Pseudarthrosis of the Lumbar Spine

John M. Larsen, MD, and Daniel A. Capen, MD

Abstract

Pseudarthrosis can be a costly and disabling complication of lumbar spinal fusion. This review focuses on the incidence, causation, diagnosis, and nonoperative management of this condition, as well as surgical approaches that can be effective in treating carefully selected patients. Judicious initial selection of patients for fusion and the use of meticulous surgical technique in the first operation continue to be the best means of prevention.

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Although there is no clear consensus on many of the indications for lumbar fusion, the procedure is currently used to treat a variety of pathologic conditions. Little controversy exists regarding surgical treatment of spinal fractures and dislocations predicted to be acutely or potentially unstable, those that pose a risk of progressive neurologic impairment, and those that could result in unacceptable deformity if treated nonoperatively. Surgical treatment of selected primary and metastatic tumors often necessitates spinal stabilization and fusion, which may involve long interpositional grafts. Fusion of areas affected by spinal infections, particularly in cases of Pott's disease, has been shown in large multicenter trials to decrease the deformity associated with tuberculous infections. Spinal stabilization and fusion is also a well-accepted treatment for spinal deformities, such as scoliosis in children, degenerative deformities in carefully selected adults, spondylolisthesis, and new or impending spinal instability due to extensive lumbar decompression.

The use of fusion in the treatment of many degenerative spinal diseases is less uniformly accepted. While it is generally agreed that fusion offers little additional benefit in the surgical treatment of primary disk herniations, there is continued debate about its role in the management of recurrent herniations. The greatest controversy concerns the management of patients with chronic disabling low back pain whose symptoms are thought to result from degenerative disk disease.

Despite these controversies, the annual incidence of the use of lumbar spine fusion has risen dramatically in recent years, particularly in the treatment of degenerative spinal conditions. From 1978 to 1990, the rates of lumbar fusion in the United States increased 100%, from 13 to 26 operations per 100,000 population per annum.[1] Katz[1] has described wide variations in the incidence of fusion between nations and between different geographic locations within the United States. Among the reasons cited for these differences and dramatic increases are population aging, a greater focus on medical care for elderly patients with spinal disorders, advances in radiologic imaging, and advances in spinal fixation, which are thought to improve the results of fusion. However, the best predictor of the incidence of spinal operations, including spinal fusion, is the number of spine surgeons in a geographic area.

During this period of increased incidence of the use of fusion, it has become evident that the costs of fusion are substantially greater than those of decompressive operations alone. The hospital costs of laminectomy and fusion without fixation exceed those of laminectomy alone by 50%, and this difference doubles if internal fixation is used.[1] These increased costs are also associated with greater medical and surgical complications, particularly in the elderly.[1]

Dr. Larsen is Attending Surgeon, Rancho Los Amigos Medical Center, and is in private practice with Southwestern Orthopedic Medical Group, Downey, Calif. Dr. Capen is Associate Clinical Professor of Orthopedics, University of Southern California School of Medicine, Los Angeles, and Attending Surgeon, Rancho Los Amigos Medical Center, and is in private practice with Southwestern Orthopedic Medical Group.

Reprint requests: Dr. Larsen, Southwestern Orthopedic Medical Group, 7700 East Imperial Highway, Suite R, Downey, CA 90242.

Unfortunately, lumbar fusion is not always successful. The rates of successful outcome range from 16% to 95%.[2] After an extensive review of the literature, Turner et al[2] estimated that only 68% of all fusion surgeries have a successful functional outcome. Among the causes for failure are inadequate initial patient selection, incorrect diagnoses, problems with operative techniques, and a variety of complications, including pseudarthrosis.

Definition and Overview

The term "pseudarthrosis" implies a false joint, but is commonly understood to connote absence of solid bone union. Generally, the diagnosis cannot be confirmed with certainty until a year after surgery, although the diagnosis may be suspected within 6 months of the index operation.

Cleveland et al[3] are generally cited as the first to detail the diagnosis and treatment of pseudarthrosis in their survey of a large group of patients who had undergone midline posterior lumbar fusion. They concluded that the diagnosis was suggested by continued back pain and sometimes continued or new leg pain, localized midline lumbar tenderness, and the absence of visible bone union on plain radiographs. They emphasized the diagnostic importance of vertebral motion as detected on flexion and extension radiographs. In their series, failure of fusion was identified on plain radiographs in 11% of the patients; this rose to 21% when identification on motion radiographs was used as the criterion. They also noted that the rate of pseudarthrosis increased dramatically as the number of vertebral levels spanned by the fusion increased. Cited as possible causes were the use of too little bone graft, the use of cortical rather than cancellous bone, inadequate decortication of the graft bed, and inadequate postoperative immobilization.

It is currently believed that pseudarthrosis occurs in at least 15% of primary lumbar fusions. Similar to the experience of Cleveland et al, the reported rate varies substantially with the accuracy of the diagnostic methods employed.

Histology

Friedlaender[4] has carefully detailed the histology of bone graft incorporation, which is beyond the scope of this review. In 1993, Heggeness et al[5] analyzed the histologic features of established pseudarthroses in biopsy specimens taken from 35 patients undergoing further surgery. The soft tissue found between adjacent mobile bone segments was predominantly fibrous, but neurologic tissue could not be identified. The bone immediately adjacent to the fibrous areas was always sclerotic, accompanied by microfractures of the cancellous bone. They speculated that these microfractures could be a source of pain.

Classification

In 1991, Heggeness and Esses[6] described the most common classification for pseudarthrosis (Fig. 1).

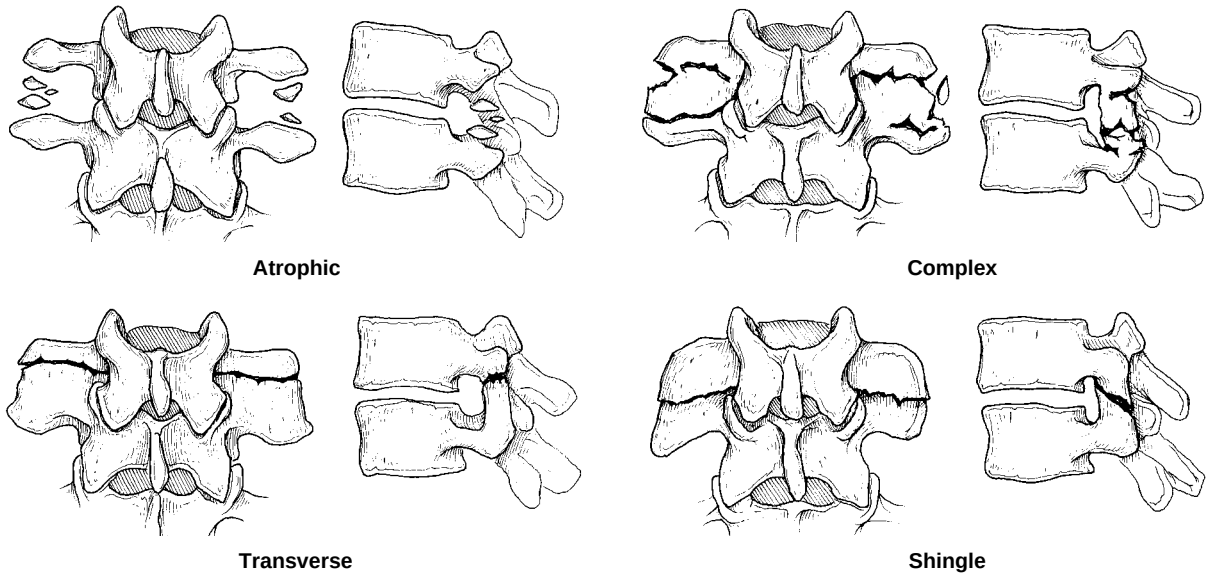

Fig. 1 Morphologic classification of pseudarthrosis.[6]

Four distinct morphologic categories were identified: atrophic, transverse, shingle, and complex. The transverse, shingle, and complex varieties were thought to be capable of load bearing, whereas the atrophic form appeared to have no load-bearing or load-sharing potential. A striking association was noted between the atrophic pattern and the presence of a clearly recognizable facet joint. They reasoned that the intact facet joint provided stress shielding to the bone graft, leading to atrophy of the graft in accordance with Wolff's law. Similar atrophy of graft has been shown when rigid implants are employed (Fig. 2). In the study by Heggeness and Esses, 61% of patients with internal fixation and pseudarthrosis had the atrophic pattern, compared with 38% of the patients whose original operation did not include internal fixation.

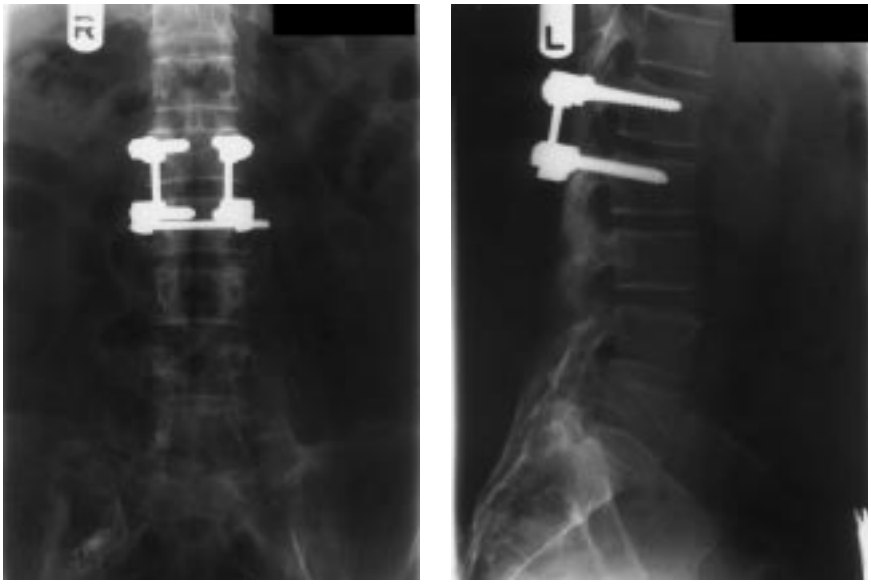

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Fig. 2 Attempted posterolateral fusion with internal fixation at L1-L2 resulted in atrophic pseudarthrosis. Anteroposterior **(A)** and lateral **(B)** radiographs depict solid fusion between L4 and S1.

Risk Factors

A variety of conditions have been associated with an increased risk of pseudarthrosis after lumbar spinal fusion. A number of systemic factors, including hormonal balance, osteoporosis, and nutrition, were reviewed by Boden and Sumner[7] and shown to influence the rate of fusion. Both growth hormone and thyroid hormone have a positive effect on bone healing. Androgens and estrogens are thought by some to stimulate bone formation. While the presence of osteoporosis makes rigid fixation more difficult, the specific effect of deficient bone mass on fusion formation is unclear. Nutritional inadequacies have been shown to adversely influence bone healing. Such abnormalities can be identified by measuring serum albumin and transferrin levels and total lymphocyte count, as well as by skin-antigen testing, anthropometric measurements, and nitrogen balance studies. Hematologic disorders can decrease the number of osteoprogenitor cells available for fusion consolidation.

Several pharmacologic agents have been shown to adversely affect fusion success.[7] Corticosteroids decrease the synthesis rates of the major components of bone matrix necessary for bone healing. Nonsteroidal anti-inflammatory medications suppress the inflammatory response and may inhibit bone repair and spinal fusion. Chemotherapeutic agents curb bone formation and healing if administered early in the postoperative period.

Therapeutic radiation treatment has also been shown to adversely affect fusion when used within 3 weeks after fusion surgery.[7] Animal studies suggest that preoperative radiation may have a similar effect.[7]

A more common problem is cigarette smoking, which interferes with bone metabolism and revascularization and inhibits bone formation. Brown et al[8] retrospectively compared the data on 50 smokers and 50 nonsmokers who had undergone two-level posterolateral lumbar fusion for a variety of pathologic conditions. Pseudarthrosis was present in 40% of smokers, compared with 8% of nonsmokers. These observations have been confirmed in other studies in which various fusion techniques as well as internal fixation were used. For these reasons, cessation of both nonsteroidal anti-inflammatory medications and smoking is strongly recommended as part of the pre- and postoperative treatment program for patients considered for spinal fusion.

Factors Affecting Success of Surgical Treatment

Cleveland et al[3] first described a relationship between the risk of pseudarthrosis and the primary dis-

order for which the fusion was performed. When the indication was adjunctive to primary disk excision, pseudarthrosis developed 11% of the time; when the indication was a less specific degenerative condition, pseudarthrosis occurred in 29% of the patients. The evidence accumulated since this early observation suggests that a number of factors may be operative. If the primary pathologic condition treated has a greater degree of instability, the risk of fusion failure would be expected to increase. Less certain is the impact of other patient characteristics. For example, Hanley and Levy[9] showed that the rate of fusion for isthmic spondylolisthesis was reduced when the patient's symptoms were attributed to work injury. Although differences in age and smoking history explained part of this variation, other health and social habits may have been operative.

Since the patient review by Cleveland et al[3] in 1948, it has been well established that the rate of pseudarthrosis increases with the number of vertebral levels incorporated in the fusion mass, and is more common when other lumbar operations preceded the fusion. It has come to be commonly understood that intertransverse process fusion has a lower rate of fusion failure than the traditionally employed posterior midline fusion techniques. This difference has been attributed to the great vascularity of the fusion bed and the mechanical advantage of graft placement closer to the vertebral center of rotation. On the basis of a literature review, Herkowitz and Sidhu[10] attempted to determine the relative advantages of different fusion techniques, but no definite conclusions could be reached. The pseudarthrosis rates ranged from 5% to 25% for posterolateral fusion, 6% to 27% for posterior lumbar interbody fusion, and 20% to 30% for anterior lumbar interbody fusion. Although unproved in randomized prospective trials, the combined anterior and posterior technique has been thought to achieve fusion in more than 90% of patients.

Stabilization

Before the advent of internal fixation devices, external braces and even prolonged bed rest were thought to be positively associated with a greater rate of fusion. Few studies have scientifically evaluated the beneficial effects of bracing, and the results have been indeterminate. Prolonged immobilization is now generally accepted to have no beneficial effects and is associated with negative physiologic sequelae, such as osteoporosis and muscular deconditioning.

The most important advance in operative technique thought to promote fusion has been the use of multiple internal fixation devices, most recently, pedicle fixation. Zdeblick[11] most recently prospectively compared the fusion rate for patients treated without internal fixation, with semirigid pedicle-screw fixation systems, and with rigid pedicle-screw fixation systems. His results showed that the use of pedicle fixation led to greater rates of radiographically evident fusion than did surgery without internal fixation. The fusion rate was also greater when rigid pedicle-fixation systems were compared with semirigid fixation devices. Potentially offsetting these advantages is the higher risk of complications when these devices are used.[12]

Clinical Importance

The clinical importance of lumbar pseudarthrosis has been debated for decades. DePalma and Rothman[13] retrospectively compared the data on patients with radiographically proved lumbar pseudarthrosis with those on a matched cohort whose lumbar fusion appeared radiographically solid. No difference could be identified between the two groups as measured by recovery or symptoms. They hypothesized that fibrous stabilization was essentially as effective as bone fusion. It should be emphasized, however, that the original indication for fusion was principally as an adjunct to lumbar disk excision.

Although similar results have been reported in studies in which patients were followed up for a minimum of 10 years after combined lumbar disk excision and midline spinal fusion, these results have not been confirmed by others. For example, Kim and Michelsen[14] retrospectively reviewed the data on 50 patients with failed back surgery. A satisfactory outcome was achieved in 81% of patients in whom a solid fusion was achieved, but in only 23% of those whose pseudarthrosis repair was unsuccessful. A similar opinion was reached by Turner et al[2] on the basis of their analysis of the literature.

More recently, Carpenter et al[15] reported successful functional outcomes for repair of pseudarthrosis in only 27% of 86 patients. Interestingly, after the revision procedure, the radiographs of 94% of the 86 patients had the appearance of solid fusion. A more optimistic conclusion was reached by Stewart and Sachs,[16] who found that 72% of 39 patients had good or excellent results after revision fusion procedures.

Evaluation

Differential Diagnosis

In addition to pseudarthrosis, a wide variety of conditions can cause

persistent back and/or leg pain after a lumbar spinal fusion. Failure to recognize the pathologic condition causing the patient's original symptoms remains a leading cause of failed fusion procedures. Intraoperative problems, such as dural injury and internal fixator complications, are also known causes of persistent pain. In some cases, psychosocial issues can make a satisfactory functional outcome unlikely; in general, these patients never achieve the desired relief of symptoms or return to full function.

Even more controversial is the optimal treatment of patients who have persistent pain despite unequivocal radiographic evidence of solid lumbar arthrodesis. In this situation, the differential diagnosis again includes failure to appreciate alternative causes of pain not addressed at surgery. We concur with others who believe that failures may occur when a posterolateral fusion has been used to treat diskogenic causes of back pain and that the patient's continued symptoms are the result of elasticity of the fusion mass such that the disk continues to be loaded and produce pain.

If initial satisfactory relief of symptoms and return to function have occurred, other possible causes should be sought, including not only pseudarthrosis but also disorders in adjacent motion segments, such as spinal stenosis and acquired instability.

Diagnostic Modalities

The diagnosis of an established pseudarthrosis is rarely difficult. Depending on the original indication and the type of fusion employed, patients may complain of pain, have evident hardware failure, show loss of correction of a preexisting deformity, or have abnormal motion on dynamic films. In the presence of pseudarthrosis, particularly early in the postoperative course, the subjective picture may vary from complete absence of pain to constant severe back pain, with or without lower extremity symptoms.

The physical findings generally are nonspecific and include lumbar tenderness and restriction of motion. Objective neurologic deficits may be present, depending on the initial diagnosis. Development of new neurologic symptoms and objective signs more likely predicts either new pathologic changes or a surgical complication.

The most sensitive method of assessing the integrity of the fusion is direct surgical exploration, but this approach is not recommended until the patient has been completely evaluated. Radiologic assessments described in the literature include plain radiography, motion radiography, biplanar radiographic techniques, stereophotogrammetry, tomography, axial-plane computed tomography (Fig. 3), two-dimensional reformations and coronal techniques, bone scintigraphy, magnetic resonance imaging, and diskography. Unfortunately, when the results of radiographic studies are compared with direct surgical observations, the sensitivity, specificity, and predictive value of these various modalities are either disappointing or have not been analyzed sufficiently well to allow the drawing of definite conclusions.[17,18]

Kant et al[18] used plain radiographs to assess the integrity of fusion. In 75 cases in which the plain-radiographic and surgical findings were correlated, the sensitivity of radiography was 68%. Technetium bone scintigraphy has been analyzed in two studies. Hannon and Wetta[19] concluded that this technique had little predictive value. In a larger group of 110 patients, McMaster and

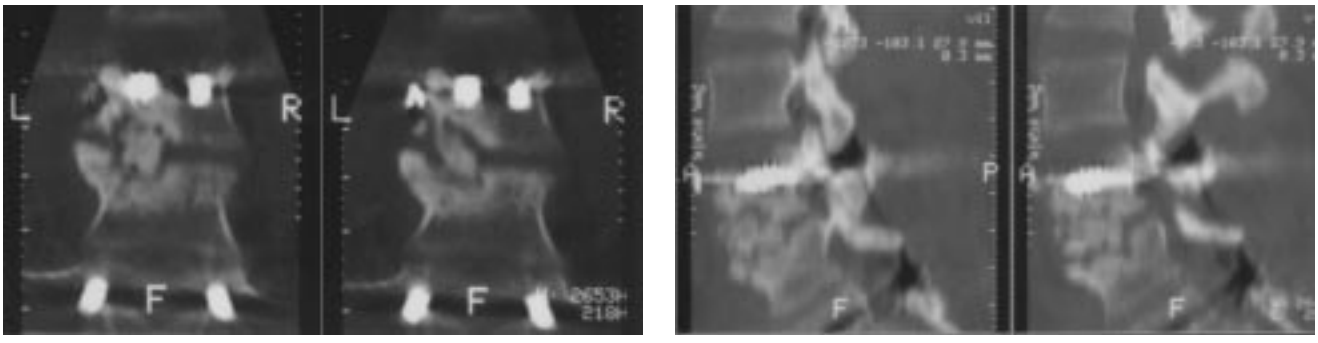

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Fig. 3 Anteroposterior **(A)** and lateral **(B)** computed tomographic reconstructions demonstrate pseudarthrosis of an anterior interbody bone graft.

Merrick[20] found a 50% false-positive rate. However, their data suggested that a positive bone scan obtained 1 year or more after the fusion was more predictive than a positive result at 6 months postoperatively.

The predictive value of using multiple imaging techniques was studied by Larsen et al[17] in a group of 25 patients who were suspected of having pseudarthrosis of a previous lumbar fusion performed with the use of pedicle-screw fixation. Their evaluation included plain films, dynamic lateral radiographs, computed tomographic scans, and bone scintigraphy, followed by surgical exploration. They concluded that surgical exploration was the best diagnostic technique.

A variety of other imaging and pain-provoking tests have also been used with varying, but in general minimal, success. Johnson and Macnab[21] correlated the diskographic and surgical findings in 24 patients with suspected pseudarthrosis and concluded that diskography should not be the sole basis for the decision to reoperate. Local injections of anesthetics into suspected pseudarthroses have been recommended, but the data supporting their diagnostic sensitivity and specificity are minimal.[22]

Trial immobilization with the use of braces or casts has often been cited as a useful technique with little direct evidence of diagnostic utility.[22] As an extension of the concept of trial immobilization, temporarily applied external fixators have been used on an experimental basis.[22]

The most accurate diagnostic method used to date is anteroposterior tomography (Fig. 4). Dawson et al[23] retrospectively analyzed the data on 198 patients who had undergone fusion for scoliosis. The standard radiographs of 21% of the patients were not interpretable, as were the lateral tomograms of 60% of the patients. The identification of pseudarthrosis on anteroposterior tomograms correlated with the intraoperative findings in 96% of their patients who underwent exploratory surgery. Hence, the false-positive rate was only 4%, but the false-negative rate could not be computed.

Diagnostic Approach

When encountering a patient with pain and substantial functional impairment who has undergone prior lumbar fusion, a careful and thorough diagnostic evaluation must be undertaken (Fig. 5). Only after the cause of a patient's persistent symptoms has been established unequivocally can there be any hope of successful treatment.

First, the rationale for previous surgical treatment must be evaluated, including review of all imaging studies. It is possible that a prior procedure did not accurately address the source of symptoms or deal with major psychosocial issues, such as substance abuse. If a clearly defined disorder is still present, revision surgery should be aimed at treating it.

Second, the technical details of the prior procedure should be carefully reviewed. Incomplete neurologic decompression with persistent radiculopathy or stenosis and technical difficulties with hardware are examples of possibly remediable postoperative pain. Obviously, a successful revision procedure must include correction of such problems.

Third, it is possible that the pathologic condition has arisen since the last surgical procedure and is

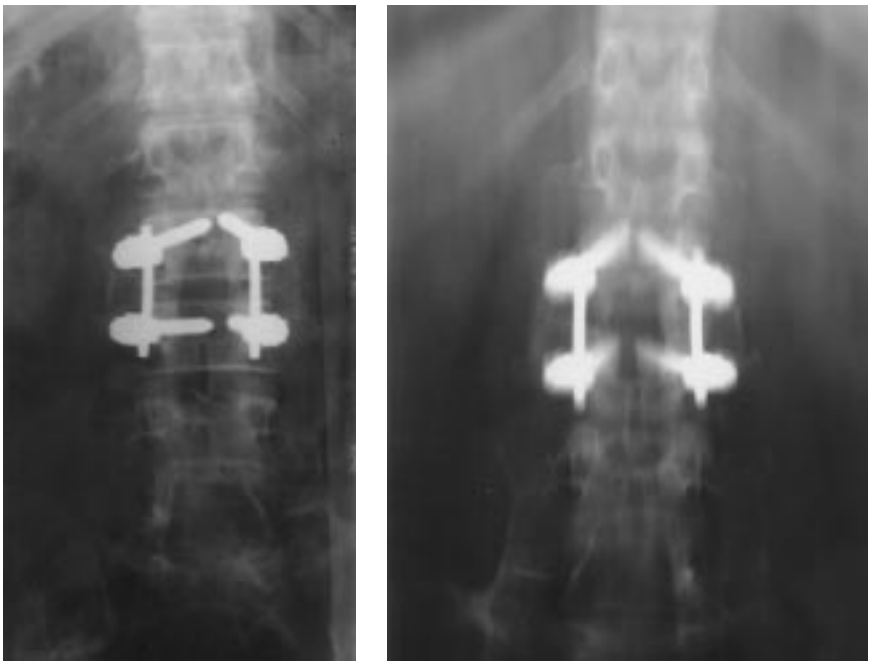

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Fig. 4 A complex pseudarthrosis was suspected after L2-L3 posterolateral fusion **(A)** and was confirmed by anteroposterior tomography **(B)**.

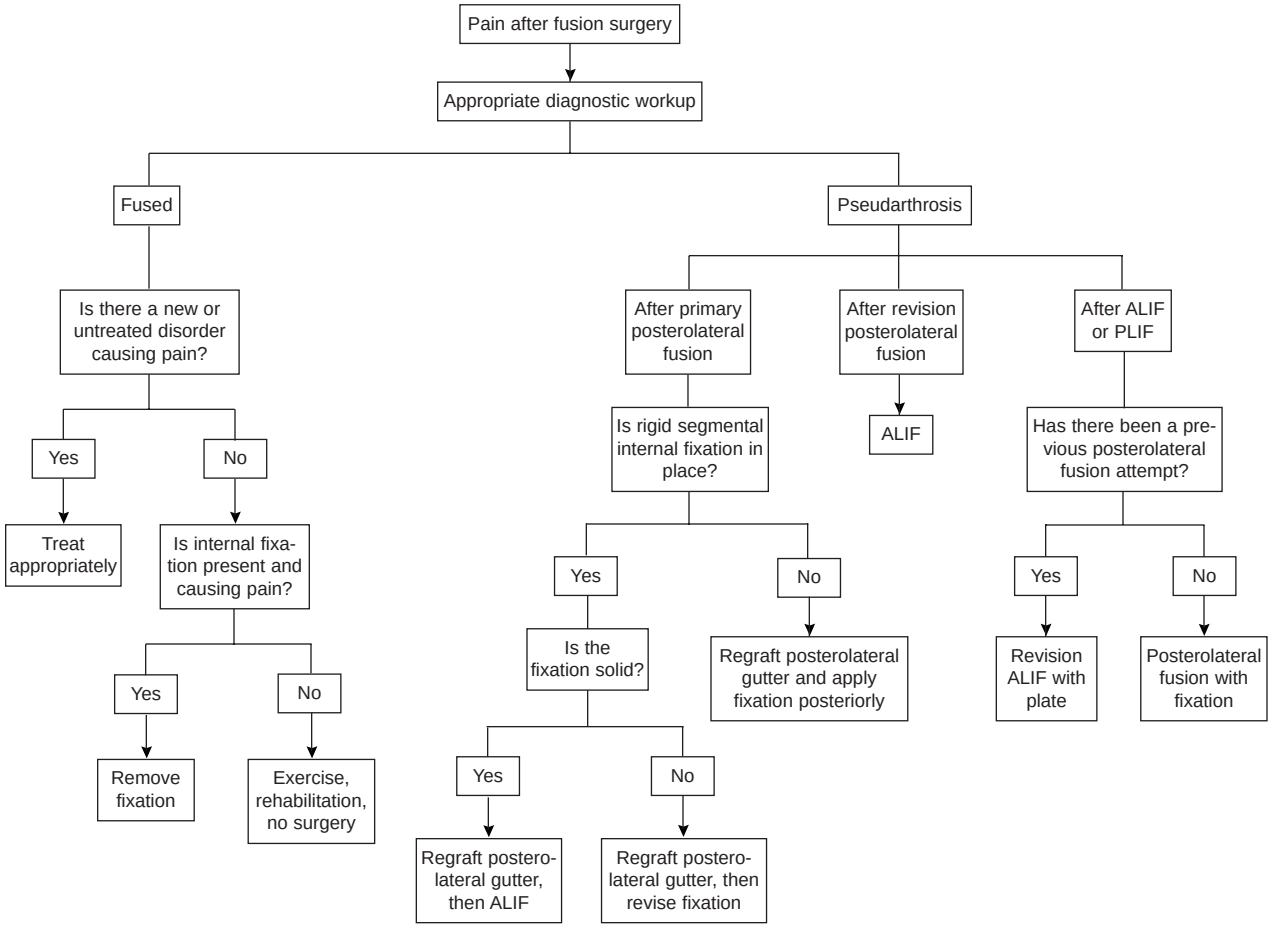

Fig. 5 Algorithm illustrating diagnostic approach to the patient with suspected pseudarthrosis. ALIF = anterior lumbar interbody fusion; PLIF = posterior lumbar interbody fusion.

responsible for the patient's present symptoms. Recurrent disk herniation and/or instability or stenosis adjacent to a fusion mass are examples of these problems. Radiologic investigation of these reasonable possibilities is appropriate.

Fourth, nonsurgically treatable sources of pain, such as deconditioning, medication abuse, and psychosocial problems, should be evaluated carefully. If any of these problems is present, it is unlikely that further surgery will improve the patient's condition.

Finally, the possibility of pseudarthrosis must be considered. Many times this diagnosis is difficult to appreciate radiologically. In our practice, we rely most commonly on plain radiography, motion radiography, and anteroposterior tomography. When all reasonable causes of pain have been excluded, we surgically explore the fusion mass and, if nonunion is found, attempt to promote solid bone union. It must be emphasized that successful pseudarthrosis repair will lead to a successful surgical result only if the rationale for the original surgical procedure was sound and if other pathologic conditions potentially responsible for the patient's pain have been appropriately treated. Also, it must be candidly explained to the patient that the expectations of revision surgery do not match those of primary procedures. Revision surgery is associated with higher complication rates and less favorable outcomes.

Before surgery, it is necessary to define and treat any systemic factors that could lead to the failure of fusion. Metabolic abnormalities should be corrected. The nutritional status of the patient should be optimized. Smoking should cease. The patient should not be exposed to nonsteroidal anti-inflammatory drugs, corticosteroids, chemotherapeutic agents, or radiation therapy.

Nonsurgical options, such as bracing and external stimulation, can be used in an attempt to treat nonunion. It has been our experience that these modalities are best used as adjuncts to surgical treatment and should not be relied on alone.

Surgical Treatment

The surgical treatment of pseudarthrosis varies with the many clinical situations in which it is encountered. A comprehensive description of the surgical techniques used in each and every one of these clinical situations is beyond the scope of this review.

In general, if the patient has nonunion of a posterolateral fusion without fixation, rigid internal fixation is applied across the affected motion segments, and additional graft material is applied (Fig. 6). We prefer pedicle-screw instrumentation and, if at all possible, autologous bone graft. An et al[24] have described the surgical results that can be anticipated when freeze-dried, frozen, or mixed allografts are used. Newer bone substitutes are also being researched. However, we consider these options only after autologous donor sites have been exhausted.

When posterior fixation is in place, an attempt must be made to determine whether it is providing adequate immobilization across the pseudarthrosis. Loose or broken fixation should be repaired, and the area regrafted. A second option, which we consider less attractive, involves removing the fixation and regrafting the nonunion site, combined with internal or external electrical stimulation and bracing. Should a second posterior procedure fail to result in solid bone union, anterior lumbar interbody fusion is recommended (Fig. 7). In the rare instance when the posterior fixation is found to be intact, the posterolateral area is regrafted, and anterior lumbar interbody fusion is performed at the same time or, if necessary, as a second-stage operation.

Pseudarthrosis of a primary posterior lumbar interbody fusion is an indication for posterolateral fusion accompanied by rigid internal fixation. If the initial procedure included both posterior lumbar interbody fusion and posterolateral fusion with internal fixation, we follow the protocol for a failed posterolateral fusion.

When a failed primary anterior interbody fusion is encountered, we initially attempt to remedy the situation posteriorly. Rigid posterior segmental fixation is required, along with bone grafting in the posterolateral gutter. In the event that revision anterior grafting is necessary, special care is taken during the dissection to avoid damage to the anterior vessels, ureters, and sympathetic plexus. Anterior fixa-

Fig. 6 **A,** An attempted in situ posterolateral fusion at L5-S1 resulted in pseudarthrosis. **B** and **C,** The lack of solid union was confirmed on dynamic lateral views. **D,** Rigid segmental internal fixation was applied, resulting in solid union and symptomatic relief.

A B C

Fig. 7 **A,** An attempted posterolateral fusion involving internal fixation resulted in pain and radiographically apparent pseudarthrosis. **B,** The fixation was found to be loose and was revised. Autologous bone was placed across the pseudarthrosis at L4–S1. At the same sitting, the L4-L5 level was approached anteriorly, and an anterior lumbar interbody fusion was performed. **C,** The fixation device was subsequently removed, and the fusion was found to be solid.

tion is appropriate when instability is encountered.

Summary

Revision surgery for pseudarthrosis remains costly and complicated. Self-destructive practices that can lead to fusion failure should be completely controlled before reoperation. The conditioning of the patient should be optimized. Smoking should cease. Chemical dependency and other psychosocial problems must also be addressed preoperatively to enhance the postsurgical result. The anticipated outcomes must be clear to both the practitioner and the patient. There will always be a group of patients whose clinical outcomes are good without radiographic evidence of arthrodesis. For this group, monitoring is the treatment of choice. If there is no risk to the spine, activities as tolerated are encouraged.

Prevention of pseudarthrosis is the most successful treatment. This begins with appropriate patient selection and presurgical reduction of risk factors. It extends to a well-planned procedure in which equal attention is given to bone grafting technique and to safe application of internal fixation. It ends with a well-managed postoperative rehabilitation. This remains the key to cost control and the high probability of a successful outcome.

The current health-care environment has deemphasized expenditure for chronic benign conditions that cause pain. This may be dissatisfying to surgeons who devote time and energy to treating spinal pain. However, if it serves to lower the pseudarthrosis rate, it will certainly lower costs and improve outcomes.

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