Long-Term Follow-Up After Interbody Fusion of the Cervical Spine

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Summary: The aim of this work was to add to the body of data on the frequency and severity of degenerative radiographic findings at adjacent levels after anterior cervical interbody fusion and on their clinical impact and to contribute to the insights about their pathogenesis. One hundred eighty patients who were treated by anterior cervical interbody fusion and who had a follow-up of >60 months were clinically and radiologically examined by independent investigators. For all patients, the long-term Odom score was compared with the score as obtained 6 weeks after surgery. For myelopathic cases, both the late Nurick and the Odom score were compared with the initial postoperative situation. For the adjacent disc levels, a radiologic "degeneration score" was defined and assessed both initially and at long-term follow-up. At late follow-up after anterior cervical interbody fusion, additional radiologic degeneration at the adjacent disc levels was found in 92% of the cases, often reflecting a clinical deterioration. The severity of this additional degeneration correlated with the time interval since surgery. The similarity of progression to degeneration between younger trauma patients and older nontrauma patients suggests that both the biomechanical impact of the interbody fusion and the natural progression of pre-existing degenerative disease act as triggering factors for adjacent level degeneration.

Key Words: adjacent level degeneration, cervical spine, interbody fusion, long-term follow-up

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The concept of accelerated degeneration at adjacent disc levels after interbody fusion of the cervical spine is widely postulated.[1–19] However, data on the radiographic frequency and severity of these degenerative changes and on their clinical impact are scarce. Furthermore, it remains controversial whether this accelerated adjacent level degeneration is due to natural progression of the disease[12,13,20] or to increased motion stress related to biomechanical factors secondary to the surgical fusion itself.[1,7,16,18,21–23] It has also been postulated that both factors contribute simultaneously.[14]

MATERIALS AND METHODS

Anterior cervical interbody fusion with autologous iliac crest graft, with or without plating, has, since 1984, been a commonly performed surgical procedure for a series of different pathologies at our institution. Three surgeons have been operating, using a common technique that did not change over the years. Indications for plate fixation were trauma with instability of the spine, fusion at more than two disc levels, and corpectomy; each time, the Caspar plating system was used. All patients who were operated on at least 5 years previously received a letter, sent to their original address, with the invitation for a long-term clinical and radiologic examination. At the same time, all these patients received a call to their original phone number, explaining the purpose of this additional examination. For those patients who could not be found by letter or call, the general practitioners from the time of surgery were called and asked for possible information about the new address of their patients.

The clinical and radiologic examinations were performed by investigators who had no therapeutic relationship to the individual patient.[24] All radiographs were examined by one independent radiologist.

For all patients, the initial postoperative Odom score,[25] as derived from office records at the moment of the first postoperative visit 6 weeks after surgery, was compared with the long-term score, which was prospectively recorded. A decrease from "excellent" to "good" was called a 1-point decrease in Odom score, a decrease from "excellent" to "fair" a 2-point decrease, etc. For myelopathic patients, both the initial Nurick score[26] and the Odom score were compared with the late postoperative situation.

For the late radiologic follow-up, a lateral x-ray was made. This x-ray was compared with an early x-ray, obtained in the immediate preoperative or postoperative period. The degrees of disc narrowing and of anterior osteophytosis formation at the superior and inferior adjacent levels were assessed.

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The height of an adjacent disc was defined to be normal when it was equal to the height of the disc located either one level more cranially or caudally, on the condition that that particular segment did not show any sign of degeneration. Otherwise, the next level was chosen for comparison of the disc height. A decrease of disc height to 75–100% of the normal height was scored "mild degeneration," to 50–75% "moderate degeneration," and to <50% of the normal disc height "severe degeneration" (Fig. 1). Similarly, a just detectable anterior osteophyte formation was scored "mild degeneration," a clear anterior osteophyte extending anteriorly over a distance less than one-fourth of the anteroposterior (AP) diameter of the corresponding vertebral body was scored "moderate degeneration," and an anterior osteophyte extending more than one-fourth of the AP diameter of the corresponding vertebral body was scored "severe degeneration" (Fig. 2). As a consequence, the "degeneration score" was defined as the most severe degree of degeneration, obtained either from disc height examination or from anterior osteophyte study. This degeneration score was determined for both the superior and the inferior adjacent levels. The early degeneration score was compared with the degeneration score of the long-term study: A transition from, for example, "no degeneration" to "mild degeneration" was indicated as an increase in degeneration score of 1 point, a transition from "no degeneration" to "moderate degeneration" an increase in degeneration score of 2 points, etc. Looking at both the superior and the inferior disc levels, the most severely deteriorated adjacent disc level determined the increase of degeneration score for each individual patient. Eventually, the degree of lordosis or kyphosis at the fused segment(s) was examined.

The data were statistically analyzed using the Student *t* test and one-way analysis of variance (ANOVA) for comparing groups, Spearman correlation coefficients for correlations with the clinical and radiologic scores, and χ^2 test for correlations between quantitative variables. The test that was used in

FIGURE 1. A, A 6-week postoperative plain radiograph in lateral projection of a patient operated on for soft disc herniation at C5–C6. B, A 9-year postoperative plain radiograph in lateral projection of the same patient: progressed degenerative changes at C3–C4, C4–C5, and C6–C7. At C4–C5, there is a decrease of disc height to 50–75% of the normal height: "moderate degeneration." At C6–C7, there is a decrease of disc height to <50% of the normal height: "severe degeneration."

FIGURE 2. An 8-year postoperative plain radiograph in lateral projection of a patient operated on for soft disc herniation at C5–C6. At C4–C5, anterior osteophytes extend anteriorly over a distance of more than one-fourth of the AP diameter of the corresponding vertebral body: "severe degeneration."

each particular situation is indicated in Results. Calculations were made by means of the STATISTICA software (StatSoft). Significance levels were chosen at 0.05.

RESULTS

Of the initial group of 355 with a postoperative time interval of >60 months, 28 patients died during the follow-up period, each time because of unrelated reasons. One hundred forty-seven patients could not be located anymore. None of the patients who could be located refused the invitation to come to the long-term examination. One hundred eighty patients were thus available for long-term clinical and radiologic examination (55.1% of the living patients).

The interval between operation and last follow-up visit ranged from 60 to 187 months with a mean follow-up of 100.6 months (SD 30.9 months).

The distribution of genders demonstrated a male preponderance in the study group of 123:57. Sixty-six patients were treated for trauma, 111 for degenerative disc disease (75 for radiculopathy, 36 for myelopathy) and 3 for other reasons (tumor, infection). The duration of follow-up for each of these pathologies was statistically not significant different (one-way ANOVA, $P = 0.065$; mean follow-up for trauma: 108.6 months; radiculopathy: 96.1 months; myelopathy: 96.3 months; miscellaneous: 88.3 months). The age distribution of the whole group at the moment of surgery was 14–75 years with a mean of 42.5 years. We found a statistically significant difference in age distribution in trauma (mean 31.6 years with range from 14 to 68 years) versus nontrauma (mean 48.8 years with range from 26 to 75 years) cases (Student *t* test, $P < 0.001$). One hundred eleven of 180 cases were operated at one level, 60 at two levels, 7 at three levels, and 2 at four levels. Ninety-seven of 180 patients (54%) had no additional instrumentation, and 83 of 180 patients (46%) were plated.

Clinically, 115 of 180 patients (64%) had no decrease in Odom score between the initial postoperative situation and the long-term follow-up, 52 of 180 (29%) had a decrease with 1 point, 11 with 2 points (6%), and 2 with 3 points (1%). There was no statistically significant correlation between decrease in Odom score and age of the patients at the time of surgery (Spearman $r_S = 0.009$, $P = 0.900$) or with the number of levels fused (Spearman $r_S = 0.060$, $P = 0.419$) or type of pathology (one-way ANOVA, $P = 0.169$).

For the myelopathic patients, the Nurick score did not change in 24 cases (67%) and worsened with one grade in 11 cases (30%) and with two grades in 1 case (3%); there were no patients with worsening of more than two grades of the Nurick score. The decrease in Nurick score did not correlate with age (Spearman $r_S = -0.196$, $P = 0.252$) or with the number of levels fused (Spearman $r_S = 0.171$, $P = 0.319$).

At radiologic examination, 14 patients demonstrated no increase in degeneration score (8%), 89 patients had an increase with 1 point (49%), 65 patients with 2 points (36%), and 12 patients had an increase with 3 points (7%). Taken together, 92% of the patients demonstrated an increase in degeneration score at long-term follow-up. There was no correlation between the increase of the radiologic degeneration score and the age of the patients at the time of surgery (Spearman $r_S = -0.033$, $P = 0.660$) or with the number of levels fused (Spearman $r_S = -0.011$, $P = 0.879$). The increase in degeneration score was statistically equally distributed among trauma cases, radiculopathic cases, and myelopathic cases (one-way ANOVA, $P = 0.868$). There was a statistically significant correlation between radiologic deterioration and time interval since operation: The longer the time after operation, the more degeneration at the adjacent levels, as indicated by the degeneration score (Spearman $r_S = 0.156$, $P = 0.036$).

Fifty-two of 180 patients presented at the long-term examination a more or less kyphotic or a straight position of the spine at the fused level(s), whereas 128 of 180 cases eventually had a lordotic curve: There was no statistical correlation between increase in degeneration score and degree of lordosis or kyphosis (Spearman $r_S = 0.002$, $P = 0.983$). There were no cases of pseudarthrosis at long-term examination in this series of 180 patients.

A suggestive trend of correlation was found between radiologic and clinical changes (as expressed by the Odom score) at a P value of 0.06: The Odom score deteriorated in 2 of 14 patients without radiologic changes (14.3%), in 31 of 89 patients with 1-point radiologic deterioration (34.8%), in 26 of 65 patients with 2-point radiologic deterioration (40%), and in 6 of 12 patients with 3-point deterioration in radiologic degeneration score (50%) (Spearman $r_S = 0.140$, $P = 0.062$). However, when the clinical situation of myelopathic patients was described by the Nurick score, no correlation was found between radiologic deterioration and increased Nurick grade: The Nurick score did not change in the 2 patients without radiologic changes (0%), and there was an increase in Nurick grade in 5 of 18 patients with 1-point deterioration in radiologic degeneration score (27.8%) and in 7 of 14 patients with 2-point radiologic deterioration (50%); the Nurick score did not change in the 2 patients with 3-point radiologic deterioration (Spearman $r_S = 0.189$, $P = 0.271$).

The presence or absence of a plate was not related to the degree of increase in degeneration score (Student t test, $P = 0.773$).

Reoperation because of adjacent level degeneration was performed in 11 cases (6.11%). Reoperation was done only when clear signs and symptoms of radiculopathy and/or myelopathy due to adjacent level disease, not responding to longtime conservative therapy, were present.

DISCUSSION

Although laminoforaminotomy, performed by a posterior approach without fusion, might serve as a therapeutic alternative in a number of cases,[27–30] perhaps avoiding long-term accelerated degeneration at adjacent levels if performed without fusion, anterior discectomy with interbody fusion has been the procedure of choice in most surgeons' hands when dealing with cervical compressive radiculopathy and with a number of cases of myelopathy due to degenerative cervical disc disease. By their nature, these diseases are generally not life threatening and occur in middle-aged patients.[1,4,6,9,31,32] Postoperative life expectancies of several decades emphasize the importance of a sufficiently long follow-up period in the evaluation of cervical discectomy performed together with interbody fusion as a procedure.

Number of Patients Lost to Follow-Up

One of the weak points of many long-term studies is the number of patients lost during follow-up.[14,21,33,34] In our own study, 44.9% of our living patients with a follow-up period of >5 years could not be located anymore. An initial analysis was performed on a series of 120 of our patients; afterwards, 60 more patients were located for inclusion in the long-term follow-up analysis. The trends for the initial group of 120 patients and for the eventual group of 180 patients were exactly the same, which is an argument for the validity of our findings.

Radiologic Degeneration at Adjacent Levels

Assessing the Degree of Adjacent Level Degeneration

From a radiologic point of view, several criteria have been proposed to evaluate the degree of degeneration at adjacent levels after interbody fusion: Cherubino et al[21] examined the height of the discs above and below the fusion as well as the size of anterior and posterior osteophytes. DePalma et al[6] added to these criteria the degree of rounding of the anterior-superior border of the vertebra below the adjacent disc. Gore et al[9] assessed disc space narrowing, anterior and posterior osteophyte formation, and end-plate sclerosis. For two reasons, in our study the evaluation of adjacent level degeneration has been restricted to the degree of disc space narrowing and of anterior osteophyte formation: 1) To limit radiation exposure, for long-term examination, only a lateral radiographic image of the cervical spine was available; and 2) the assessment of the degree of posterior osteophytes on such an image is not always easily and precisely possible. In the general population, posterior osteophytes tend to develop less frequently and to a lesser degree than anterior osteophytes.[35] Anterior osteophytes are thus the most common roentgenographic disc space abnormality and are known to occur sometimes also as an isolated entity.[36] They may be a precursor of other disc abnormalities such as narrowing and posterior osteophyte formation, which invariably indicate disc degeneration.[9] Whereas Nathan[35] studied anterior osteophytes rather by their shape, establishing eventually four different categories, we did it more quantitatively.

Frequency of Adjacent Level Degeneration

At late follow-up after cervical interbody fusion and in comparison with the initial radiographic findings, additional degeneration at the superior and/or inferior adjacent disc levels was found in 92% of our cases. This often coincided with clinical deterioration. The finding of 92% increase in radiologic degeneration score at adjacent levels is in accordance with some data from the literature.[4,6] Other data from the literature are at first sight less impressive.[2,21] Differences in duration of follow-up between these studies may to some extent explain the discrepancies in the figures. In our study, and in concordance with the findings of Shinomiya et al,[37] a statistically significant correlation was found between the degree of adjacent level radiologic degeneration and the time interval after the operation.

In a series of 121 patients having undergone anterior cervical discectomy and interbody fusion for degenerated or protruded discs with a mean follow-up of 5 years, Gore et al[9] found 61 cases with new or increased spondylosis at adjacent levels. In another study, the same authors compared radiographic changes at a mean follow-up of 5 years following cervical interbody fusion with those of an age- and sex-matched population without neck pain and without neck surgery. In general, the incidence of degenerative changes did not differ between operated and control patients at the levels above and below the fusion. Anterior osteophyte formation, however, was more frequently observed in those with fusion than in the nonfusion group.[10]

Natural Progression of Disc Degeneration

Of course, natural progression of disc degeneration is also known to occur over time and has been documented, even in initially asymptomatic people who were not operated on. Recently, Gore[38] studied 159 initially asymptomatic patients who had baseline cervical radiographs and follow-up x-rays 10 years later. In that study, 34% of subjects who had no initial radiographic evidence of degenerative disease developed degenerative radiographic features, assessed quite similarly to our current study, over 10 years. Ninety-seven percent of patients who had evidence of degeneration on their initial examination had evidence of progression. It is not possible to determine what proportion of the progression is due to worsening of the already initially degenerated level and what is due to involvement of other levels. In any event, it seems to be reasonable to expect that patients who have had degenerative cervical spine disorders requiring surgery differ in some way from the asymptomatic population and would therefore have a higher rate of degeneration.

Natural Progression of Degenerative Disc Disease or Biomechanical Effect of Fusion?

The question should thus be answered whether the degeneration at adjacent levels after fusion is due to the natural progression of degenerative disc disease or to increased motion stress related to biomechanical factors due to the surgical fusion itself. Both factors may contribute simultaneously.[14] Whereas some authors advocate the hypothesis of natural progression,[11–13] others focus on the altered biomechanics at adjacent levels after fusion, resulting from increased mobility,[1,7,18,21,22] increased longitudinal or shear strain,[16] or increased intradiscal pressure.[23] On the other hand, Fuller et al[39] denied the existence of adjacent level hypermobility; however, their study was performed on spine specimens harvested from cadavers that averaged 74 years of age and therefore might have been too stiff to be applicable to the situation in a younger living human being. To shed light on the question, Braunstein et al[4] suggested examination of the long-term results in traumatic fusion patients who are generally younger than the population with degenerative disc disease, most of them having no pre-existing arthrosis. Birney and Hanley[40] noticed two cases of adjacent level degeneration in a series of eight children or adolescents who received an arthrodesis because of traumatic subaxial cervical spine lesions. These cases had a mean follow-up of 5.5 years. McGrory et al[17] found degeneration in 66% of the nonfused adjacent segments $\geq$20 years after arthrodesis of the cervical spine for fractures and dislocations in children and adults, even though most patients were operated using a posterior approach. In a previous long-term study with follow-up times ranging from 5 to 9 years after anterior interbody fusion of the cervical spine for trauma, we found radiologic degeneration at adjacent levels in 60% of the 25 evaluated cases.[8] The similarity of progression to degeneration at adjacent levels between younger trauma cases without pre-existing degenerative disc disease and older nontrauma cases, operated mainly for disc herniation or spondylosis, as noticed in our current study, suggests that not only natural progression of pre-existing degenerative disc disease but also biomechanical factors due to the interbody fusion itself are important. Although the absence of a matched nonsurgical control group of patients might be a weak point in our study, we thus consider the young trauma patients as our control group, according to the suggestion by Braunstein et al.[4] The findings in Klippel-Feil syndrome, where degenerative changes were found in up to 100% of discs adjacent to the congenital fusion,[41] seem to confirm our interpretations.

Rahm and Hall[42] found that patients who developed pseudarthrosis in the lumbar spine were less likely to develop adjacent level degeneration. There were no patients with obvious radiologic nonunion at late follow-up at the fusion level in our study.

The presence or absence of instrumentation did not influence the amount of increase in degeneration score at adjacent levels in our study.

Clinical Impact

Although in the opinion of several authors, radiologic degeneration at adjacent levels after fusion does not have any or only limited clinical impact,[2–4,6,17,19,21,29,43,44] others noticed more or less important long-term clinical deterioration after an initial phase of clinical improvement.[10,11,20,37,44,45] This disparity may be due to some methodologic reasons: duration of follow-up, inclusion of all symptomatic cases or only those who needed second surgery, and survivorship analysis.[12] Hillibrand et al[12] studied 374 degenerative cases after cervical fusion. New symptomatic adjacent level disease was found to develop during the first 10 years after the operation at a relatively constant incidence of 2.9%/year.[12] The findings of Hillibrand et al are similar to those of Lunsford et al[46] as well as to the figures of our current study, taking into account our mean duration of follow-up of 100.6 months. We noticed a deterioration of late versus initial postoperative Odom score in 36% of the cases, and there was a suggestive trend of correlation of this finding with the degree of increase of radiologic degeneration score at a statistical P value of 0.06. In contrast, for myelopathic cases, evaluated by changes in the Nurick scale, such a correlation was not found. Possible explanations for this discrepancy are the sample size (the subgroup of myelopathic patients was small) and the sensitivity of the applied scores (the Nurick scale differs from the Odom scale in that deterioration from one grade to the next generally reflects a substantial clinical degradation).

Reoperations

Up to the moment of termination of this study, reoperation because of adjacent level degeneration was performed in 6.11% of the cases. Reoperation was done only when clear signs and symptoms of radiculopathy and/or myelopathy due to adjacent level disease, not responding to long-time conservative therapy, were present. Thus, in our series, pure, although sometimes intense, axial neck pain has not been an indication for reoperation. These criteria explain the difference in the overall reoperation number of 6.11% and the 36% long-term clinical deterioration number, when using the Odom score. Since a statistically significant correlation was found between postoperative time interval and degree of degeneration at adjacent levels, it is feared that the number of reoperations in our patient series might increase in the future. In the series of Hillibrand et al,[12] in more than two-thirds of all patients in whom the new adjacent level disease developed, nonoperative treatment failed and additional surgical treatment was eventually needed. Our number of reoperations is in concordance with some data from the literature: 9 of 122 cases in the series of Bohlman et al (7.3%),[3] 11 of 121 in the series of Gore and Sepic (9%),[10] 10% in another series of Hillibrand et al,[13] and 9% in the series of Watters and Levinthal.[33]

CONCLUSION

Despite its shortcomings, our long-term follow-up study identified a high prevalence of radiographic adjacent segment degeneration after anterior cervical fusions. These radiographic observations were independent of patient age, preoperative diagnosis, or use of instrumentation. The findings are consistent with an influence of fusion, which is independent of the natural history of cervical spondylosis.

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