A FURTHER ANATOMICAL STUDY OF SPONDYLOLYSIS IN HUMAN LUMBAR VERTEBRAE

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INTRODUCTION

The nature of spondylolysis is still a matter of considerable controversy where opinions oscillate between regarding the condition a stress fracture or due to congenital defect at the interarticular isthmus. The subject of spondylolysis was first recorded by lambl (1858) and Neugebauer (1881) and since that time it has aroused the interest of obstetricians and orthopaedic surgeons as a cause of forward displacement of lumbar vertebrae (spondylolisthesis). Unilateral or bilarteral cases were reported to occur in 4.2% of lumbar vertebrae with a greater frequency in males than in females (Roche and Rowe, 1951 a). Previous investigations dealt with description of post-mortem specimens or vertebrae removed during surgical operations in addition to examination of long series of radiograms on vertebral columns.

The objective of the present work is to investigate further the nature of spondylolysis as seen in dried lumbar vertebrae.

MATERIAL AND METHODS

Seventeen dried adult lumbar vertebrae and one separate vertebral arch were collected for this study out of 90 human skeletons. Four of these specimens were obtained from one tomb. Five specimens showed discontinuity at the interarticular isthmus on one side whereas the remaining 12 vertebrae exhibited bilateral defects with the respective neural arches missing. All vertebrae showing bilateral defects were 5*th* lumbar. In addition, the bodies of 26 normal 5*th* lumbar vertebrae were measured for comparison. The defected areas were described as regards their shape, contour and size. For the purpose of comparison of both sides the following measurements were undertaken in the unilateral cases :

The maximum height and breadth of the superior and inferior facets.

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The height and thickness of the pedicle.

The height of the inferior intervertebral notch taken from the inferior border of the pedicle to the inferior border of the related body.

OBSERVATIONS

Bilateral spondylolysis :

The defect affects the interarticular isthmus (the area between the superior and inferior articular processes) nearly at the same site on both sides (fig. 1). In general, the measurements taken for the pedicle and superior articular facets on both sides are symmetrical. The average vertical height of the pedicle is found 12.40 mm (range= 9—15mm) on the right side and 12.33mm (range= 9—15mm) on the left side whereas its thickness is 19.25mm (range= 16—23mm) on either side. The height of the superior articular facet measures 17.1mm and 16.08mm for the right and left sides respectively while their transverse measurements are 14.7mm and 14.3 mm respectively.

As regards the measurements of the vertebral body, the average anteroposterior diameter taken in the median plane is 35.33mm for the upper surface and 35.25mm for the lower surface, whereas the transverse diameters are 50.82mm and 51.60mm for the two surfaces respectively. The average vertical measurement of the body differs at the anterior surface from that at the posterior surface where they are found 26.5 mm and 22.42 mm respectively. The vertical measurements carried out on 26 normal 5th lumbar vertebrae for comparison reveal that the average height of the anterior surface is 29.00mm (range= 25—35mm) while that of the posterior surface is 25.08mm (range= 19—28mm).

The surface of the defected area is rough with irregular outline and its long axis passes transversely while its shorter axis is directed anteroposteriorly. On the left side the range of the transverse measurement is 10—18mm and that of the anteroposterior one is 5—12mm, whereas on the righ side they are 11—17mm and 7—10mm respectively.

The defect may appear as an irregular depression or provided with one or more elevations. The surface looks downwards and backwards, downwards and medially or directly downwards. In some cases, the plane of the defect is cut flush with the inferior border of the pedicle.

The separate neural arch belongs to an adult lumbar vertebra and consists of the spine, the two laminae and the inferior articular facets (Fig. 2). The two sides of the arch are almost symmetric. Small areas with a slightly rough surfaces (not so smooth as an articular sur-

face) are seen at the free ends of both sides.

Unilateral spondylolysis

Specimen (1) : A 5th lumbar vertebra shows an absent left lamina with the gap extending from the superior articular facet to the spine of the vertebra (fig. 3). The surface of the defect is slightly irregular and its plane passes horizontally at right angle to that of the superior facet. The bone is projecting downwards on its medial edge for 4 mm and on its lateral edge for 6mm. The surface of contact at the spine is slightly rough (9×8mm) with minute scattered foramina and two spurs of bone projecting both above and below the defected surface.

Specimen (2) : A lumbar vertebra (probably the 4th) of an adult subject shows spondylolysis on the right side. The diameters of the superior facet are 13 mm and 11 mm while those of the inferior one are 10 mm and 6 mm respectively. The right pedicle measures 12 mm in height and 8mm in thickness whereas the height of the related inferior intervertebral notch is 11mm. The height of the left superior facet is 17mm (the breadth is not complete). The height and thickness of the left pedicle are 17 mm and 9 mm respectively while the height of the related inferior intervertebral notch is 7mm. The external surface of the left pedicle shows an anteroposterior ridge extending from the vertebral body to the root of the transverse process and is separated from its inferior border by 6 mm. This ridge is not present on the right side. The thickness of the lamina just posterior to the superior facet is greater on the left (10 mm) than on the right side (6 mm).

Specimen (3) : A lumbar vertebra (probably the 3rd) of an adult subject has a linear defect at the left isthmus that separates the vertebral lamina with the inferior articular facet, on one hand from the anterior part of the vertebral arch with the superior articular facet on the other hand. From the latter part, a bony process projects medially above the upper border of the left lamina from which it is separated by a space 3 mm in height. The borders of the latter space are slightly grooved as if a ligament or a cartilage plate was attached to them. The anterolateral edge of the defected left lamina comes in contact with a small process of bone where the opposing surfaces (8×8mm) are smooth not unlike those of a joint. The posterior surface is convex while the anterior one is concave and both surfaces lie above the inferior articular facet with an intervening irregular area 6 mm in height (figs. 4 & 5).

The right pedicle measures 11mm in thickness and 16mm in height. It shows a ridge on its external surface 6 mm above its lower border and extending backwards from the body of the vertebra to the lower border of the transverse process. The height

of the right inferior intervertebral notch is 5 mm. On the left side the pedicle is thinner from side to side (8mm) and shorter in height(12mm) with the inferior intervertebral notch higher (12mm); no ridge is present on its lateral surface. However, the upper intervertebral notches on both sides are equal in depth.

The superior articular facet measures 13×9mm on the left side and 15×13 mm on the right side. The mamillary and accessory processes as well as the inferior articular facets are equal in dimensions on both sides. The level of the inferior border of the left half of the vertebral arch is slightly lower than that of the right half. The thickness of the lamina measured just posterior to the superior articular facet is found to be 10mm on the right side and 6 mm on the left side.

Specimen (4) : An adult lumbar vertebra (3rd or 4th) has the defect on the right side while its left lamina is broken (after death) (fig. 6). The right pedicle measures 12×7 mm while the left one measures 16×8 mm for the height and thickness respectively. The breadth of the isthmus (from side to side) is 16 mm on the right side and 16mm on the left (just above the defect) while its thickness is 6 mm on the right side and 13 mm on the left. The right superior facet is concave (13×10 mm) while the left one is flat (15×11mm). A flat accessory facet (9×7mm) is present below the right superior facet from which it is separated by an area 6mm in height (fig. 7). The depth of the inferior intervertebral notch is 10mm on the right side and 7 mm on the left side. However, the superior intervertebral notches are equal in depth on both sides.

Specimen (5) : A 5th lumbar vertebra from an adult subject shows absence of most of its neural arch with only the right inferior articular process still attached to its isthmus. The right pedicle measures 12×19 mm while the left one is 10×20mm for the height and transverse measurements respectively. The superior articular facets measure 15×13mm on the right side and 15×15mm on the left side whereas the right inferior articular facet measures seen on the left half of the inferior 18×14mm. An osteophytic ridge is border of the posterior surface but not on the right half.

Associated degenerative changes :

Atrophic degeneration in the epiphyseal ring encircling each of the upper and lower surfaces of the body together with osteophytic lipping of the vertebral borders are seen. Vertebrae with bilateral defects show that the inferior surface is affected with a greater frequency and in a more extensive degree than the superior surface. In addition, osteophytic lipping in the form of ridges or projections are seen on the lower border of the posterior surface of the vertebral body in 7

out of 12 cases with bilateral spondylolysis. These osteophytes vary from slight to moderate elevations but are usually of lesser degree than those present on the anterior surface and sides of the same vertebrae.

In cases with unilateral spondylolysis no difference is noticed in the degree of degeneration between the upper and lower surfaces. However, in only one case (5th lumbar) an osteophytic ridge is seen on the lower border of its posterior as well as on its anterior aspect and sides.

DISCUSSION

The present study showed that the side of the defect in unilateral cases of spondylolysis was relatively underdeveloped than the opposite side. This was mainly manifested in the size of the pedicle, thickness of the lamina and dimensions of the superior articular facet. The diminution in the height of the pedicle was reflected on the height of the related inferior interventricular notch which was found deeper than that of the opposite side. However, the finding of the superior interventricular notches of both sides to be symmetric is an indication that it is the lower part of the pedicle which is affected by the defect. It seems from the available observations that spondylolysis is due to a developmental error in the chondrification or ossification of the pars interarticularis where the lower part of the pedicle, the lamina as well as the superior articular facet of the same side are affected.

The assumption that the condition is due to stress fracture or fatigue failure by Murray and Colwill (1968) and Cyron et al (1976) seems to be unjustifiable in the light of the available results. It is unreasonable for a fracture to occur on one side of a vertebra without leaving any trace of callus but on the contrary the affected side is found attenuated. Similarly, the presence of an extra-articular facet below the superior facet on the side of the lesion is not easiiy explained on the basis of fracture. However, Murray and Colwill (1968) presented radiograms of vertebrae showing healed fracture at the isthmus with callus formation. Cyron et al (1976) applied a mechanical force to a series of cadaveric lumbar vertebrae and noticed that the force required to produce fracture increases progressively from the first to the fifth lumbar vertebrae and that about 25% of the cases tested showed fracture in the pedicle. In contrast, in unilateral spondylolysis no dissolution is seen at the pedicle and that the lesion is more frequently observed in the 5th lumbar vertebrae than in the others. Furthermore, the plane of the fracture induced in the experiment did not propagate along the usual site at which spondylolysis usually takes place.

The frequent association of spondylolysis with other congenital manifestations adds a further evidence to support that the condition is of a

developmental nature rather than due to fracture. Roche and Rowe (1951a) pointed out that 4% of bilateral spondylolytic vertebrae as well as 28.1% of unilateral cases were associated with spina bifida of the neural arch. However, Guillaume et al (1976) recorded two cases of congenital unilateral defects in the pars interarticularis of the 6th cervical vertebra that were associated with spina bifida as well as a deformity in the spinal cord at the level of the defect. The record of an accessory anomalous centre of ossification in the inferior articular process of a lumbar vertebra by Roche and Rowe (1951 b) may serve as a clue to the etiology of spondylolysis, in spite of the claim of the latter authors that such centre could play no role in the genesis of a separate neural arch.

It has been stated that there is a familial and racial predisposition to the incidence of spondylolysis. Baker and Mc Holick (1956) detected the defect in 28% of the parents of children affected by spondylolysis while Wilse (1962) diagnosed the lesion in 26% of the direct relatives of his cases. A further confirmation is available from the present study where four defected vertebrae were believed to belong to close relatives as they were burried in one tomb. Stewart (1953) found a racial difference in the frequency of spondylolysis where he noticed a remarkably higher incidence (26.3%) of the defect in Alaska Eskimos and Aleuts than in other populations (15%).

Bilateral cases of spondylolysis are more common than unilateral ones and are frequently seen in the 5th lumbar vertebrae. The condition may be associated with spondylolisthesis where the whole vertebra is shifted to a more forward position. As a consequence, atrophic changes in the circumferential epiphyseal plates are present on the upper and lower surfaces of the vertebral body together with osteophytes on its borders. In the present work it is the lower surface of the 5th lumbar body which is more commonly affected by such degeneration. This observation may lead to the inference that the vertebral body moves forwards mainly at its junction with the sacrum more than at its articulation with the 4th lumbar vertebra.

In case of spondylolistheis the lower border of the posterior surface of the vertebral body becomes exposed to unusual stresses. This leads to the formation of osteophytes at that border, a finding which is not usually seen at the posterior aspect of the vertebral bodies. In the present study these posterior osteophytes are observed in about 60% of the cases with bilateral spondylolysis. In addition, these vertebrae appear to be vertically compressed from above downwards where the height of the body is shorter by 3 mm. However, the body still retains the same difference (4 mm) between the height of the anterior and posterior surfaces recorded in normal 5th lumbar vertebrae

SUMMARY

A series of dried lumbar vertebrae showing unilateral or bilateral spondylolysis (interarticular isthmus defect) was collected for this study. The symmetry on both sides of a vertebra was assessed by carrying out certain measurements on its vertebral arch as well as on its body. In bilateral spondylolysis both sides of the vertebra were found symmetric while in unilateral cases they were asymmetric. The side of the lesion was underdeveloped than the opposite side and an accessory articular facet was present in some cases. Atrophic degeneration was seen in bilateral spondylolysis affecting mainly the inferior surface of the vertebral body. In addition, osteophytes were observed at the lower border of the posterior surface of the body in 60% of the vertebrae; a site which is not known to be commonly affected by osteophytes. The etiology of spondylolysis was discussed in the light of previous investigations where most of the evidence seems to be in favour of a developmental error rather than a stress fracture.

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LEGENDS

Fig. (1) : A 5th lumbar vertebra showing bilateral spondylolysis with the two sides nearly symmetrical. The specimen shows the superior articular processes (S) still attached while the inferior processes are absent.

Fig. (2) : A separate neural arch of an adult lumbar vertebra consisting of the inferior articular processes, the spine and the two laminae. The site of the defect (marked by the arrow) is seen as a slightly rough area on each side.

Fig. (3) : A 5th lumbar vertebra showing absent left lamina.

Fig. (4) : An adult lumbar vertebra (? 3rd) showing that the left lamina is completely separated from the rest of the vertebra at the interarticular isthmus. A process of bone is seen projecting medially above the left lamina.

Fig. (5) : The inferior aspect of the same vertebra described in fig. (4) showing a defect (marked by the arrow) with its surfaces simulating a joint.

Fig. (6) : A broken adult lumbar vertebra with unilateral spondylolysis on the the right side. The right pedicle is thinner from side to side than the left one.

Fig. (7) : The same vertebra described in fig. (6) showing a flat accessory facet (marked by the arrow) below the right superior articular facet.

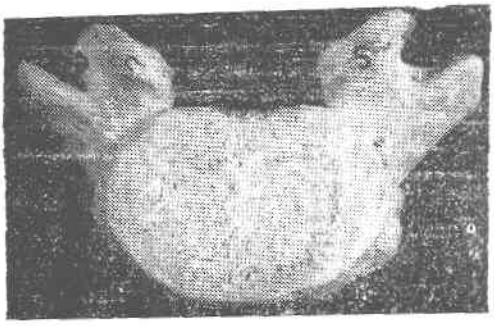


Fig. (1)

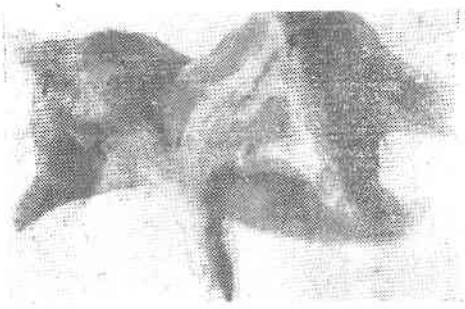


Fig. (2)

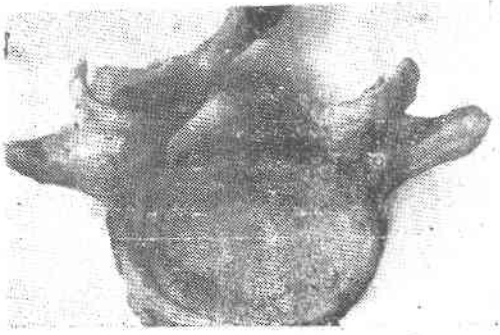


Fig. (3)

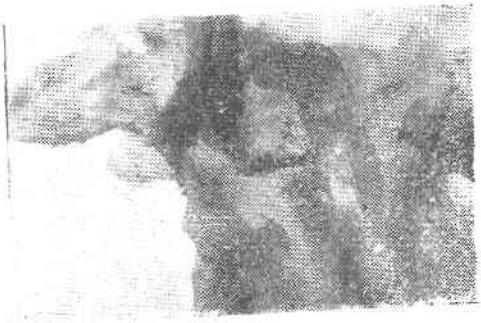
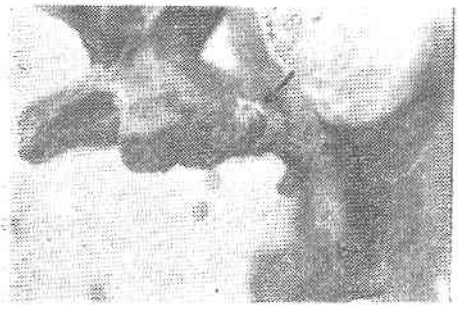


Fig. (4)



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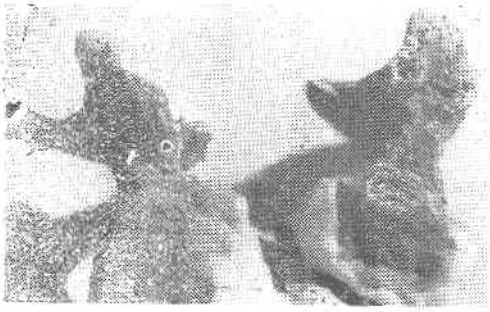

Fig. (6)

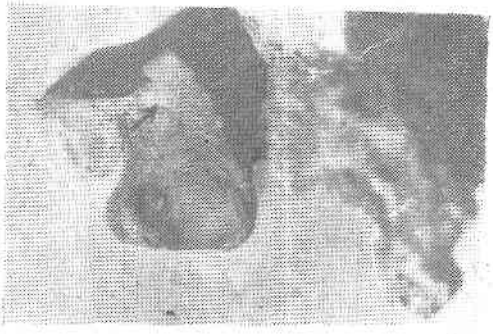

Fig. (7)