CONCLUSIONS

1. A relatively large number of fractures of the neck of the femur occur in which no active attention can be given to the fracture, because of the general condition of the patient. About 65 to 70 per cent. of the cases receive active treatment for the fracture.

2. Various methods of treatment with metallic fixation leave a great deal to be desired as to the outcome.

3. Osteotomy as a primary therapeutic procedure allows more certainty in the prediction of results, but demands the sacrifice of part of the function of the hip.

4. Primary bone-grafting after closed reduction eliminates the disadvantages of the methods described here; that is to say, it will more surely prevent aseptic necrosis and neck resorption, and at the same time it will maintain better hip function. At the present time, we prefer this method of treatment to all others, because the results have been better.

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PSEUDARTHROSIS IN THE LUMBOSACRAL SPINE *

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THOMPSON, M.D., NEW YORK, N. Y.

From the Orthopaedic Service of St. Luke's Hospital, New York City

Some in this audience will remember the furor with which surgical fusion of the spine was greeted when it was first proposed. Despite the fact that various complications soon became apparent, this procedure, at first proposed for tuberculosis of the spine, was gradually extended to include the treatment of many conditions. Among these were numerous disabling lesions involving the lumbosacral area. The obvious dangers of mortality and complications after such operations have been fairly well established, and accounts of pseudarthroses or failures of continuity in desired fusion areas have been recounted in a few series. Comparative statistics or percentages of pseudarthroses developing as a result of operative procedures employing varying techniques, carried out by the same limited personnel, are, to our knowledge, not available. While the operations reported here were all performed by three surgeons, they were carried out at six different institutions. This would indicate that the results were not due to unusual hospital advantages, but were the result of uniform surgical technique and ability. The mortality and complications have proved to be of minor importance. Failure of accomplishment of the desired end—namely, successful arthrodesis of a selected series of vertebrae in the lumbosacral region—has proved to be of major importance. We shall herewith review and report failures of fusion occurring in a consecutive series of patients in whom arthrodeses were attempted across the lumbosacral joint. The paper will be divided into two main parts: first, the incidence of pseudarthrosis in fusion of the lumbosacral spine; and, second, statistics regarding the repair of pseudarthroses.

TABLE 1
RELATION OF PSEUDARTHROSIS TO EXTENT OF FUSION AND NUMBER OF PATIENTS WITH SOLID FUSION NOT RELIEVED OF PAIN

<table>
<thead>
<tr>
<th>Fusion Intervals</th>
<th>No. of Operations</th>
<th>Pseudarthroses</th>
<th>Pseudarthroses</th>
<th>Solid Fusion without Relief of Pain</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>Per cent.</td>
<td>With Pain</td>
<td>Without Pain</td>
</tr>
<tr>
<td>Fifth lumbar to first sacral</td>
<td>145</td>
<td>5</td>
<td>3.4</td>
<td>3</td>
</tr>
<tr>
<td>Fourth lumbar to first sacral</td>
<td>357</td>
<td>62</td>
<td>17.4</td>
<td>36</td>
</tr>
<tr>
<td>Third lumbar to first sacral</td>
<td>78</td>
<td>26</td>
<td>33.3</td>
<td>15</td>
</tr>
<tr>
<td>Second lumbar to first sacral</td>
<td>18</td>
<td>6</td>
<td>33.3</td>
<td>4</td>
</tr>
</tbody>
</table>

INCIDENCE OF PSEUDARTHROSIS IN FUSIONS OF THE LUMBOSACRAL SPINE

Pseudarthroses in the Total Series

Clinical Incidence: In this series of cases, 647 operative procedures were carried out on 594 patients. The average postoperative follow-up period has been thirty-four months. No result has been accepted as regards solidity of fusion with less than one year of follow-up, unless controlled by both lateral roentgenograms in flexion and extension and by anteroposterior roentgenograms in right and left bends. Among the 594 patients upon whom spine fusion was performed, pseudarthroses developed in 119 instances or 20 per cent. This represents a percentage of basic failure which requires improvement.

True Incidence: Scientifically and factually, it has seemed important to determine the development of pseudarthroses according to the number of intervertebral spaces involved. Among the 594 patients, 1,329 spinal intervals were bridged. Pseudarthrosis occurred at 161 intervals among these patients, or 12.1 per cent. This represents the relative inefficiency of this type of surgery.

Incidence of Pseudarthrosis as Related to Extent of Fusion: We had expected that the percentage of pseudarthrosis would rise rapidly as the number of spinal intervals which were crossed increased. This was found to be true. When the fifth lumbar interval alone was bridged, pseudarthrosis developed in only 3.4 per cent.; when fusion of the fourth and fifth lumbar intervals was attempted, pseudarthrosis developed in 17.4 per cent.; as another interval was added, covering the third, fourth, and fifth lumbar intervals, the proportion rose rapidly to 33.3 per cent., and remained relatively the same as other intervals were added (Table I). A patient was often relieved of preoperative symptoms, in spite of the development of pseudarthrosis. Of all patients in whom pseudarthroses developed, 41.4 per cent. were relieved of the pain and disability which had been present before operation.

This analysis showed that a certain number of patients were unrelieved, even though solid fusion developed. This percentage rapidly decreased from 11.7 to 0 as the number of intervals successfully crossed was increased from one to four. To secure relief of symptoms for the greatest percentage of patients requires, therefore, a delicate balance. As the area of fusion is lengthened, there is an increase in the incidence of pseudarthrosis, but a marked decrease in the number of patients with solid fusion who are unrelieved of their symptoms.

Influence of Bending Roentgenograms on Results: Failure of fusion was demonstrated much more frequently when roentgenograms of front and side bending (biplane) were

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superimposed (Fig. 1) than by the use of flat roentgenograms and clinical observation. In these biplane roentgenograms, the lateral flexion and extension plates should show the fused elements completely superimposed. In the superimposed anteroposterior lateral-bending roentgenograms, the fused elements appear as if stereoscoped, but the borders of the bodies of the spinous and transverse processes are parallel. As early as 1933, lateral flexion and extension roentgenograms were occasionally used (Fig. 2). For more accurate determination, we frequently connect comparable points on the vertebrae with lines and superimpose these. Since 1940, roentgenograms with motion in two planes have been superimposed in order to denote solid arthrodesis. The use of such superimposed roentgenograms has increased the known percentage of pseudarthrosis, when tabulated both as to clinical incidence and true incidence.

In a review of this series of cases, only 11.8 per cent. were diagnosed as having failure of fusion by clinical judgment and flat roentgenograms. In 21 per cent. of the patients, pseudarthrosis was shown by biplane bending roentgenograms. The authors believe that the increased percentage shown to have pseudarthroses by the bending roentgenograms indicates accurately that clinical judgment, aided by flat roentgenographic plates, does not truly establish the number of pseudarthroses present in any series.

Relation of Pseudarthrosis to Primary Lesion for which Arthrodesis Was Performed

Posterior Herniation of the Intervertebral Disc: Here are grouped only those cases which had frank herniations of the disc with unequivocal extrusion of material. All cases with bulging of the disc, et cetera, are excluded and placed under the heading of lumbosacral strain. Of the typical posterior herniations of the intervertebral disc, pseudarthroses de-
### Table II

Relation of Pseudarthrosis to Primary Lesion for which Fusion Was Performed

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of Operations</th>
<th>Pseudarthroses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior herniation of intervertebral disc</td>
<td>158</td>
<td>18</td>
</tr>
<tr>
<td>Lumbosacral strain</td>
<td>280</td>
<td>65</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>69</td>
<td>16</td>
</tr>
<tr>
<td>Arthritis</td>
<td>37</td>
<td>11</td>
</tr>
<tr>
<td>All others</td>
<td>16</td>
<td>4</td>
</tr>
</tbody>
</table>

veloped in 11.4 per cent. (Table II). This low percentage is believed to be due to the universal use of the clothespin graft, plus quantities of additional bone.

**Lumbosacral Strain:** In this group were placed all patients with chronic lumbosacral backache, non-specific sciatic symptoms, and lesions, the basic pathology of which was not clearly disclosed before or after operation. Failure of fusion developed in 22.5 per cent. Before 1940, when biplane bending roentgenograms were not required, there was an incidence of pseudarthrosis of only 15 per cent. Following 1940, with all cases controlled by such roentgenograms, the percentage of pseudarthroses rose to 21.3. Here, again, is clear indication that pseudarthroses are missed with flat roentgenograms and clinical examination alone.

**Tuberculosis:** Under this heading were included only known tuberculous lesions of the spine. Any questionable lesions of this nature were placed under the heading of arthritis. Pseudarthroses developed in 16.1 per cent. of cases.

**Spondylolisthesis:** Spine fusion was carried out on sixty-nine occasions, with development of pseudarthrosis in 23.2 per cent. Before 1940, the incidence of pseudarthrosis was

![Fig. 2](image-url)

Lateral views of flexion and extension roentgenograms alone are not sufficient. These were used as early as 1933, but pseudarthroses have been shown to exist by the anteroposterior lateral-bending views, when the lateral views in flexion and extension superimpose with complete accuracy.

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TABLE III

DEVELOPMENT OF PSEUDARTHROSIS AFTER VARIOUS TYPES OF OPERATIVE PROCEDURE

<table>
<thead>
<tr>
<th>Technique</th>
<th>No. of Operations</th>
<th>Pseudarthroses</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>No.</td>
</tr>
<tr>
<td>Trisacral fusion</td>
<td>85</td>
<td>9</td>
</tr>
<tr>
<td>Double clothespin graft</td>
<td>356</td>
<td>68</td>
</tr>
<tr>
<td>Iliac strips</td>
<td>74</td>
<td>16</td>
</tr>
<tr>
<td>Local bone</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>Hemifusion</td>
<td>45</td>
<td>14</td>
</tr>
</tbody>
</table>

TABLE IV

REPAIR OF PSEUDARTHROSIS

<table>
<thead>
<tr>
<th>Number of pseudarthrosis repairs</th>
<th></th>
<th>43</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repaired once</td>
<td></td>
<td>29</td>
</tr>
<tr>
<td>Repaired twice</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>Repaired three times</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Total number of patients</td>
<td></td>
<td>35</td>
</tr>
</tbody>
</table>

35 per cent. After 1940, when double clothespin grafts of iliac bone supplemented by iliac strips were first used, the incidence of pseudarthrosis dropped to 16.3 per cent.

Arthritis: Of thirty-seven patients treated by fusion operation, pseudarthrosis developed in 29.7 per cent.

All Others: There were sixteen cases with such diagnoses as foreign body, fracture of the lamina, hemivertebra, or scoliosis. Pseudarthroses were found in 25 per cent.

Pseudarthroses Developing from Various Types of Operative Procedure

Trisacral Fusion: The lumbosacral joints were crossed in this operative procedure in eighty-five instances, with the development of pseudarthrosis in 10.6 per cent. (Table III). In the majority of cases this operative procedure was performed where the fifth lumbar vertebra alone was added to the sacrum, covering only one interval. For this reason a high percentage of successful arthrodeses resulted. Further analysis of the series shows that most of the pseudarthroses occurred where both the fourth and fifth lumbar interspaces were crossed. Where the fifth lumbar vertebra alone was arthrodesed to the sacrum, only 3.3 per cent. of pseudarthroses occurred. When both the fourth and fifth lumbar vertebrae were fused to the sacrum, 29.2 per cent. of pseudarthroses appeared, almost ten times as many as when a single interval was crossed.

Double Clothespin Graft: The double clothespin graft was used in 356 operations; 19.1 per cent. of pseudarthroses resulted. Analysis again shows that the number of intervals crossed determines the percentage of pseudarthrosis encountered. In operations in which the fifth lumbar vertebra was fused to the sacrum, one case of pseudarthrosis was found or 2.1 per cent. When two spinal intervals were crossed, 16.2 per cent. of pseudarthrosis occurred. When three intervals were crossed, the pseudarthrosis rate rose to 39.2 per cent.

Iliac Strips: In seventy-four operations, strips of iliac bone were used without other support; pseudarthroses developed in 21.6 per cent. This is nearly as good a record as with the double clothespin graft. Immediate stability following operation, however, is lacking.

Local Bone: When bone from the posterior elements of the vertebrae themselves was used, without reinforcement of osseous material from adjacent structures, the percentage of pseudarthrosis rose to 30.
PSEUDARTHROSIS IN THE LUMBOSacRAL SPINE

TABLE V
LOCATION OF PSEUDARTHROSIS AND INTERVALS INVOLVED

<table>
<thead>
<tr>
<th>No. of Interspaces</th>
<th>No. of Cases</th>
<th>Intervals Involved</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Location</td>
</tr>
<tr>
<td>1</td>
<td>19</td>
<td>Second lumbar</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>Third lumbar</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>Fourth lumbar</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>Fifth lumbar</td>
</tr>
</tbody>
</table>

Total number of pseudarthrosis intervals: 63

Hemifusion: In forty-five operations, iliac strips of bone were placed entirely on one side of the spinous processes, in contact with the underlying laminae. Of these, pseudarthrosis developed in 31.1 per cent. The authors had expected to find this method of fusion more satisfactory in this area of the spine.

Arthrodesis of Only the Fourth to Fifth Lumbar Interspace

Arthrodesis of the single interval at the fourth lumbar vertebra was performed on six occasions for disc hernia. In three, the fusion had to be extended to the sacrum, and two other patients are still partially disabled with lumbosacral complaints.

Mortality

Although this summary is concerned mainly with the development of pseudarthrosis, the mortality is reported for the entire series. There were six deaths. Two resulted from shock, two from infection, one from nephritis with resulting anuria, and one from embolus. This represents a mortality rate of approximately 1 per cent. Transfusions have been administered routinely since 1942, starting with operation, and since that date shock has not been a problem.

STATISTICS REGARDING THE REPAIR OF PSEUDARTHROSIS

Of the 119 patients in whom pseudarthrosis developed, only thirty-five returned to the authors for repair. Many of the remainder had symptoms insufficient to demand surgical treatment. A few refused further care or went elsewhere for repair. Forty-three repairs were done on these thirty-five patients (Table IV). In four instances, two repairs were carried out on each patient; and in two instances, three repairs were done. Of the twenty-nine others, each had one attempt at repair. The average time interval from the original spine fusion to repair of the pseudarthrosis was 21.2 months. The average length of follow-up has been 44.9 months. The average age of the patients was 35.6 years. No case was accepted for study until at least a year after operation or unless the result had been checked by biplane bending roentgenograms which were superimposed. Since in no instance in the whole series have we seen a spine fusion become solid later than eight months after operation, when checked by biplane bending roentgenograms, we have accepted results as regards pseudarthrosis as final after such a period, when so controlled. One death occurred in this series of patients operated upon for repair of pseudarthrosis. This death is the one previously reported as resulting from anuria due to nephritis.

Preoperative flexion roentgenograms in two planes have been required in all cases since 1940. Of thirty-one patients, on only one occasion did biplane bending roentgenograms fail to show that a pseudarthrosis was present. In twelve cases in which flat roent-
Fig. 3-A: Two types of pseudarthrosis are shown, the usual transverse type and the type occurring at the end of a chondroin graft.

Fig. 3-B: Repair of such pseudarthrosis is carried out on one side only. Transverse processes and articular facets are exposed, and the site of previous fusion is denuded on its posterior surface only.

Fig. 3-C: A wide iliac strip is set vertically on the transverse processes outside the articular facets, and in contact with them. Strip grafts of ilium are then placed over the dorsum of the previous fusion on one side, in the angle between the fusion and the vertically placed graft. The remainder of the previous fusion on the opposite side is not exposed, being shown in the illustration only for clarity. It is left alone for such support as the body mass can provide.
genograms alone were taken, four or 33.3 per cent. failed to show pseudarthroses which were found later at operation. Furthermore, we have on many occasions seen apparently solid fusion in lateral flexion and extension roentgenograms, whereas anteroposterior lateral-bending roentgenograms showed pseudarthrosis to exist. It is the authors' firm conviction that all cases of fusion in the lumbosacral spine must be checked with biplane bending roentgenograms for satisfactory statistics to be secured.

**Location of Pseudarthrosis**

The forty-three operations for repair of pseudarthrosis covered sixty-three spinal intervals with failure of fusion; in other words, more than one pseudarthrosis was found at operation in several of the patients. Most of the pseudarthroses were located at the fourth lumbar interspace; the next most frequent number were at the fifth lumbar interval (Table V). The great number found at these two intervals is accounted for by the fact that most of the spine fusions crossed them. Although all operations crossed the fifth lumbar interspace, the greatest number of pseudarthroses were at the fourth lumbar. This may be because of the relative instability of the fourth lumbar as compared with the fifth lumbar. In the twenty-five instances in which a single pseudarthrosis was found, six or 24 per cent. failed of repair. Of the twelve patients with two pseudarthroses each, only 50 per cent. success was obtained at repair. In the remaining six patients with more than two pseudarthroses, the percentage of success was even lower. Repair of pseudarthrosis is appreciably more difficult than original fusion.

**Success of Pseudarthrosis Repair as Based upon Original Diagnosis**

Nine repairs of pseudarthrosis were performed in which the original diagnosis was posterior herniation of the intervertebral disc (Table VI). There was failure to secure ankylosis in 44.4 per cent. Where lumbosacral strain had been the original diagnosis, there were twenty cases with 30 per cent. of pseudarthroses developing after attempted repair. Among eight patients with an original diagnosis of tuberculosis, there was 25 per cent. failure of repair. Spondylolisthesis patients showed 25 per cent. failure of refusion. Two arthritic patients who had pseudarthroses repaired both secured solid ankylosis.

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**TABLE VI**

**Failure of Pseudarthrosis Repair According to Original Diagnosis**

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>No. of Operations</th>
<th>No. of Persisting Pseudarthroses</th>
<th>Failures (Per cent.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Posterior herniation of intervertebral disc</td>
<td>9</td>
<td>4</td>
<td>44.4</td>
</tr>
<tr>
<td>Lumbosacral strain</td>
<td>20</td>
<td>6</td>
<td>30.0</td>
</tr>
<tr>
<td>Tuberculosis</td>
<td>8</td>
<td>2</td>
<td>25.0</td>
</tr>
<tr>
<td>Spondylolisthesis</td>
<td>4</td>
<td>1</td>
<td>25.0</td>
</tr>
<tr>
<td>Arthritis</td>
<td>2</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

---

**TABLE VII**

**Relation of Failure of Pseudarthrosis Repair to Type of Operation Used**

<table>
<thead>
<tr>
<th>Technique</th>
<th>No. of Operations</th>
<th>Failures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Iliac strips</td>
<td>18</td>
<td>4</td>
</tr>
<tr>
<td>Double clothespin graft</td>
<td>14</td>
<td>4</td>
</tr>
<tr>
<td>New procedure</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Local bone</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>

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Relation of Failure of Pseudarthrosis Repair to Type of Operation

In eighteen patients, iliac strips were used on both sides of the mid-line, with four failures or 22.2 per cent. (Table VII). These were the simpler cases. When the clothespin or buttress graft was reapplied, together with iliac strips, there were fourteen cases with four failures, a percentage of 28.6. A new procedure was developed for the more difficult cases (multiple pseudarthroses), in an attempt to reduce the percentage of failure. By this type of procedure, seven cases have been treated with two failures (28.6 per cent.). Since these were the cases with two or more pseudarthrosis intervals each, it can be seen that the reduction from 50 per cent. failure to 28.6 per cent. failure may represent a real advance. This operation will be described herewith. Local bone was used on four occasions with three failures (75 per cent.). These cases were treated many years ago, before it had become routine to add iliac or other bone strips.

In three patients a typical herniation of intervertebral-disc material was removed from beneath a pseudarthrosis.

Postoperative Care

Plaster jackets were used postoperatively for five months or more in twenty instances. Of these, new pseudarthroses developed in seven or 35 per cent. In view of this percentage of new pseudarthroses, we feel that the jacket may be dispensed with and a reinforced lumbosacral corset used.

Causes for Development of Pseudarthrosis

These cases have been explored carefully. Certain outstanding causes of failure of fusion were noted. In all but ten instances, there seemed to be a definite factor which one could recognize for each particular case. In thirteen instances it was clearly evident that an inadequate amount of bone had been used for grafting material. In five instances the pseudarthrosis could be definitely ascribed to the use of solid, heavy tibial bone, not supported by iliac bone or other fine strip grafts. Infection at the original operation for spine fusion, draining sinuses associated with tuberculosis, hematomata resulting from the original fusion, et cetera, occurred in ten instances. In five instances the solid spine fusion (as determined previously by biplane bending roentgenograms) had been fractured. In two of these cases the spinous process at the upper end of a clothespin graft had been torn loose from the underlying laminae, and in three the fusion had been broken directly across. Crossing of previous laminal defects seemed to be the basis of pseudarthrosis in ten instances. Of these ten cases, new pseudarthroses developed in five on attempted repair, or a failure of 50 per cent.

New Type of Repair

A new type of operative procedure has been used for the few more difficult cases of pseudarthrosis (Figs. 3-A, 3-B, and 3-C). It consists essentially in denuding the laminae and the lateral margins of the articular processes, with extension of the dissection to the bases of the transverse processes on one side only (hemifusion). The medial portion of the transverse process is likewise denuded. A thin, wide flap is removed from the outer cortex of the ilium and implanted vertically on the transverse processes. Iliac strips are then placed over the denuded posterior elements of the involved vertebrae themselves, the angle between the implanted massive iliac graft and the mid-line being filled in. Wandering of the chips is prevented by the laterally placed large iliac graft. Furthermore, contact is made with the transverse processes and the outer surfaces of the articular facets, as well as across the previous spine fusion on one side. When this form of repair is used, only one side of the spinal area is dissected and one half of the pseudarthrosis area is seen. The remaining previous bony masses on the opposite side are left intact for such stability as they may already produce.
Although percentages have been indicated, too few of these operations have been done for a final estimation of their efficacy.

CONCLUSIONS

1. The percentage of pseudarthrosis developing in spine-fusion operations in the lumbosacral region may be reduced by an adequate amount of bone of good texture, firmly implanted and free from infection.

2. The possibility of pseudarthrosis should be discussed with the patient before operation in every instance, so that he is forewarned, and so that consent for repair may more readily be obtained, when necessary.

3. One should avoid covering any greater number of spinal intervals than are absolutely essential in performing a fusion at the lumbosacral juncture, but the fusion should always extend to and include the sacrum.

4. For statistical and practical purposes, it is useless to report a series of spine fusions at the lumbosacral juncture without control of the series by biplane roentgenograms, taken with the patient in flexion and extension, and with right and left bends. The roentgenograms should then be accurately superimposed. Furthermore, even with such roentgenograms, a few instances of pseudarthrosis in any series will fail to be recognized.

NOTE: The authors wish to acknowledge the assistance, in the compilation of these statistics, of Kazuo Yanagisawa, M.D., and Alfonso Della Pietra, M.D.


DISCUSSION

Dr. Joseph S. Barr, Boston, Massachusetts: Dr. Cleveland and his associates have presented a most interesting paper on a timely and important subject. Spine fusion is an important procedure in the armamentarium of the orthopaedic surgeon. It is necessary that we re-examine all of our patients who have had fusion to determine what the percentage of failures is and to take such steps as will enable us to lower the percentage of failures. Dr. Cleveland has stated that the major causes of failure of fusion are: (1) the use of an inadequate amount of bone, (2) infection, and (3) fracture of the graft. To this list of important factors I would like to add some additional points.

1. Complete fixation of the segments to be fused, so that all motion is obliterated, should be our aim. Fixation by external means, such as plaster casts and shells and prolonged bed rest, is demonstrably ineffective, for varying amounts of motion occur, no matter what type of apparatus is used. The double clothespin graft, or H graft as I prefer to call it, is a very effective means of immediate internal fixation, and I think that where it can be used, it represents a definite advance in technique.

2. The use of screws across the facets and bone plates between spinous processes has become popular in certain clinics. There are disadvantages to the use of metals which may outweigh their advantages.

I agree with the authors’ conclusions that, if the fourth lumbar space is fused, the fifth lumbar must be included. Dr. Cleveland has omitted reference to what, if anything, he does to the articular facets at the time of fusion. This is a difficult question. They can be left untouched. They can be cut across and bone grafts laid over them. They can be curetted and excised or a key graft placed across the facet, as advocated by McBride. There is room for further study of this problem. Theoretically, at least, if one succeeds in obtaining fusion of the articular facets, motion between the involved segments will be obliterated. Fractures through the neural arches may occur, however, unless additional bone is used.

I believe that careful preparation of the bed and of the facets, as advocated by Hibbs, plus the use of an H graft with additional cancellous bone from the ilium, is the most satisfactory method of fusion available today.

No matter what method is used, biplane bending roentgenograms, taken after one year, will reveal pseudarthrosis in an unpleasantly high percentage of cases. Repair of the pseudarthrosis is unnecessary in about 50 per cent. of the cases, as clinically they are asymptomatic.

I find myself in complete agreement with the authors in practically all of their major premises, and wish to congratulate them again on an excellent paper.

Dr. Eugene M. Regen, Nashville, Tennessee: You have heard another typical Cleveland, Bosworth, and Thompson report. The tremendous value and significance of this analysis cannot be appreciated in the short time they have had to present their findings, and I would urge their careful examination in less
hurried moments, I could profitably emphasize many of their conclusions, but the virtues of their paper are so obvious that I shall confine myself to some few questions that have arisen as I read this report.

1. A curve to indicate the incidence of pseudarthrosis year by year, as new operative procedures developed and as the surgeons improved their technique, might be enlightening.

2. No report was made on the type of postoperative care following the original fusion. It is my opinion that there now exists over the country a distinct trend toward inadequate postoperative fixation and bed rest following spine fusion. One wonders whether the prospect of a relatively short period of bed confinement may serve as an inducement for the patient to accept this major operative procedure. Since the incidence of pseudarthrosis varies inversely with the security of the fifth, fourth, and third lumbar vertebrae to the pelvis and their distance from it, I believe that this would indicate the use of adequate plaster fixation and bed confinement for from two to three months after the operation.

3. In discussing the causes of pseudarthrosis, the authors did not mention the possible influence of spinal fluid escaping after the accidental opening of the dura. All of you who have explored the spinal canal know that this is not an infrequent occurrence.

4. The authors have proved conclusively the value of biplane bending roentgenograms. They require the accurate superimposition of corresponding points on the roentgenographic films, but it is a fact that fibrous fixation alone can be secure enough to prevent the detection of motion at a given vertebral joint by the method of examination they describe.

5. The paper states that the relief of symptoms is directly proportional to the length of successful fusion above the sacrum, but the authors did not emphasize the danger of limiting a working man's usefulness by stiffening too many of his lumbar joints.

6. Since the vast majority of lumbosacral operations are performed for mechanical disorders, with or without nerve-root compression, I believe one should universally perform the fusion from the sacrum to the fourth lumbar vertebra only, unless there is a distinct indication to go higher.

7. The necessary period of postoperative fixation is usually followed by temporary stiffening of joints above the site of fusion. I routinely employ a set of simple exercises, begun three months after operation, which have materially shortened convalescence. These exercises mobilize the joints above the site of fusion, and greatly strengthen the glutaeus maximus and anterior abdominal muscles.

8. My experience does not compare with that of the authors in number of cases. My postoperative follow-up does not meet their criteria, but observation of my own patients has not revealed pseudarthrosis to be noticeably prevalent. I feel reasonably sure that it is well under the 20 per cent. which the authors report in their series.

9. Finally, even though a painful pseudarthrosis does exist, the symptoms can often be largely, if not entirely, relieved, and a secondary operation can be avoided by postural exercises which tend to remove the stress and strain from the site of abnormal joint irritation.

DR. ALAN DEFOREST SMITH, NEW YORK, N. Y.: It has been the habit at the New York Orthopaedic Hospital to make periodic surveys of the results of fusion operations. The results in the lumbosacral cases have been comparable to those which Dr. Cleveland reported.

Our first survey showed 12 per cent. of failures at the fifth lumbar, and 20 to 30 per cent. between the fourth and fifth lumbar; and that has continued, although we have reduced the percentage to 8 at the lumbosacral joint. The failures between the fourth and fifth lumbar vertebrae still remain high. That seems to be the critical point. Internal fixation has not helped. In any case in which fusion extends above the fifth lumbar, I believe that a double spica should be used, and the patient should be confined to bed for at least eight weeks.

I was interested to see the results with the clothsipin graft, and to note that they showed no difference from those cases in which other methods were used.

DR. D. M. BOSWORTH (closing): This study was attended by a great deal of difficulty. We tried to divorce entirely the question of pseudarthrosis from that of recovery on a symptomatic basis.

All these fusions were done by three surgeons only. They were a control series, not done by residents, but accurately performed by careful, well-trained men. They were performed in six hospitals, so there was no variation in incidence of complications based on the type of hospital used.

The postoperative care in most of the cases has been two and one-half to three weeks of bed rest, and thereafter a lumbosacral belt reinforced with light steel. The biplane bending roentgenogram was established for the purpose of follow-up accuracy. A few cases of pseudarthrosis will be unrecognized, even with biplane bending roentgenograms. In our series, in only one instance was pseudarthrosis unrecognized by such roentgenograms. Patients securing solid fusion become free of back disability, as a rule. They do not notice loss of spine motion clinically. As to the tight graft, I know of one H graft which was placed too tightly by the surgeon.

As to the question of removal of the articular facet, the facets were usually left intact in our cases. If a large series were run without débridement of the articular facet, and the percentage remained the same as with débridement of the articular facet, we would feel that that particular procedure would not be necessary.