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The Fate of the Adjacent Motion Segments After Lumbar Fusion

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Summary: Lumbar spine fusion is a commonly performed procedure in various pathologic conditions of the spine. Its role remains debated, and moreover, delayed complications may occur, among which is transitional segment alteration leading to recurrence of back pain, gross instability, and neurologic symptoms. Little is known about the long-term prevalence of this complication because of a lack of specific studies. We analyzed the fate of the transitional segments in a homogeneous group of patients operated on during a 14-year period for degenerative conditions of the lumbar spine resistant to conservative treatment. Follow-up ranged from 2 to 15 years. Seventy-five percent of our study group had a minimal 5-year follow-up. In this subgroup, 41% of the patients developed transitional segment alterations, and 20% needed a secondary operation for extension of the fusion. Potential risk factors such as postoperative delay, length of fusion, and spine imbalance were recognized. The frequency of delayed alterations of the adjacent segment and the severity of symptoms related to this complication in this study raise questions about the justification of fusion procedures in degenerative conditions of the spine without threatening instability. Data from the literature confirm the severity of the problem, but many uncertainties remain because of the lack of homogeneous and complete data on both the normal evolution of motion segments of the lumbar spine with age and the fate of the same segments when transformed in transitional segments. Future prospective studies on the subject are needed and must deal with homogeneous groups of patients. More reconstructive surgical procedures need to be developed to lessen the need for fusion procedures. **Key Words:** lumbar fusion, transitional segments, motion segments, degenerative spine

INTRODUCTION

Though the place for fusion remains controversial in the management of severe low back pain, especially in the absence of true instability of the spine, it is a widely performed procedure in many developed countries. If a majority of well-selected patients are expected to obtain pain relief after successful lumbar fusion, "fusion generates a conflict between immediate benefit and late consequences," as stated by Ehni over 20 years ago.[1]

One of the most obvious drawbacks of fusion comprises the biomechanical modifications induced at the level of the adjacent motion segments. Some kind of overloading is inevitable and may lead to premature degenerative alterations and even true mechanical breakdowns of these motion segments, with recurrence of pain and sometimes even neurologic symptoms.

Potential adjacent motion segment alterations (AMSAs) are dehydration of the disk visible only on magnetic resonance imaging (MRI), disk space narrowing, disk space vacuum, osteophyte formation, appearance or increase of degenerative retrolisthesis, antelisthesis or rotatory dislocation, spinal stenosis due to hypertrophy of the posterior facets, disk or ligament bulging, and instability with static or dynamic malalignment of the spine. The importance of back pain induced by these secondary changes is often unpredictable and inconsistent with the imaging, as in primary degenerative conditions of the lumbar spine.

The treatment has to take into account both the symptoms and the anatomic status of the spine. In the case of asymptomatic or mildly symptomatic alterations of the adjacent motion segments, observation is the rule. When

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treatment is required, the options range from ordinary painkillers to repeat surgery with, in some cases, the need for aggressive procedures to correct imbalance of the spine.

AMSA after lumbar spine fusion represents an important and unavoidable problem. It is strange that quite few publications deal specifically with this topic: In a review of the literature from spring 2002, only 22 articles were found that dealt precisely with the clinical situation and 6 with more basic studies of the problem. Even more startling are the contradictory results from both in vitro and clinical studies and the mixture of different pathologies (fractures, spondylolysis, degenerative problems) included in the series, though the initial status of the spine in these different conditions is inhomogeneous.

This study focuses on the long-term evolution of the adjacent segment in patients fused only for degenerative conditions of the lumbar spine, excluding other pathologies.

PATIENTS AND METHODS

This is a retrospective study of 149 patients operated on by the same surgeon between 1987 and 1994. After attempts to review all the patients and radiologic files, 106 cases could be reviewed with a follow-up of 2–15 years; 78 patients (ie, 75% of the series) had a minimum follow-up of 5 years. The medical records were carefully reviewed for recurrence of mechanical pain or neurologic symptoms after a period of postoperative relief, and the radiologic files were studied to recognize the occurrence of the above-mentioned alterations. All patients had undergone a one-level or multilevel instrumented posterolateral lumbar fusion for intractable pain related to degenerative conditions of the spine. The fusion was performed in all cases with autologous iliac bone, the instrumentation used either Louis plates with pedicle screws (Howmedica or Cremascoli) or Cotrel-Dubousset-type instrumentation with rods and pedicle screws (original Cotrel Dubousset, Compact Cotrel Dubousset or Horizon, Medtronic-Sofamor-Danek). The sex ratio was two-thirds women and one-third men; age at index operation ranged from 22 to 81 years, with a mean age of 55.

A number of possible risk factors favoring junction breakdown were defined: length of time elapsed from index surgery, length of fusion, postoperative lifestyle, body weight, a partial fusion (ie, the fusion of one or more unstable levels in association with a decompressive procedure while the remaining levels were degenerated but not unstable and hence not fused), postoperative sagittal or frontal imbalance of the spine, and age at index procedure.

RESULTS

The patients were distributed in different groups, according to the existence of AMSAs or not. Subgroups were defined according to the length of follow-up (minimum 2 years and minimum 5 years) and the need for reoperation or not. The results are listed in Table 1.

The postoperative delay clearly influenced the existence of secondary alterations of the adjacent motion segments. Thirty-eight percent of the patients developed some kind of alterations of the adjacent motion segment. The mean delay for appearance of junctional alterations was 57 months. This explains why in the subgroup of 28 patients with <5 years' follow-up, there are only 8 patients (29%) who developed problems, whereas in the group of patients with >5 years' follow-up, 32 of 78 showed alterations (41%). Interestingly, the ratio between reoperated and nonreoperated patients presenting AMSAs was the same in the group with >5 years' follow-up (47% reoperation rate) and in the group with <5 years' follow-up (50% reoperation rate). This could signify that the most severe alterations, leading to instability or neurologic problems, occur more rapidly.

The length of the fusion seemed to influence the occurrence of AMSA. Results related to this topic are listed in Table 2.

Among 37 cases of single-level fusions, 32% developed some AMSAs but mostly asymptomatic or well tolerated; only 11% needed an extension of the fusion and always after >5 years' postoperative delay.

With two-level fusions, the occurrence of ASMA increased sharply. Thirty-one percent of a group of 26 patients developed alterations, and 27% (87% of the AMSA subgroup) needed reoperation. This means that in this group, AMSA was more severe, requiring in almost every instance a lengthening of the fusion or a lengthening and a decompression procedure. Reoperation was sometimes

TABLE 1. *Distribution of subgroups according to postoperative delay, existence of AMSA, and need for reoperation*

Group	Follow-up (yrs)	Reoperation	No. of patients	% of total series
1: with AMSA			40	38
1.A		Reoperated	19	18 (47)
1.A.1	>5	Reoperated	15	14 (37)
1.A.2	<5	Reoperated	4	4 (10,5)
1.B		Not reoperated	21	20 (53)
1.B.1	>5	Not reoperated	17	16 (42)
1B2	<5	Not reoperated	4	4 (10,5)
2: no AMSA			66	62
2.1	>5		46	43 (69)
2.2	<5		20	19 (31)

The numbers in parentheses represent the percentages in the subgroups compared with the main groups 1 and 2.

TABLE 2. *Relations between length of fusion, rate of transitional segment alteration, and reoperation*

Length of fusion	ASMA reoperation	No. of cases	%	Significance
1 segment		37		
	ASMA	12	32	Reference
	Reoperated	4	11	Reference
2 segments		26		
	ASMA	8	31	NS
	Reoperated	7	27	S
3 and 4 segments		27		
	ASMA	18	66	S
	Reoperated	9	33	S
≥5 segments		10		
	ASMA	1	10	NS
	Reoperated	1	10	NS

S, significant; NS, not significant.

needed before a postoperative delay of 5 years had elapsed.

In the group of 27 cases with three- or four-level fusions, a 66% AMSA occurrence rate was observed and 33%, half of the AMSA cases, needed a second operation, with various delays from index surgery.

Among the 10 cases with a more than four-level fusion, only 1 patient developed AMSA and needed a reoperation, but these results are meaningless because of the scattered length of fusion ranging from 5 to 10 levels. When it existed, extension up to the thoracic area could have lessened the risk for AMSA since the transitional segments might have been better protected against overload, thanks to the corset-like effect of the rib cage.

The other possible risk factors listed above were sought after and evaluated in regard to the occurrence of AMSA. The presence of one or more risk factors was greater in patients developing AMSA and requiring secondary surgery than among those who did not develop AMSA at long term. In patients with >5 years' follow-up and no transitional segment alterations, only 23% had risk factors, but 30% risk factors were present if AMSA occurred and 33% if a secondary operation was necessary. In patients with <5 years' follow-up, 16% had risk factors when AMSA was absent, 25% when some kind of alteration occurred, and 46% when a secondary operation was necessary.

Because of the multiple risk factors and the relatively small number of subgroups if patients are divided according to AMSA occurrence, reoperation rate, length of follow-up, and length of fusion, the significance of each individual risk factor is difficult to establish. Some risk factors may also be linked, such as age and postoperative lifestyle or age and length of fusion. Though not statistically significant, some observations may be pointed out because they may help our thinking on how to improve long-term results.

Heavy work after fusion may have favored AMSA, even in young patients who underwent short fusions. Overweight may have favored the need for reoperation when AMSA occurred. Age could not be individualized as an isolated predisposing factor. Sagittal deformity of the whole lumbar spine or the fused area (loss of lordosis), frontal deformity (scoliosis, frontal imbalance of the trunk, obliquity of the junctional motion segment), all conditions leading to bad three-dimensional malalignment of the junctional motion segment, may have favored the occurrence of AMSA (frontal deformities) or the need for a second operation (frontal and sagittal deformities).

A partial fusion, for instance, a fusion performed to stabilize part of the lumbar spine presenting signs of instability when a decompression procedure was performed while the whole lumbar spine showed more benign degenerative alterations, did not seem to be accompanied by a worse outcome of the adjacent motion segment, though in these cases, the fusion obviously did not end at the level of a healthy transitional segment. This finding is interesting because, unfortunately, in a number of cases, the fusion scheduled to treat intractable back pain in patients presenting no true instability or neurologic problems possibly missed a number of levels showing no alterations on normal radiographs but that could have already shown some alterations on MRI. Indeed, in this retrospective study, because of the unavailability of MRI in the older cases, a perfect appraisal of the status of the future transitional disk was not obtained before the index surgery in all patients of the series. Because it is more invasive, diskography was not performed in all cases before the availability of MRI to check the status of the expected junctional level. For the last decade, MRI has been systematically obtained to have a precise appraisal of the status of each motion segment and the fusion area aimed at ending at the level of a healthy and well-balanced disk. In older patients, however, even in the MRI era, the length of fusion has often been a compromise because of diffuse degenerative disease. In these patients, the fusion area was chosen mainly depending on the existence of unstable segments and ended at a well-balanced level on the plain radiographs, even if dehydration with no Modic signs was present. Before the availability of MRI, when performing a fusion in younger patients with a high activity level expectancy, a diskogram of the expected junctional disk was sometimes performed, but many patients had the free adjacent motion segment selected on the basis of an apparently normal radiograph (normal disk height and three-dimensional alignment).

Reoperations

Among the 40 patients who developed AMSA, 19, about 50%, needed a second operation because of severe

back pain or the development of instability with back pain and neurologic deficit. Six patients required a one-level extension of the fusion, three of them an associated laminectomy at the junctional level, and one of them an anterior fusion. Thirteen patients required a multilevel extension of the posterior instrumentation and fusion, six of them an associated laminectomy, and in three cases a combined anterior and posterior approach was necessary to correct a severe deformity of the spine. The reoperations were in certain cases serious procedures for older people.

DISCUSSION

The place for fusion in lumbar degenerative disk disease must be questioned if one considers that 37% of our patients developed AMSAs and that 50% of them required further surgery. Moreover, in this retrospective series, due to the loss of patients before a 2-year follow-up and even between the 2- and 5-year postoperative delay, the rate of transitional segment alterations and the need for reoperation could be underestimated.

Little is known from the literature on the behavior of the motion segments adjacent to a fusion or instrumentation of the spine. A certain number of in vitro studies support the idea of a potentially harmful overload of the transitional segment. Shono and co-workers[2] concluded, in a deformation-controlled loading study performed on calf spines, that instrumented spines showed a greater adjacent segment mobility in flexion and extension; this hypermobility was proportional to the length and the rigidity of the instrumentation. The authors performed a deformation-controlled loading study, assuming that patients try to obtain the same degree of mobility after their spine surgery than without a fusion. Bastian et al[3] observed the same changes using human cadaveric spines and also showed that the hypermobility of the junctional segments returned to normal after removal of the instrumentation. Weinhoffer et al[4] also observed an increase of intradiskal pressure at the adjacent level of a spinal instrumentation, proportional to the length of the instrumentation, and the increase being also greater in the segment directly adjacent to the instrumentation than in the following one.

On the contrary, Rohlman and co-workers[5] were unable to show significant differences in the behavior of one specific motion segment that became adjacent to a fusion compared with the same segment in the uninstrumented spine. These authors used and advocate a load control protocol, assuming that patients accept a loss of motion after fusion and will not try to bend their spine as far as normally. They concluded that mechanical factors were probably not significant in the development of AMSA. But they considered that malalignment of the lumbar spine could favor AMSA by altering the constraints at the level of the transitional segment. Dekutoski et al[6] studied dog spines in vitro and in vivo, with load-controlled protocols and motion-controlled displacement protocols. They concluded that motion of the transition segment was augmented during walking but that pure axial loading of the spine was of no influence.

If most results are in favor of a link between the presence of a stiffened spine segment, the length and rigidity of this segment, and the occurrence of transitional segment overload, some authors doubt this hypothesis. In vitro studies do not take into account the potentially protective stabilizing role of the muscles or the potentially harmful preload they impose on the different motion segments. Clinical studies offer various incomplete and conflicting observations; in a number of cases, the conclusions are very much debatable.

Axelsson et al[7] performed stereophotogrammetric analysis of the mobility of the L4–L5 segment before L5–S1 fusion for spondylolysis and at 3, 6, and 12 months after surgery. They concluded that fusion can alter the kinematics of the transitional zone and lead to redistribution of the mobility toward hypermobility in the juxtafused levels. If their first conclusion about alteration of the kinematics is acceptable, their second conclusion concerning hypermobility is debatable since they observed increased, decreased, and unchanged mobility of the adjacent segment after fusion in the same proportions. Other drawbacks of their study are that the status of the future transitional zone was assessed only by plain radiographs, possibly missing existing dehydration of disk bulging of this segment, leading to a possibly inhomogeneous group of patients, and that the follow-up was only 1 year.

Brodsky et al[8] made a retrospective study on 206 L4–L5 floating fusions performed over a period of 32 years. They observed only 2.7% of adjacent disk problems requiring a secondary extension of the fusion at the L5–S1 level out of an available series of 184 patients. They concluded that including the L5–S1 segment in a fusion performed initially for an L4–L5 pathologic condition should not be the rule. Their follow-up ranged from 6 months to 32.5 years. If the reoperation rate was low, leading the authors to speak about a 2.7% rate of secondary diskopathy, we must not miss other numbers in this study that alter the optimistic conclusions of the authors: in 94 complete radiologic files, they observed some disk space narrowing after fusion in 64% of the cases above the fusion and in 59.6% below the fusion; they stressed, however, that there was no full correlation between these radiologic alterations and clinical outcome. Their 2.7% "significant lumbosacral sequelae" rate also neglects 10 patients requiring secondary laminectomy for spinal stenosis. They give no

information on the existence of symptomatic or reoperated upper-level alterations.

Buttermann et al[9] studied 165 patients with a posterolateral fusion. Late clinical results, which was the main object of their work, were better among patients suffering from nondegenerative pathologies, but only 3% of the patients with degenerative pathology and 9% with diskectomy-associated fusion needed a further extension of their fusion, whereas the rate was 14% in patients with low-grade lytic or degenerative spondylolisthesis. These results are astonishing, but degenerative spondylolisthesis should probably have been included in the degenerative group instead of being mixed in with spondylolysis patients. As in most other retrospective studies, the precise preoperative status of the future transitional disk at the time of index surgery was unknown.

Cauchoix and David[10] made a study on 75 patients who underwent either a posterior fusion or an anterior fusion without any posterior surgery. They observed degradation of the spine above the fusion at a 10-year follow-up in 79% of the patients but noted the absence of correlation between radiologic signs and clinical symptoms. Unfortunately, there is no information on a possible difference of AMSA between patients operated from a posterior or an anterior approach. The authors stressed the need to perform preoperative diskography to assess the status of the future transitional disk, to include all painful levels, and to avoid surgery if the length of fusion seemed too extensive.

Guigui et al studied in four works[11–14] the clinical outcome in patients who underwent fusion for degenerative conditions, spondylolysis with and without spondylolisthesis, and in patients who underwent laminectomy with or without fusion. Fusion was combined with posterior instrumentation or not. Overall conclusions were that transitional zone alterations are more common after laminectomy with fusion and also after instrumented fusions than after isolated laminectomy. Transitional segment alterations were less well tolerated if they occurred after fusion than after laminectomies. There is, however, no information on the role of the length of fusion or the rigidity of the instrumentation. The mixture of cases makes clear-cut conclusions difficult, but we may note the occurrence of up to 49% of disk space narrowing, 30% of true destabilization, 32% of angular hypermobility, and 35% translational hypermobility at a mean 8.9-year follow-up.

Hambly et al[15] reviewed 42 patients who had undergone a posterolateral fusion through the Wiltse approach with an average of 22.6 years. They pointed out that degenerative changes occurred at the second level above the fused segment with an equal frequency to those occurring at the first level. In this study, the operated patients were compared with an age- and gender-matched control group of nonoperated patients seeking medical advice for low back symptoms. The rate of degenerative alterations at the transitional levels was similar to the rate of degenerative alterations of the corresponding motion segments in the control group. This is probably the most important conclusion of this study because of the lack of control groups in almost all other publications.

Hutter[16] reviewed a personal series of 492 patients followed for at least 5 years. All his patients had undergone posterior interbody fusion without instrumentation. The interbody fusion could have played a significant role in the maintenance of an adequate lumbar sagittal alignment, but, unfortunately, the author did not study the balance of the spine in his work in correlation with the existence of transitional segment alterations. This potentially interesting work is disappointing because the only information we get is the need for diskectomy at the transitional level in 8 of 492 patients.

Kumar et al[17] compared the fate of the transitional segments between a group of 28 patients fused for degenerative disease matched with a group of 28 patients who had undergone a laminectomy during the same period. Narrowing of the disk space was observed in 35.7% of the fused group as opposed to 18.5% in the decompression group, and instability was observed respectively in 18.5% and 7.4%. No comment on the balance of the spine was made.

In another study, Kumar et al[18] studied the correlation of sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. A homogeneous group of 83 patients with a degenerative pathology of the lumbar spine who underwent posterior CD instrumentation and posterior fusion, 30 of which also had a PLIF, was reviewed. The authors observed alterations of the transitional segments in 36.1%, mainly retrolisthesis, at the upper level, appearing at a mean postoperative delay of 5.2 years. Patients with a good sagittal alignment of the spine were less prone to AMSA. Fifty percent of the patients with transitional segment alterations needed a secondary operation. These numbers are very similar to our findings.

In a study that, unfortunately, lacks information on the techniques of fusion and the spinal balance, Lee[19] reported on 18 patients who developed a transitional segment alteration from 1 to 38 years after index fusion; these patients were not part of a particular group but were individuals seeking advice for recurrence of back pain. Half of the patients developed the problem within 5 years; the mean symptom-free period had been 8.5 years (range 1–38 years). All alterations were at the upper transitional level. Half of the patients ultimately needed extension of the fusion, and half of these needed a second extension of the fusion within 1–6 years. Though incomplete, this work stresses the frequency of necessary secondary or even ter-

tiary operations in patients first fused for degenerative problems of the lumbar spine.

Lehman et al[20] reported on a series of 66 patients, part of a group of 94, who sustained a posterior fusion without instrumentation. The reason for fusion was spondylolisthesis, degenerative spine conditions, or instability. At long-term follow-up, only 15% of all the patients had had repeat surgery, but in the subgroup of 33 patients with a complete radiologic file, 42% showed lumbar stenosis, and segmental instability above the fusion was present in 45%. There was no correlation between transitional segment alterations and clinical symptoms. Even if the operated patients were not doing as well as the general population, they considered themselves satisfied with the results of their surgery.

Luk et al[21] performed an in vivo radiologic study on healthy volunteers and on patients having sustained an anterior fusion. They observed no increase of mobility at the level of the transitional segments compared with the corresponding levels of healthy volunteers in physiologic limits of mobility. This observation is astonishing since there was no posterior approach likely to alter the posterior facets, leading to stiffening. The authors concluded that since there was no increase of mobility at the level of the transitional segments, secondary breakdown of those was probably not linked to overload in mobility. Their conclusion agrees with those of Rohlman et al[5] in their in vitro study.

Malter et al[22] reported on the complication and reoperation rate in patients operated on for degenerative conditions during a 1-year period in the state of Washington. During a 5-year postoperative observation period, they found that complications and reoperations were more frequent in patients who sustained a fusion (18% of 1041 patients) than in patients who sustained a nonfusion procedure (7% of 5335 patients). The reoperation rate was slightly and not significantly greater in the fusion group (18%) versus the nonfusion group (15%). The authors stressed the point that despite the significant number of complications in fused patients, the rate of fusion operation increased 100%, whereas nonfusion operations increased only 50% between 1979 and 1990, despite strong evidence for the benefit of such operations in degenerative conditions of the spine. Unfortunately, in this study addressing patients with specifically degenerative cases, the authors give no information on the specific problems arising at the transitional levels. This shows the limits of large population-based cohort studies based on hospital file summaries used for statistical analysis. Moreover, from our data and other studies, we saw that a 5-year follow-up is only the minimal delay to recognize most of the patients developing secondary transitional segments alterations.

Penta et al[23] specifically addressed the problem of transitional segment alterations using MRI assessment of the junctional disk in patients having sustained anterior interbody fusion of disks that were proved symptomatic at provocative diskography with a follow-up of at least 10 years. Of an initial group of 108 patients, 52 could be evaluated precisely because a normal disk space above the planned fusion had been demonstrated by preoperative diskography. Among this selected group, 68% of the patients showed a normal MR signal of the transitional area at the time of the study. There was no influence of the length of fusion, but this study included only one- or two-level fusions, with just one three-level fusion.

Phillips et al[24] studied 33 patients who developed spinal stenosis requiring surgery at the transitional level 3–28 years (mean 7.8 years) after index surgery. Unfortunately, we do not know what proportion of the initial group of operated patients this subgroup represents. This study gives insight only into the evolution of reoperated patients. It is interesting to note that 22 patients were considered for extension of the fusion at the same time as laminectomy and that 6 patients required a third operation because of a stenosis at the level of the new transitional segment. This study has the advantage of addressing only degenerative spine patients, but, unfortunately, we have no information on the status of the future transitional segment before index surgery and the authors give no information on the status of the future transitional segment after the first reoperation. Hence, the rate of transitional segment complications cannot be evaluated.

Schlegel et al[25] reported on 58 patients seeking medical advice for back pain recurrence after a minimal 2-year pain-free interval (mean 13.1 years) after lumbar fusion performed for different indications. The initial status of the transitional segments is unknown. The authors point out that at the time of consultation, adjacent segment alterations were as common at the second level above the fusion as at the first level. They stress the importance of properly evaluating the length of fusion extension. Among 37 reoperated patients who were followed for a minimum of 2 years, 7 needed a third surgery. The authors observed that sagittal alignment of the spine was often altered in patients presenting with transitional alterations, but this observation was not statistically significant.

Steib et al[26] reviewed 113 patients having sustained posterolateral bone fusion in combination with a Compact Cotrel-Dubousset instrumentation that theoretically allowed for adequate restoration of the sagittal profile. Pathologies were unfortunately mixed. The overall rate of transitional alterations was 55%, and the rate of reoperation, apart from instrumentation removal, was 15.9%. The authors proposed that the low number of necessary reoperations could be explained by the restoration of the lumbar lordosis with the rod-screw instrumentation and that in

patients in which the lordosis regained at index surgery was lost over the years, there were more transitional alterations. They therefore stressed the need for more frequent interbody fusion to lessen the risk of sagittal malalignment of the spine.

Whitecloud et al[27] also reported on patients consulting for transitional segment problems but with no information on their initial status or their population. Though incomplete, this study pointed out that the delay between index surgery and reoperation ranged from 3 to 29 years (mean 11.5 years) and that worse situations were observed when the delay before transitional breakdown was short.

Are There Means to Improve the Late Results?

Theoretically, one should aim to end a fusion at the level of a normal motion segment. This is particularly true when operating on younger patients with greater functional expectations. In this regard, the use of systematic preoperative MRI should be contemplated, and in the case of doubt, the planned future transitional disk should be checked with a provocative diskography. If an excessively long fusion should be performed because of multilevel alterations, one should avoid surgery or at least weigh the possible benefit of a compromise fusion spanning the most affected levels and leaving altered but asymptomatic levels according to MRI and diskography free and the disadvantages of a long fusion. Provocative diskography should always be performed at the level of a degenerated disk at the stage of commonplace disk dehydration since such alterations may be very well tolerated. As reported by Boden et al,[28] up to 35% of an asymptomatic population aged 20–39 years and almost all people older than 60 may show disk alterations. Including black disks with no Modic signs or high-intensity zones in a fusion is probably excessive; their cause of suffering should be proved. On the other hand, an asymptomatic degenerated segment could become symptomatic after a fusion ending at this level because of the overload induced. When high-intensity zones exist at the posterior border of the disk or if Modic signs exist, the correlation with back pain symptoms is more reliable, as shown by Lam and co-workers,[29] and provocative diskography to further assess these segments may well be less necessary.

In this series, posterior instrumentation and fusion, by weakening the spinal muscles, could have favored loss of biological protection of the adjacent segments and even injury to the facets of the adjacent motion. Anterior approaches could lessen the risk for AMSA. However, multilevel anterior fusion of the lumbar spine is not always possible. Another advantage of the anterior approach is the possibility to restore disk height with interbody fusion and lessen the risk for three-dimensional malalignment of the lumbar spine and especially the junctional level. Posterior interbody fusion has the same advantage but can be difficult and potentially harmful at the upper lumbar levels and does not avoid aggression of the posterior musculature.

CONCLUSION

As a result of our study and the observations retrieved from the literature, we must conclude that our knowledge of the fate of the transitional segments after lumbar fusion remains largely incomplete. In vitro studies have their inherent limitations, few clinical studies address fully documented patient groups, and many works include different pathologies—all this leads to debatable conclusions. Our study is, unfortunately, also weakened by the loss of patients at long-term follow-up, but it has the advantage of including only patients operated on for degenerative disease. From our experience with this study and an ongoing study on the fate of the transitional segments of patients fused for spondylolytic spondylolisthesis in which no more than 21% of patients showed transitional problems after 5 years and with only a 2.4% reoperation rate, we feel that such studies should include only comparable patients, avoiding specifically the mixture of pathologies such as degenerative disease, spondylolysis, trauma, and tumors. Even in a quite homogeneous group of degenerative disease patients, there is probably not much in common between a 35-year-old patient requiring fusion for a postdiskectomy status and a 70-year-old patient sustaining a fusion associated with laminectomy for a spinal stenosis due to degenerative spondylolisthesis or rotatory dislocation. As a result, we clearly need prospective studies on the fate of the transitional segments after lumbar posterior, anterior, or combined fusion in homogeneous groups of patients. We also need more studies on the normal evolution of spinal motion segments over time to compare specific segments with their counterparts becoming transitional segments after lumbar fusion. Finally, we also need to find more reconstructive surgical procedures for the management of symptomatic degenerative spines resistant to conservative treatment. The conclusion of one author[26]—that delayed transition segment alteration is a normal evolution after lumbar fusion and must be accepted as a late consequence and not considered as a complication—is unsatisfactory. One solution could be preventive reinforcement of the transitional segment by some kind of ligamentoplasty. Such a simplistic mechanical proposition could, however, miss the point by leading to overprotection of transitional disks and degradation of these segments because of lack of adequate biological response to normal stress. Another solution could be the development of reliable arthroplasty procedures of spinal motion segments in selected patients.

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