assumes that the axis for such

FIG. 286.—Severe spondylolisthesis with rotato-scoliosis.

a movement must lie at the centre of the vertebral bodies. There are several mechanical factors that combine in the lumbar region to make it feasible for the axis of rotation to be placed posterior to the spinal canal. The centre of the circle of which the normal lumbar curve is a segment is situated posteriorly, and it is therefore easier for rotation also to occur upon a posterior

axis. If the lumbar concavity is increased, the centre of gravity is displaced posteriorly in relation to the lumbar vertebral bodies. Supposing that the axis of rotation were to be displaced to the tips of the spinous processes, the
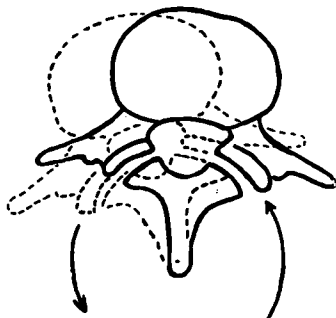

FIG. 287.—Diagrammatic out-line of a lumbar vertebra demon-strating in exaggerated form possible rotation upon a posterior axis.

arrangement of the articular facets would be admirably suited to allow of a fair range of movement of this type (*Fig.* 287).

Factors Limiting Displacement.—That the supports of the spondylolisthetic 5th lumbar vertebra are very insecure is obvious; nevertheless in the majority of cases the displaced body comes to a final position of rest after making only a moderate forward movement. There are several factors that favour natural arrest. One of these is provided by the iliolumbar ligaments that pass from the transverse processes of the last lumbar vertebra to the iliac crests; these are assisted by the interspinous ligaments and the posterior spinal muscles. The effect of all these ligamentous structures is increased
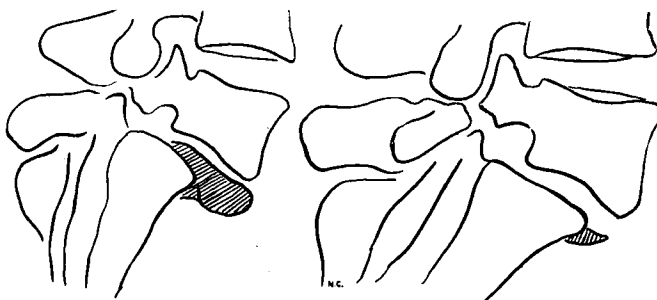

FIG. 288.—Tracings of lateral views of two cases of spondylolisthesis with buttress formation beneath the last lumbar vertebra.

by the tendency of the pelvis to assume a more vertical position by rotation on its transverse axis. Bone often proliferates from the anterior surface of the sacrum beneath the displaced portion of the 5th lumbar vertebra, forming a sufficient buttress to prevent further slip (*Fig.* 288). In many weight transmission must be partly assumed by the laminæ and spinous processes, and it is possible in some for the 4th lumbar vertebra, through its inferior articular facets, to come into direct contact with the sacrum.

Clinical Features.—In well-advanced cases it is usually not difficult to make the diagnosis of spondylolisthesis on clinical examination alone. A

shortened trunk in which the lower ribs are depressed, sometimes almost into the pelvis, is associated with a rotation of the pelvis upon a transverse axis so that the sacrum appears more vertical (*Fig.* 289). There is a small hollow behind the lumbar spinous processes, and at the lower end of this hollow there is a bony projection which in the commonest type of spondylolisthesis is the tip of the spinous process of the 5th lumbar vertebra, and not, as often stated, the upper border of the sacrum. A peculiar waddling gait may be observed ; this is due to hyperextension of the hips secondary to the pelvic rotation.

Pressure upon the branches of the cauda equina is not uncommon, and is manifested by sciatic neuralgia or neuritis. In the very early cases, low back pain is a common complaint, but nothing characteristic may be found except a small prominence of the 5th lumbar spinous process.
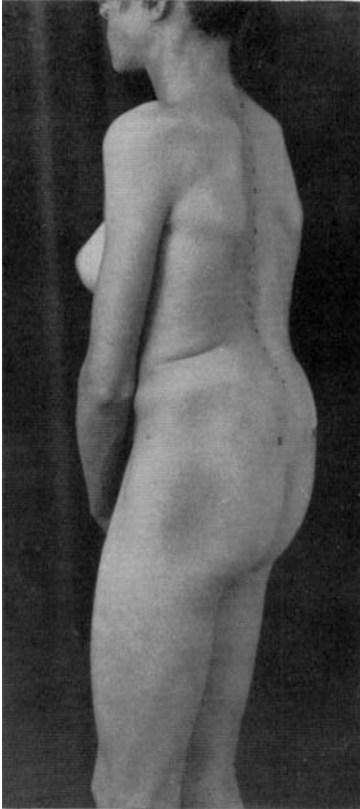

FIG. 289.—A patient with severe spondylolisthesis, showing characteristic rotation of the pelvis upon a transverse axis.

X-ray Appearances.—For early diagnosis X-ray examination is essential. In the antero-posterior view (*Fig.* 290) the well-developed cases give very characteristic appearances, as is well illustrated in Brailsford's article. The lateral view is of greater importance for early diagnosis, and the following points at the lumbosacral junction

FIG. 290.—Antero-posterior view of a case similar to that shown in *Fig.* 289.

must be observed : (1) Alinement of the anterior and posterior borders of the vertebral bodies ; (2) Width of the intervertebral disc ; (3) Shape of the intervertebral foramina ; (4) Continuity

of the neural arches ; (5) Length and relation of the spinous processes ;
(6) Evidence of structural bone changes ; (7) Degree of lumbar curve and
angle of the sacrum ; (8) Evidences of spontaneous arrest.

1. In advanced cases, the forward displacement of the 5th lumbar body
is easily seen.   Because of the thickness of the intervertebral disc milder
projections of the anterior border of the 5th lumbar body may be more
difficult to distinguish.   For such cases Ullmann has devised a test which is
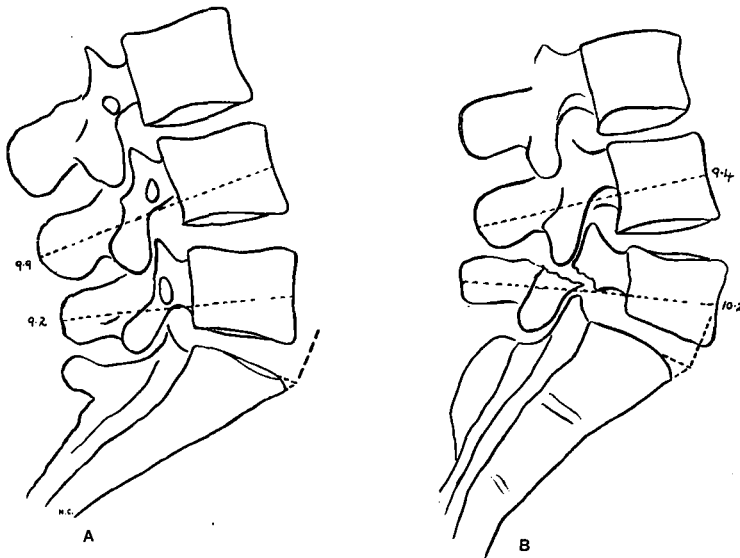illustrated in *Fig.* 291.   Regarding alinement of the posterior borders of the

FIG. 291.—Two tests for early spondylolisthesis : (1) Comparison of antero-posterior
diameters of last two lumbar vertebræ ; and (2) Ullman's sign. In the latter a line is
drawn at right angles to the upper border of the sacrum at its anterior edge ; the 5th lumbar
vertebra should lie entirely behind this line. A, Normal spine ; B, Spondylolisthesis.

vertebral bodies some caution must be exercised in the interpretation of dis-
placement, as a normal joint (because of some obliquity of the X-ray tube)
may show an apparent subluxation.   This is due to the shadow cast by the
lateral mass of the sacrum which may project behind the posterior border
of its body.

2. There is often some narrowing of the intervertebral space, which in
most cases is probably secondary to the displacement ; when due to the
destructive lesion of tuberculosis it may be a causal factor in the origin of
a spondylolisthesis.

3. The intervertebral foramina of this interval are the smallest of the
lumbar series, and in spondylolisthesis are elongated irregularly in the antero-
posterior direction.

4. One of the most characteristic features, which is usually seen best in
early cases, is the break in the laminæ ; this may appear as a gap continuing
the lumbosacral intervertebral clear space backwards *above* the spinous process

FIG. 292.—Untouched print of a lateral skiagram of early spondylolisthesis. The laminal defect is well shown, but the spinous processes are unfortunately lost in printing.
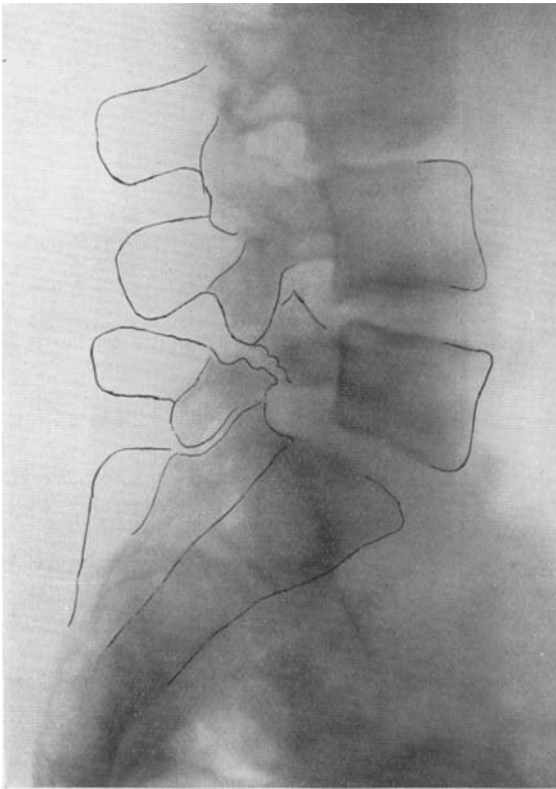

FIG. 293.—A skiagram of a similar case to that shown in *Fig.* 292. Certain of the bony details have been outlined in ink.

of the *5th* lumbar vertebra. Occasionally this defect may be observed in the antero-posterior view (*Figs.* 292–294).

5. Normally the 5th lumbar spinous process is the shortest of the lumbar series, but in the commoner type of spondylolisthesis it projects backwards beyond the 4th spine. A useful diagnostic point is to measure the antero-posterior diameters of the 4th and 5th lumbar vertebræ. In these cases the 5th will usually be found longer than the 4th; a reversal of the normal (*see Fig.* 291).

6. As further evidence of the wedge-like influence of the sacrum there may be found, besides the separation of the lowest lumbar vertebra into two
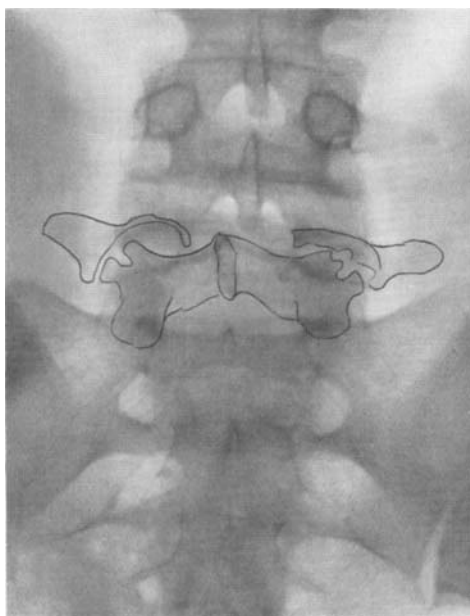

Fig. 294.—Antero-posterior view of same case as *Fig.* 293. The defective laminæ have been outlined.

portions, an angulation of the two halves so that their extremities point downwards.

7. In my experience the degree of lumbar curve and the angle of the sacrum have not been excessive; as already stated, in the extreme cases the latter tends to assume the vertical.

8. As evidences of spontaneous arrest, bony buttress formation may be seen attached to the anterior surface of the sacrum under the projecting portion of the 5th lumbar vertebra, and the lower articular process of the 4th may rest on the sacrum (*see Fig.* 288).

Treatment.—That many patients have spondylolisthesis without symptoms cannot be denied. In the early cases the temptation is great to try to prevent the further development of the deformity by bone-grafting operations. The

early treatment should, however, be that of any postural backache: the removal of conditions of labour likely to accentuate the lesion, a period of rest, and the provision of a brace where necessary. Operation should be reserved for cases not responding to such treatment or which are giving evidence of further slipping. Bone-grafts undoubtedly assist many patients, but it must be remembered that the result does not, from the mechanical point of view, possess great efficiency. Tremendous forces are brought to bear upon the graft, which is badly placed for the prevention of further slipping. In cases with sacral spina bifida it is difficult to obtain fixation for the graft at the lower end (*see Fig.* 285). The ideal operation would be either an anterior bone-graft so placed as to fix the body of the 5th lumbar vertebra to the sacrum and forming a buttress, or some form of anteroposterior fixation of the two halves of the divided vertebra (*Fig.* 295).

FIG. 295.—Theoretical alternatives to the posterior bone-graft operation for spondylolisthesis.

The technical difficulties of such procedures, however, preclude their trial.

SUMMARY.

Spondylolisthesis, equally common in men and women, is found to be of two types. The more usual results from a separation, through a probable congenital defect, of the 5th lumbar vertebra into two portions. Besides the forward displacement of the body of this vertebra, its spine and laminæ are displaced backwards with the sacrum.

The place of trauma in producing the subluxation and the influence of other factors besides lordosis are discussed. The author believes that the sacrum acts as a wedge, the apex of which (the upper and posterior edge) is driven upwards and causes a diastasis of the last lumbar vertebra, and that the posterior portions of the lumbar vertebræ take a more active part in the production of spondylolisthesis than is usually recognized.

Factors favouring natural arrest of the displacement are described; the surest of these is the formation of a bony buttress from the front of the sacrum.

Good lateral X-ray studies are frequently the only means of detecting the very early displacements, which will be found to be more common than is usually suspected. Roentgenological tests for early cases are illustrated.

Mechanically ideal, though technically unsuitable, operative procedures

are mentioned and the usual treatment is outlined; this in most cases should first be conservative.

I wish to acknowledge my indebtedness to the late Dr. P. M. Hickey, Professor of Roentgenology at the University of Michigan, who inspired me to carry out this study and who generously placed the resources of his department at my disposal.

BIBLIOGRAPHY.

ALBEE, F. H., *Jour. Bone and Joint Surg.*, 1927, ix, 427.
BRAILSFORD, J. F., *Brit. Jour. Surg.*, 1929, xvi, 562.
FALDINI, G., *Chir. d. Org. di Mov.*, 1928, xii, 545.
FITCH, R., *Amer. Jour. Orthop. Surg.*, 1912, x, 587.
HINTZ, A., *Forts. a. d. Geb. d. Röntgenstr.*, 1922, Kongressheft, 88.
KLEINBERG, S., *Arch. of Surg.*, 1921, iii, 102.
KLEINBERG, S., *Amer. Jour. Surg.*, 1930, x, 521.
LANE, W. A., *Trans. Pathol. Soc. Lond.*, 1885, xxxvi, 364.
LAWRENCE and BLACKER, *Trans. Obst. Soc. Lond.*, 1901, xlii, 75.
MOUCHET, A., and ROEDERER, C., *Rev. d'Orthop.*, 1927, xiv, 461.
MYERDING, H. W., *Jour. Bone and Joint Surg.*, 1931, xiii, 39.
NEUGEBAUER, F. L., New Sydenham Soc. Monograph, London, 1888, cxxi.
PICOT, M., *Jour. de Radiol. et d'Electrol.*, 1927, xi, 419.
SHORE, L. R., *Brit. Jour. Surg.*, 1927, xvi, 431.
TURNER, H. T., and TCHIRKIN, N., *Jour. Bone and Joint Surg.*, 1925, vii, 763.
TURNER, H. T., *Zeits. f. orthop. Chir.*, 1929, li, 23.
ULLMAN, H. J., *Radiology*, 1924, ii, 305.
WEGENER, E., *Arch. f. Orthop.*, 1928, xxvi, 73.
WHITMAN, A., *Jour. Bone and Joint Surg.*, 1924, vi, 808.
WILLIS, T. A., *Amer. Jour. Anat.*, 1923, xxxii, 95.

For more complete bibliographies, the reader is referred to the articles by Fitch, Brailsford, and Faldini.