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Neck Muscle Strength Before and After Cervical Laminoplasty

Relation to Axial Symptoms

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Study Design: A prospective study to investigate serial changes in neck muscle strength before and after cervical laminoplasty.

Objectives: To examine the correlation between neck muscle strength and axial symptoms, and to clarify the risk factors for axial symptoms.

Summary of Background Data: Axial symptoms are common complications after posterior cervical spinal surgery. Although several technical considerations have reduced axial symptoms, the causes of axial symptoms are still largely unknown. Previous studies have indicated that neck muscle strength is reduced in patients with neck pain.

Materials and Methods: Nineteen consecutive patients underwent cervical expansive laminoplasty for cervical spondylotic myelopathy. Age, sex, operative time, blood loss, clinical results, cervical curvature, range of motion, visual analog scale (VAS) for axial symptoms, and manual muscle strengths were examined before and after surgery. At 3 and 12 months, these factors were compared statistically between the no pain (NP) group (VAS < 3) and the pain (P) group (VAS ≥ 3). The correlation between VAS and neck muscle strength, and the reduction in neck muscle strength in extension were analyzed statistically.

Results: Six patients (31.5%) complained of axial symptoms at 3 months, and the symptoms continued in 3 patients (15.8%) at 12 months. At 3 months, cervical lordosis was 15.7 degrees in the NP group and 5.0 degrees in the P group, and neck strength in extension was 104.9% and 61.8%, respectively. At 12 months, neck strength in extension was 124.3% and 62.2%, respectively. These differences were statistically significant. The correlation between neck pain VAS and neck muscle strength, and the reduction in neck muscle strength in extension were statistically significant.

Conclusions: Neck muscle strength recovered to the preoperative value by 3 months and increased to 120% by 12 months in the NP group, whereas in the P group, neck muscle strength remained reduced by 60% and did not recover. Neck muscle strength and axial symptoms were strongly correlated.

Key Words: cervical spondylotic myelopathy, laminoplasty, axial symptoms, muscle strength

(*J Spinal Disord Tech* 2010;23:197–202)

Expansive laminoplasty is a standard operative procedure for cervical spondylotic myelopathy. Several surgical methods and excellent clinical results for expansive laminoplasties have been reported.[1–3] Hosono et al[4] first described neck and/or shoulder pain caused by laminoplasty, referring to it as "axial symptoms". Axial symptoms are common complications after posterior cervical procedures.[5] The incidence of axial symptoms has been reported to range from 0% to 80%. Its etiology remains largely unknown. To reduce postoperative axial symptoms, several surgical modifications have been introduced, such as semispinalis muscle preservation, C7 spinous process preservation, skip laminectomy, and brief external immobilization.[6–10]

The knowledge of neck muscle strength is important for any understanding of the potential relationship between muscle function and pathology. Subjects with neck pain often have reduced neck strength, and strength training is associated with a reduction in pain.[11]

We hypothesized that axial symptoms result from a reduction in neck muscle strength, caused by the surgical impact on the extensor muscles, and that this reduction in muscle strength is an important factor in axial symptoms. In this study, neck muscle strength was measured before and after the operation, and its relationship to axial symptoms was examined.

PATIENTS AND METHODS

Nineteen consecutive patients underwent cervical laminoplasty (C3 to C6) for cervical spondylotic

Received for publication September 2, 2008; accepted February 5, 2009.
From the Department of Orthopaedic Surgery, Graduate School of Medicine, Kyoto University, Kyoto, Japan.
Conflict of Interest: No funds were received in support of this study.
No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.
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myelopathy from May 2005 to March 2006. The study subjects were 12 men and 7 women, with a mean age at surgery of 61.6 years (range: 33 to 76 y). In cases of combined radiculopathy, posterior foraminotomies were included. Patients with rheumatoid arthritis or ossification of the posterior longitudinal ligament were excluded. The operative procedure was a modified double-door–type laminoplasty from C3 to C6, using an anchoring screw to secure the opened laminae.[12] In all cases, the C2 semispinalis attachments and the C7 spinous processes were carefully preserved (Figs. 1A, B). After the operation, the patients wore a soft brace for 2 weeks. The rate of recovery of the Japan Orthopedic Association (JOA) score,[13] cervical curvature (C2 to C7 lateral Cobb angle), and the 10-point visual analog scale (VAS) score for axial symptoms were examined at 1, 3, 6, and 12 months. Axial symptoms were defined according to the descriptions of reference 4: (1) nuchal pain distributed over the posterior neck; (2) shoulder pain, including pain of the suspensory muscles; and (3) shoulder muscle spasm, that is, stiffness and tension of the suspensory muscles. The range of motion (ROM; the difference in the lateral Cobb angle between flexion and extension) and manual muscle strengths were examined at 3, 6, and 12 months. The JOA recovery rate was calculated as follows: recovery rate (%) = (postoperative JOA score – preoperative JOA score) × 100/(17 – preoperative JOA score). The 10-point VAS was ascertained by self-assessment. The isometric neck muscle strengths at flexion, extension, right bending, and left bending were measured manually using the microFET2 (Hoggan Health Industries, UT) 3 times at each time point (Fig. 2A). The subject kept his/her neck in an isolated position while the force was applied by the examiner, and the average values at failure (Newton) were recorded as the intrinsic strength (Figs. 2B, C). The value for postoperative muscle strength was normalized to the preoperative value [n-manual muscle testing (n-MMT)]. Related factors such as age, sex, operative time, blood loss, recovery rate of the JOA score, cervical curvature, ROM, VAS for the axial symptoms, and manual muscle strengths were examined at both 3 and 12 months, and were compared statistically between the no pain (NP; VAS < 3) and pain (P) groups (VAS ≥ 3) with the Mann-Whitney U test. Correlations between axial pain and neck muscle strength or the reduction in muscle strength (n-MMT) in extension were analyzed using Spearman rank correlation coefficient. Statistical significance was defined as $P < 0.05$.

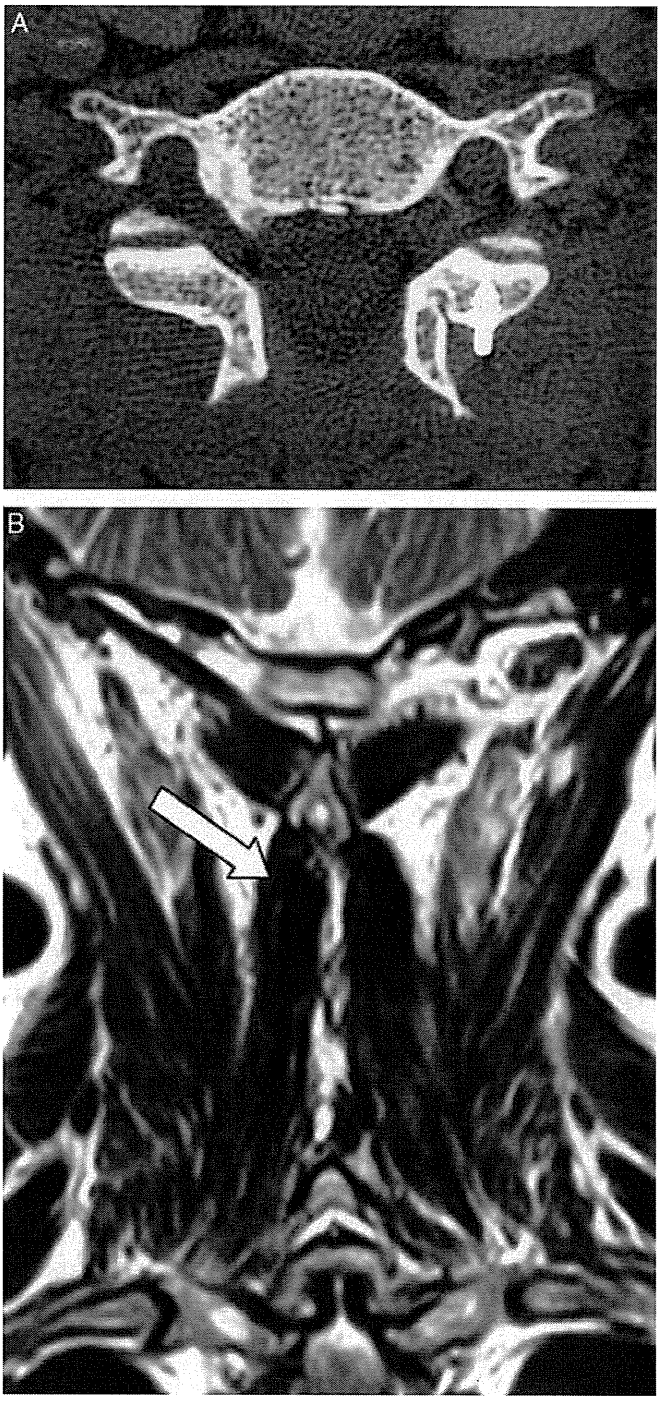

FIGURE 1. A and B, Postoperative axial computed tomographic image (A). Postoperative T2-weighted coronal magnetic resonance imaging demonstrates semispinalis muscle (arrow) preservation (B).

RESULTS

Clinical Results and Axial Symptoms

The mean operative time was 106.9 ± 28.3 minutes, and the mean blood loss was 41.4 ± 41.2 mL. The overall recovery rate of the JOA score was 51.8 ± 29.9% at 3 months and 57.1 ± 28.1% at 12 months. Preoperatively, 8 patients (4 men and 4 women) complained of significant neck pain, and the mean neck pain VAS was 2.8 ± 3.5. All the patients who complained of severe preoperative neck pain reported a reduction in neck pain postoperatively. At 1 month, there were 8 patients (7 men and 1 woman) in the NP group (VAS, 0.75) and 11 patients (5 men and 6 women) in the P group (58.0%; VAS, 4.18). At 3 months, there were 13 patients (11 men and 2 women) in the NP group (VAS, 0.46) and 6 patients

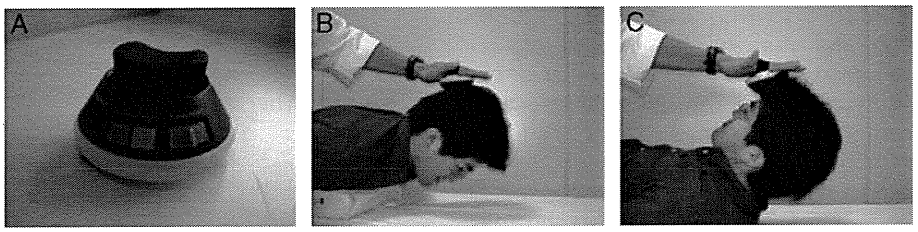

FIGURE 2. A to C, Measurements of neck muscle strength. The subjects kept their necks in an isolated position while the force was applied by the examiner, and the values at failure were recorded as the intrinsic strength: A, measurement device; B, extension; and C, flexion.

(1 man and 5 women) in the P group (31.5%; VAS, 3.83). At 6 months, there were 16 patients (11 men and 5 women) in the NP group (VAS, 0.5) and 3 patients (1 man and 2 women) in the P group (15.7%; VAS, 3.33). At 12 months, there were 16 patients (11 men and 5 women) in the NP group (VAS, 0.35) and 3 patients (1 man and 2 women) in the P group (15.7%; VAS, 4.0). The axial symptoms gradually decreased in all patients during the experimental period. At each time point, women complained of more axial symptoms than did men. The preoperative VAS was lower and the JOA score recovery rate was higher in the NP group than in the P group, although not statistically significantly. Other parameters, such as age, preoperative JOA score, and operative time, were not related to the degree of axial symptoms at 3 months (Table 1).

Radiologic Assessments

The mean preoperative cervical lordotic angle was 14.1 ± 11.8 degrees, and the ROM was 41.2 ± 13.3 degrees. At 3 months, the lordotic angle was significantly higher in the NP group (15.7 ± 9.2 degrees) than in the P group (5.0 ± 9.6 degrees; $P = 0.023$). At 12 months, the lordotic angle was 13.1 ± 10.5 degrees in the NP group and 15.4 ± 11.8 degrees in the P group, but the difference between the groups was not significant (Fig. 3). There was no case of progressive kyphotic alignment. The ROM of the cervical spine was 35.8 ± 8.2 degrees at 3 months and 40.0 ± 11.1 degrees at 12 months in the NP group, and 29.0 ± 10.9 degrees and 51.8 ± 16.5 degrees, respectively, in the P group. The differences were not significant between the 2 groups at either time point. Preoperative cervical lordosis and ROM did not differ between the NP and P groups at either time point.

TABLE 1. Relationship Between Patient Preoperative Demographic Data and Axial Symptoms at Three Months

	NP Group[13]	P Group[6]	*P*
Age (y)	61.0 ± 13.0	63.2 ± 13.6	NS
Pre VAS	2.0 ± 3.1	4.5 ± 4.1	NS
Pre JOA	11.1 ± 2.7	12.7 ± 3.0	NS
Operative time (min)	108.9 ± 33.8	102.5 ± 10.8	NS
Blood loss (mL)	49.5 ± 48.5	20.3 ± 2.6	NS
Pre C2-C7 lordosis (degrees)	16.1 ± 9.8	8.6 ± 16.3	NS
Pre ROM (degrees)	41.0 ± 8.7	41.7 ± 24.0	NS
Pre flexion (N)	75.1 ± 28.1	56.9 ± 27.1	NS
Pre extension (N)	100.9 ± 27.9	100.3 ± 43.0	NS
Pre right bending (N)	85.3 ± 24.3	73.5 ± 33.9	NS
Pre left bending (N)	87.5 ± 19.1	76.1 ± 34.5	NS

Values are means ± SD.

JOA indicates Japan Orthopedic Association; N, Newton; NP, no pain (VAS < 3); NS, not significant; P, pain (VAS ≥ 3); Pre, preoperative; ROM, range of motion; VAS, visual analog scale.

Muscle Strength

Preoperation

The mean preoperative intrinsic muscle strength was 69.1 ± 27.6 N in flexion, 99.3 ± 32.1 N in extension, 80.1 ± 27.2 N in right bending, and 82.4 ± 24.8 N in left bending. The mean muscle strength of the men was significantly higher than that of the women in all directions, compared with an unpaired *t* test (flexion, 83.7 ± 22.7 N vs. 44.1 ± 13.3 N, respectively, $P = 0.0006$; extension, 110.5 ± 33.9 N vs. 80.0 ± 17.2 N, respectively, $P = 0.042$; right bending, 91.3 ± 26.7 N vs. 60.9 ± 15.0 N, respectively, $P = 0.014$; left bending, 92.0 ± 24.2 N vs. 66.0 ± 16.5 N, respectively, $P = 0.022$).

At 3 Months Postoperation

The normalized flexion strengths did not differ between the NP and P groups. The normalized strength of the extensor muscle was 104.9 ± 40.8% in the NP group and 61.8 ± 24.9% in the P group. The difference between the 2 groups was statistically significant ($P = 0.011$;

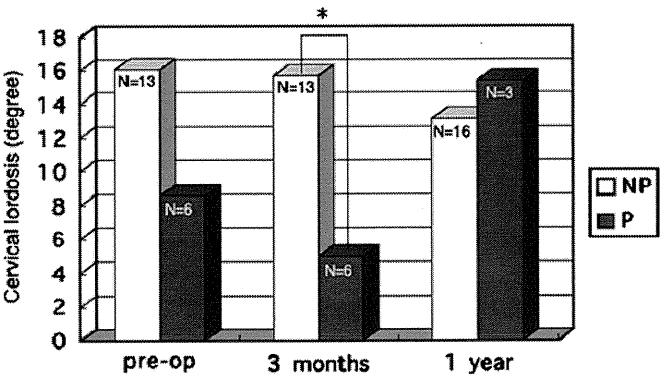

FIGURE 3. Cervical lordotic angle. Cervical lordosis was significantly higher in the NP group than in the P group at 3 months. At 12 months, no difference was identified between the 2 groups. *Statistically significant. NP indicates no pain group; P, pain group.

Fig. 4). Right bending was 116.0 ± 57.3% in the NP group and 82.2 ± 23.5% in the P group. Left bending was 112.9 ± 55.6% in the NP group and 65.5 ± 18.9% in the P group. Both side-bending strengths were significantly higher in the NP group than in the P group ($P = 0.039$ and $P = 0.004$, respectively).

At 12 Months Postoperation

The flexion strengths did not differ between the NP and P groups. The extension muscle strength was 124.3 ± 38.5% in the NP group and 62.2 ± 6.0% in the P group, and the difference was statistically significant ($P = 0.007$). Right bending was 126.9 ± 49.3% in the NP group and 82.0 ± 13.3% in the P group. Left bending was 122.9 ± 49.0% in the NP group and 60.6 ± 6.7% in the P group. Thus, the side-bending strengths were significantly higher in the NP group than in the P group ($P = 0.007$ and $P = 0.007$, respectively). The preoperative muscle strengths for all directions did not differ between the NP and P groups at both 3 months and 12 months. The data are summarized in Tables 2 and 3. VAS and neck muscle strength in extension were weakly correlated (rs = −0.366, $P = 0.0066$). VAS and the reduction in neck muscle strength (n-MMT) in extension were strongly correlated (rs = −0.609, $P = 0.0002$; Fig. 5).

DISCUSSION

No previous study has evaluated the sequential changes in subjective muscle strength before and after cervical surgery. In this study, neck muscle strength was measured successfully before and after the operation, and was evaluated in relation to axial symptoms. Statistical analysis indicated that the neck pain VAS and neck muscle strength were significantly correlated.

The source of axial symptoms is thought to be multifactorial and to include deep extensor muscle denervation, facet joint injury, C2 or C7 muscle invasion, neural element compression, and prolonged postoperative external immobilization.[7–10] Several modifications have recently been applied to reduce the axial symptoms. In accordance with evidence, the C2 and C7 muscles have been preserved, facet joint invasion has been reduced as much as possible, and postoperative immobilization is brief, as in our procedure.[12]

We hypothesized that muscle strength might be reduced by surgical invasion to the deep extensor muscles, which might be related to axial symptoms. However, interestingly, muscle strength was recovered by 3 months and had increased to 120% of the preoperative value by 12 months after the operation in most patients. These findings indicate that although a temporary reduction in muscle strength occurred during the early postoperative period, caused by operative invasion or wound pain, operative invasion to the deep extensor muscles was not a crucial factor in maintaining neck muscle strength. Surgical decompression of the spinal cord or nerve root will reduce neck pain, and will also contribute to the subsequent increase in muscle strength. Our findings actually demonstrated that all patients who complained of severe preoperative neck pain reported a reduction in neck pain postoperatively.

The results of this study showed that axial symptoms occurred more in women than in men. The causes of sex difference for axial symptoms were not well

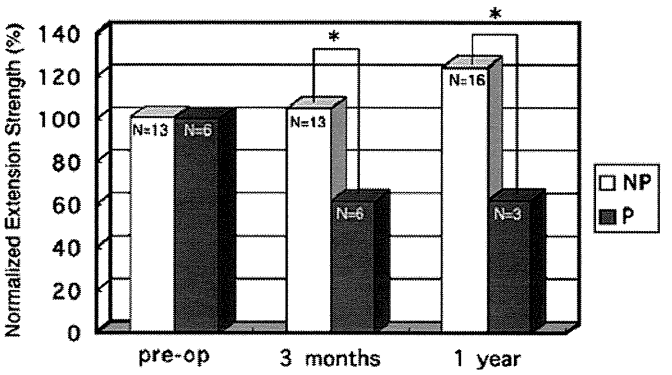

FIGURE 4. Normalized muscle strength in extension. The extension strength was significantly higher in the NP group than in the P group at 3 months. At 12 months, the extension strength was 124.3% in the NP. Preoperative values are intrinsic strengths (Newtons). *Statistically significant. NP indicates no pain group; P, pain group.

TABLE 2. Relationship Between Clinical Data and Axial Symptoms at Three Months

	NP Group[13]	P Group[6]	*P*
JOA recovery rate (%)	58.8 ± 27.5	36.7 ± 31.8	NS
C2-C7 lordosis (degrees)	15.7 ± 9.2	5.0 ± 9.6	0.002*
ROM (degrees)	35.8 ± 8.2	29.0 ± 10.9	NS
Flexion (%)	103.9 ± 28.7	87.1 ± 13.6	NS
Extension (%)	104.9 ± 40.8	61.8 ± 24.9	0.011*
Right bending (%)	116.0 ± 57.3	82.2 ± 23.5	0.039*
Left bending (%)	112.9 ± 55.6	65.5 ± 18.9	0.004*

Values are means ± SD.
*Statistically significant: $P < 0.05$.
JOA indicates Japan Orthopedic Association; NP, no pain (VAS < 3); NS, not significant; P, pain (VAS ≥ 3). ROM, range of motion; VAS, visual analog scale.

TABLE 3. Relationship Between Clinical Data and Axial Symptoms at 12 Months

	NP Group[14]	P Group[3]	*P*
JOA recovery rate (%)	61.0 ± 25.5	36.1 ± 37.6	NS
C2-C7 lordosis (degrees)	13.1 ± 10.5	15.4 ± 11.8	NS
ROM (degrees)	40.0 ± 11.1	51.8 ± 16.5	NS
Flexion (%)	113.2 ± 28.2	79.6 ± 18.1	NS
Extension (%)	124.3 ± 38.5	62.2 ± 6.0	0.007*
Right bending (%)	126.9 ± 49.3	82.0 ± 13.3	0.007*
Left bending (%)	122.9 ± 49.0	60.6 ± 6.7	0.007*

Values are means ± SD.
*Statistically significant: $P < 0.05$.
JOA indicates Japan Orthopedic Association; NP, no pain (VAS < 3); NS, not significant; P, pain (VAS ≥ 3). ROM, range of motion; VAS, visual analog scale.

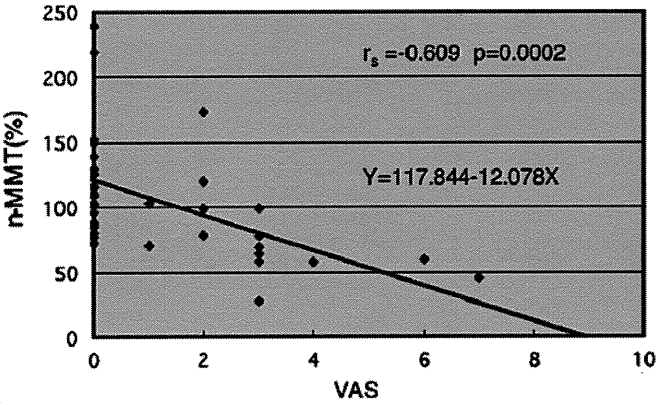

FIGURE 5. Correlation between neck pain VAS and the reduction in muscle strength (n-MMT) at extension using Spearman rank correlation coefficient. n-MMT = postoperative MMT/preoperative MMT × 100 (%). MMT indicates manual muscle testing; VAS, visual analog scale.

discussed, we wondered about the correlation of muscle strength and symptoms. These findings are similar to those of previous reports, in which the muscle strengths of normal volunteers were 2 times stronger in men than in women.[15] The same trends were also observed in our study. Although in the current study preoperative muscle strength was not identified statistically as a risk factor for axial symptoms, surgeons should keep in mind the sex difference of the incidence of axial symptoms.

The results of current study raise a query as to whether weakness causes pain or pain causes weakness. Our study demonstrated the correlation between axial symptom and neck muscle strength, but could not clarify as to whether weakness caused pain or pain caused weakness. Previous studies have indicated that flexor and extensor muscle strength are reduced in patients with neck pain, which indicated neck pain caused the muscle weakness.[11] If neck pain is the main cause of muscle weakness, sex difference of axial symptom can not explained. In consideration of sex difference and pain relief after neck muscle exercise, axial symptom was liable to occur in patients with weak muscle strength preoperatively, which combined with operative invasion. That is, reduction of the muscle weakness by limited operative invasion, brief postoperative external immobilization, and strengthening of muscle after surgery will contribute to reduce the incidence of axial symptoms.

Because the cervical curvature was affected not only by neck pain but also disc degeneration, facet arthrosis, neck muscle strength, and whole spine posture, the relationship between axial pain and cervical curvature was still controversial. Matsumoto et al[16] studied cervical curvature after whiplash injury and the results indicated no association between clinical symptoms and cervical curvature. Yoshida et al[14] reported no correlation between axial pain and cervical curvature at 6 months to 1 year after cervical laminoplasty. Although we could show the correlation between cervical curvature and axial symptom at only 3 months, because the cervical curvature and ROM are affected by wound pain or external immobilization, it is difficult to define the clear correlation between axial symptom and cervical curvature in early postoperative periods.

This study has several limitations. First, although several surgical procedures were used for cervical spondylotic myelopathy, the differences in the surgical procedures used were not evaluated. However, a recent study has demonstrated that clinical results and axial pain are not dependent on the surgical procedure used.[17] Second, the sample size was relatively small. To clarify the risk factors for axial symptoms, another extensive longitudinal study with a large sample of patients is required.

In conclusion, neck muscle strength was measured before and after cervical laminoplasty. Axial symptoms occurred more often in women than in men. Muscle strength recovered to the preoperative level after 3 months and increased to 120% after 12 months in the NP group, whereas in the P group, neck muscle strength remained by 60% and did not recover. These data indicate that neural decompression reduced the patients' neck pain and that the surgical invasion of the C2 and C7 muscles with these surgical techniques was not crucial for, and did not affect the maintenance of, muscle strength. Although no preoperative predictive risk factors were identified, axial symptoms and reduced muscle strength were significantly correlated.

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The Spine Journal 10 (2010) 42–49

THE SPINE JOURNAL

Clinical Study

The value of palliative surgery for metastatic spinal disease: satisfaction of patients and their families

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Received 22 March 2009; revised 3 June 2009; accepted 26 June 2009

Abstract

BACKGROUND CONTEXT: Although there have been several studies in which the surgical outcomes were evaluated by pain reduction or neurological improvement, there have been few studies focused on the quality of life (QOL) of the patients after the surgery. We considered that the most important consideration in palliative surgery was to respect the wishes of patients and their families, which are likely to be influenced by the patients' QOL for their limited life span.

PURPOSE: To evaluate the value of palliative surgery for spinal metastasis and to identify the factors predicting satisfaction of patients and their families after the surgery.

STUDY DESIGN: Questionnaire-based survey of palliative surgery for spinal metastasis.

PATIENT SAMPLE: Seventy-one consecutive patients who had undergone palliative surgery and their families.

OUTCOME MEASURES: Survival period after surgery, neurological status, ambulatory period, pain scale, and satisfaction of patients and their families.

METHODS: The QOL of the patients after surgery was evaluated by analyzing the satisfaction and related parameters of patients and their families. Questionnaires were sent to 71 consecutive patients who had undergone palliative surgery for spinal metastasis. To identify the factors predicting satisfaction of patients and their families, multivariate logistic regression analyses were performed.

RESULTS: Questionnaires were successfully delivered to 71 patients or their families. Full responses were collected from 37 patients, giving an overall response rate of 52.2%. Overall, 80% of patients were satisfied with the results of the surgical treatment. Age (below 65 years) and neurological improvement after surgery were significant predictors of patient's satisfaction. Pain reduction and the continued survival of the patient were significant predictors of family member's satisfaction.

CONCLUSIONS: These results strongly suggested that palliative surgery is a valuable treatment for metastatic spinal disease. Younger patients were more likely to want active treatment and to seek any functional improvement that contributed to an improved QOL in their limited life span. Pain control and the length of patient survival were important factors for people caring for patients.

Keywords: Spinal metastasis; Palliative surgery; Satisfaction; Quality of life

Introduction

The spinal column is the most frequent site of bone metastasis, and between 30% and 70% of patients with cancer will have evidence of spinal metastasis at autopsy [1–3]. Spinal cord compression, the most serious sequela of spinal metastasis, occurs in 20% of patients with such metastasis

FDA device/drug status: not applicable.

Author disclosures: none.

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1529-9430/10/$ – see front matter
doi:10.1016/j.spinee.2009.06.016

[4]. Spinal column metastasis may cause significant clinical problems, including severe pain and neurological symptoms. Treatment of metastatic disease of the spine involves a fine balance between survival, function, and overall quality of life (QOL). Radiotherapy has been traditionally considered to be the first-line treatment for spinal metastasis. In cases of radioresistant tumors with neurological compromise or mechanical instability, nonsurgical treatment has not proved effective.

Surgery has been performed on occasion for patients with metastatic spinal tumors and has been shown to be an excellent treatment for symptoms of pain and palsy. An improvement in QOL that cannot be achieved by other methods can be immediately apparent in selected patients [5]. Surgery can provide early mobilization, return of useful ambulation or urinary function, pain reduction, and improvement in QOL, as well as prolongation of life [6]. Improvements in spinal surgical techniques and implants now allow for safe and effective decompression of neural elements and provide structural stability by means of a rigid internal fixation [7,8]. The objectives of surgical management for metastatic spinal disease are usually palliative. However, the prognostic factors affecting outcomes after spinal metastasis remain unclear, and the use of surgery is still controversial [9–12].

Because metastatic disease suggests a limited life expectancy, the ability to function and the QOL become profoundly important considerations. Although there have been several studies to objectively evaluate the effects of surgery on survival and functional status, there has been little attempt to subjectively assess the outcomes. Certainly, several physical factors, such as ambulation status, pain reduction, and prolongation of life, may be important to the QOL of the patients. We considered that the most important factors affecting the QOL of the patients with a limited life span were measures of their subjective satisfaction, such as having a stable and positive outlook. Therefore, in the present study, we chose the satisfaction of patients and their families as an indicator for success of surgical intervention for metastatic spinal disease. To establish the value of this treatment, we evaluated satisfaction using a questionnaire.

Material and methods

From April 2000 to November 2005, palliative surgery was performed in our institute and in related hospitals for 71 patients with metastatic spinal disease. Patients had a general medical status good enough to be acceptable surgical candidates and an expected survival of at least 3 months. The objectives of surgical intervention for all patients were palliative. Excisional procedures performed during this period, such as total en bloc spondylectomy [13], were excluded. Questionnaires were sent by mail to 71 patients and to their families in February 2006. Informed consent was obtained from the subjects and/or guardians.

EVIDENCE & METHODS

Context
Patient and family satisfaction following palliative surgery for metastatic spinal disease has been understudied. This article aims to address this issue.

Contribution
The authors found improved function and decreased pain in many patients following surgery. Eighty percent of patients were satisfied with their results, correlating with younger age and improved neurological status, and 73% of families were satisfied, correlating with survival and pain relief.

Implications
Despite some design limitations recognized in the study, the authors' compassionate shift of focus toward satisfaction as a primary outcome in these terminally ill patients is to be commended and, really, defines the goal of palliation.

—*The Editors*

Three months later, simultaneous analysis was performed on collected questionnaires combined with the demographic data from the patients' hospital records. The questions included whether patients survived at the time of questionnaire completion, their survival period after surgery, their neurological status before and after surgery, their ambulatory period, the pain scale before and after surgery with or without adjuvant therapy, identification of the key person responsible for decision making, and the satisfaction of patients and their families. Data obtained from patient's records included the patient's age at surgery, their gender, the anatomic site of the primary carcinoma and of the metastatic lesion of the spine, and the nature of the operative procedures. Because of the sensitivity of the situation, it was decided not to undertake an additional telephone survey.

Factors evaluated as predicting variables were age at surgery, gender, anatomic site of the primary carcinoma, survival at the time of questionnaire completion, survival period after surgery, neurological status before and after surgery (Frankel grade), improvement of neurological status, ambulatory period, pain scale before and after surgery, improvement of pain scale with or without adjuvant therapy, key person for decision making, and satisfaction of patients and their families with treatment. The severity of palsy was classified according to Frankel's classification into five grades [14], and neurological status was graded before and after surgery. Patients with Frankel Grade E were neurologically normal; those with Grade D had useful motor function below the level of involvement, with incomplete sensory loss (ambulatory); those with Grade C had

some motor function below the level of involvement and incomplete sensory loss (nonambulatory); those with Grade B had complete motor and incomplete sensory loss (nonambulatory); and those with Grade A had complete motor and sensory loss (paraplegia). Pain was categorized as no pain, mild pain, moderate pain, or severe pain. Patients with severe pain routinely used narcotic agents. For subjective assessment of the overall results of surgery, the patients or their families were asked to select from among the following options: 1) very satisfied, 2) satisfied, 3) somewhat satisfied, 4) somewhat dissatisfied, and 5) dissatisfied. In cases where the patients had died, their family members completed the questionnaires.

Statistical analysis

Cross-tables were analyzed with the Student *t* test or the Fisher exact test. p Values less than 5% were considered significant. To confirm that the 37 patients included in the study group were an appropriate sample, demographic data, including age, gender, anatomic site of the primary carcinoma and of the metastatic lesion of the spine, and neurological status, were compared with those of the 34 patients not included. To identify the influence of response difference between actual patient and family members, subgroup analysis was performed. Univariate and multivariate analyses used the Cox proportional hazards model for the variables. To identify factors predicting satisfaction of patients and their families, univariate and multivariate logistic regression analyses were performed. Satisfaction of patients or that of their families was used as the dependent variable. Binary data (very satisfied vs. others) obtained from a five-point Likert scale were analyzed. Age (65 years as the cutoff point), gender, improvement of neurological status, improvement of pain scale, and survival of patients (dead or alive) were selected as independent variables.

Surgical procedures

The standard surgical procedure was posterior decompression and stabilization using instrumentation. Preoperative selective embolizations were not routinely performed. In the case of involvement of the thoracic spine, laminectomy was performed one segment above and one segment below the metastatic lesion. Circumferential decompression

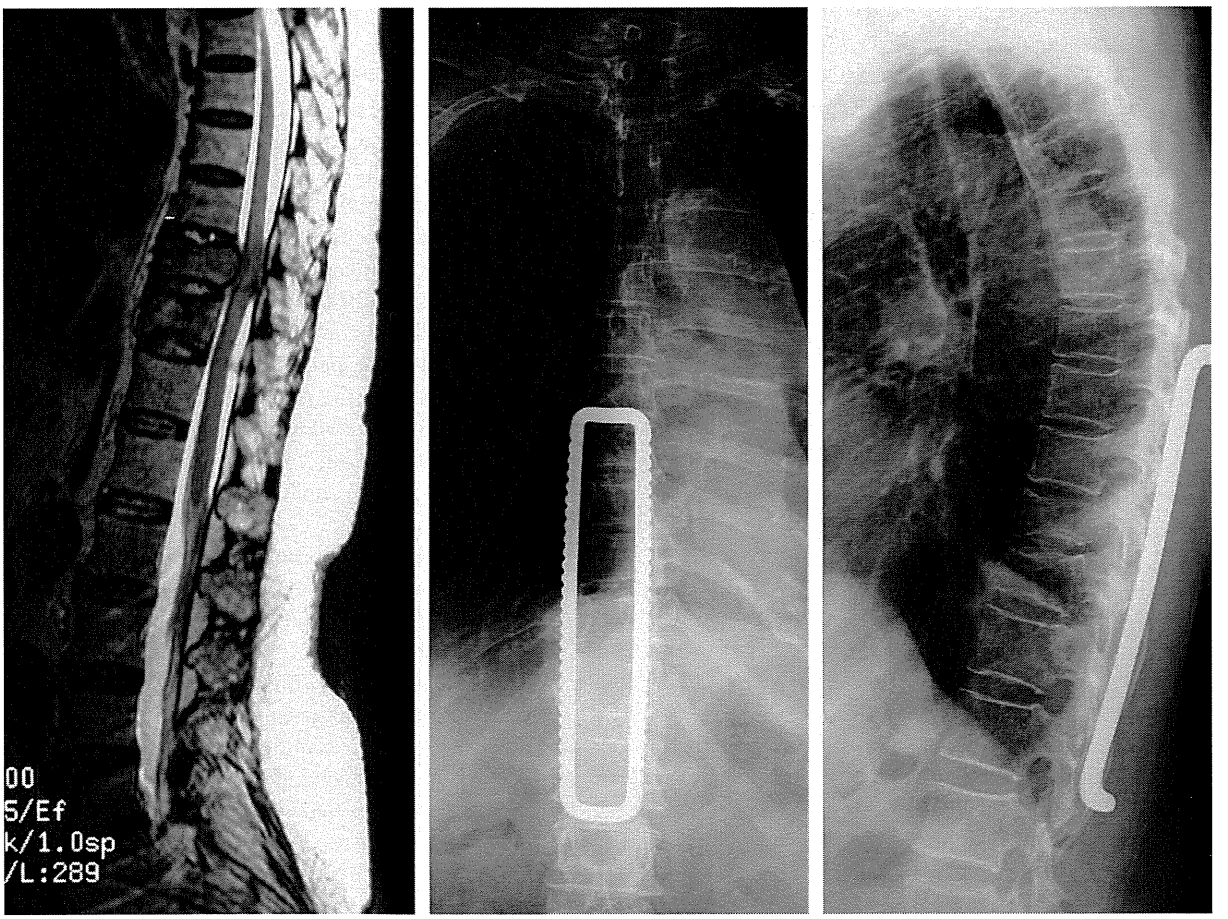

Figure. Seventy-three-year-old female with Frankel C paraparesis from lung cancer metastasis. (Left) Preoperative magnetic resonance T2WI-sagittal image demonstrates severe thoracic spinal cord compression at Th10 level. (Middle) Postoperative anteroposterior and (Right) lateral X-ray images. Circumferential decompression was performed via the posterolateral route by laminectomy at Th9 to Th11 combined with posterior stabilization using a rectangular rod.

was performed through the posterolateral route with bilateral pedicle excision. Tumor and bony fragments ventral to the dural tube, which caused the neural compression, were excised as completely as possible. Hemostasis was attempted by packing an atelocollagen sponge into the metastatic vertebrae. Bilateral thoracic nerve roots that ran into the tumor were routinely cut. An anatomically bent rectangular titanium rod was secured to the laminae using radiolucent polyethylene wire by a sublaminar wiring technique [15]. In cases of involvement of the lumbar spine or extending thoracolumbar spine, stabilizations were performed using the more rigid pedicle screw system. No autologous bone grafting was performed. A typical case of thoracic spine metastasis from lung cancer is shown in Figure.

Results

Complete responses were collected from 37 patients, giving an overall response rate of 52.1% (37 of 71 patients).

The mean age of the 37 patients (21 males and 16 females) at the time of surgery was 60.1 years. The primary carcinoma occurred in the breast in 11 patients (29.7%), the lung in 8 (21.6%), the prostate in 4 (10.8%), the kidney in 3 (8.1%), and the stomach and liver each in 2 patients (5.4%). There was one patient with each of bladder, lymphoma, ovary, sarcoma, and thyroid cancer (2.7%), and the primary carcinoma site was unknown in two patients (5.4%). Neurological status before surgery was Frankel A in 3 patients (8.1%), B in 5 (13.5%), C in 13 (35.1%), D in 9 (24.3%), and E in 7 (18.9%). The metastatic lesion of the spine, as located from the symptoms, was located in the cervical spine in 5 patients (13.5%), in the thoracic spine in 24 (64.9%), and in the lumbosacral spine in 8 (21.6%). The period between surgery and completion of the questionnaire was an average of 32.7 months (range, 3–69 months). Twenty-one patients were alive and 16 patients were dead at the time of questionnaire completion, that is, 16 responses were made by family members. Twenty-eight patients (75.8%) survived more than 6 months after the surgery. Twenty-three patients received adjuvant chemotherapy, and 28 patients received radiotherapy to the metastatic vertebrae before or after the surgical intervention. Statistical analysis, comparing the 37 patients of the study group and the 34 patients in the nonresponding group, showed no significant differences in age (p=.914), gender composition (p=.826), anatomic site of the primary carcinoma (p=.061), site of the metastatic lesion of the spine (p=1.000), or neurological status (p=.155). Thus, these demographic data were an acceptable representation of the overall data for the 71 patients. Mortality and surgically related neural tissue injury were not observed during the perioperative period. Preoperative demographic data are summarized in Table 1.

Table 1
Patients' demographic data

Factor	Overall patients (n=71)	Study group (n=37)	p Value*
Age (y)	59.3 (31–85)	60.3 (31–85)	.914 (NS)
Gender	M=41, F=30	M=21, F=16	.826 (NS)
Metastatic origin			.061 (NS)
Breast	18	11	
Lung	13	8	
Liver	11	2	
Kidney	6	3	
Prostate	5	4	
Colon	3	0	
Stomach	2	2	
Pancreas	1	0	
Others	12	7	
Metastatic lesion			1.000 (NS)
Cervical	8	5	
Thoracic	46	24	
Lumbar	17	8	
Neurological status (Frankel)			.155 (NS)
A	3	3	
B	6	5	
C	24	13	
D	25	9	
E	13	7	

M, male; F, female; NS, not significant.

* Statistical analysis was performed between 37 patients of study group and 34 patients of nonresponding group using the Student *t* test or the Fisher exact test.

Table 2
Comparison of neurological status between before and after the operation

	Postoperative Frankel					
Preoperative Frankel	A	B	C	D	E	Total
A			1	1	1	3
B	1		1	2	1	5
C			2	5	6	13
D				3	6	9
E					7	7
Total	1	0	4	11	21	37

Neurological status

The number of ambulatory patients increased from 16 (43.2%) to 32 (86.4%) after surgery. Twenty-two patients (59.4%) maintained a useful ambulatory status for more

Table 3
Comparison of pain score between before and after the operation

	Postoperative pain score				
Preoperative pain score	1	2	3	4	Total
1	2	3	2	3	10
2		4	11	7	22
3			1	1	2
4				3	3
Total	2	7	14	14	37

Table 4
Patient's satisfaction and responses

	Responses		
Patient satisfaction grade	Patient	Family member	Total
1	8	8	16
2	5	9	14
3	3	4	7
4	0	0	0
5	0	0	0
Total	16	21	37

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p=.832 (Fisher exact test).

than 6 months. The improvement of neurological status was four grades in 1 patient, three grades in 1, two grades in 9, and one grade in 13. Twelve patients showed no improvement, and the condition of one patient gradually deteriorated. The average degree of neurological improvement was one grade (Table 2).

Pain status

Twenty-seven patients (73.0%) showed improved pain status after the surgery. The improvement on the pain scale was three grades in 3 patients, two grades in 8, and one grade in 16. Ten patients showed no improvement in pain scale, including three patients with no pain before the surgery, and no patient showed deterioration. The average degree of pain improvement was 1.1 grades (Table 3).

Satisfaction and other variables

The subjective assessment showed that 16 patients (43.2%) were very satisfied with the results of the surgical intervention, 14 (37.8%) were satisfied, and 7 (18.9%) were somewhat satisfied. No patient responded as somewhat dissatisfied or dissatisfied. Overall, 30 patients (81.1%) were satisfied or very satisfied. Of the responding families, 18 (48.6%) were very satisfied, 9 (24.3%) were satisfied, 7 (18.9%) were somewhat satisfied, and 2 (5.4%) were somewhat dissatisfied. Overall, 27 (73.0%) families were very satisfied or satisfied. The decision for surgery was made by the patient in 23 cases (62.1%), by the family alone in 1 case (2.7%), by both patients and families in 12 cases (32.4%), and by the physicians in 1 case (2.7%). As such, the decision for surgery was made by the patient in more than 90% of the cases. There was no difference between the results of patient's response and family member's response for patient's satisfaction (p=.832) (Table 4). There was also no difference between the results of patient's response and family member's response for family member's satisfaction (p=.153) (Table 5). The correlation between patient's satisfaction and family member's satisfaction was statistically significant in the patient's response group (p=.003) (Table 6). The correlation between patient's satisfaction and family member's satisfaction was also statistically significant in the family member's response group (p<.001) (Table 7). These results indicated that there was no response bias between the actual patient and family members.

Table 5
Family member's satisfaction and responses

	Responses		
Satisfaction grade	Patient	Family member	Total
1	11	7	18
2	2	7	9
3	3	5	8
4	0	2	2
5	0	0	0
Total	16	21	37

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p=.153 (Fisher exact test).

Table 6
Correlation between patient's satisfaction and family member's satisfaction in patient's responding group

	Family member's satisfaction					
Patient satisfaction grade	1	2	3	4	5	Total
1	7	1	0	0	0	8
2	4	1	0	0	0	5
3	0	0	3	0	0	3
4	0	0	0	0	0	0
5	0	0	0	0	0	0
Total	11	2	3	0	0	16

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p=.003 (Fisher exact test).

Results of statistical analysis

The results of univariate logistic regression analysis are shown in Table 8. Among the variables examined, only age (crude odds ratio [OR]: 0.17, p=.024) was significantly associated with patient's satisfaction, although improvement of neurological status (crude OR: 2.03, p=.064) was close to being significantly associated. In contrast,

Table 7
Correlation between patient's satisfaction and family member's satisfaction in family member's responding group

	Family member's satisfaction					
Patient satisfaction grade	1	2	3	4	5	Total
1	6	0	2	0	0	8
2	1	7	0	1	0	9
3	0	0	3	1	0	4
4	0	0	0	0	0	0
5	0	0	0	0	0	0
Total	7	7	5	2	0	21

Satisfaction grade: (1) very satisfied, (2) satisfied, (3) somewhat satisfied, (4) somewhat dissatisfied, and (5) dissatisfied.
p<.001 (Fisher exact test).

Table 8
Patient's satisfaction and related factors

Factor	Crude OR	95% CI	p Value	Adjusted OR	95% CI	p Value
Gender	0.62	0.17–2.30	.470	6.26	0.63–62.2	.117
Age (y)	0.17	0.04–0.80	.024*	0.88	0.79–0.98	.016*
Neurological improvement	2.03	0.96–4.31	.064	2.77	1.01–7.63	.049*
Pain improvement	1.37	0.66–2.87	.403	1.33	0.47–3.70	.591
Survival	0.62	0.17–2.30	.470	0.78	0.15–4.09	.772

OR, odds ratio; CI, confidence interval.
*p<.05 (statistically significant).

improvement of the pain scale (crude OR: 2.52, p=.036) and the patient's survival at the time of survey (crude OR: 0.23, p=.037) were significantly associated with family member's satisfaction. The results of multivariate logistic regression analysis are shown in Table 9. Among the variables examined, age (adjusted OR: 0.88, p=.016) and improvement of neurological status (adjusted OR: 2.77, p=.049) were significantly associated with patient's satisfaction. In contrast, improvement of the pain scale (adjusted OR: 4.01, p=.036) and the patient's survival (adjusted OR: 0.15, p=.036) were significantly associated with family member's satisfaction. These results indicate that age below 65 years and neurological improvement were the most important variables for patient's satisfaction after surgery. Pain improvement and the patient's survival at the time of survey were the most important variables for family member's satisfaction.

Discussion

The results of this study clearly demonstrate that surgical intervention in patients with spinal metastasis had a positive impact on the patient's overall health and function. Overall, 80% of the patients in this study were satisfied or very satisfied with the surgical procedure. These results strongly suggest that during their remaining life span, both the patients and their families had a good mental state and were able to maintain hope, which might be a consequence of a good QOL.

Because the nature of a "good death" is still unclear and depends on the individual, it is difficult to determine the primary goal of palliative care [16]. Important goals of palliative care include not only symptom control but also a "good death" or "good process of dying." Physicians must take into consideration the patient's spirits and attitudes, such as "fighting against cancer" or "maintaining hope" when undertaking palliative treatment. That is, the objectives of palliative surgery should be not only functional improvement or pain reduction but also respect for the patient's wishes.

In the literature, the satisfaction rate for surgery has been reported as 82% in lumbar disc herniation [17,18], 78% in lumbar spinal canal stenosis [19,20], 75% in cervical spondylotic myelopathy [21], and 94% in scoliosis [22]. The degree of patient's satisfaction in the present study was almost equal to that of spinal surgeries for degenerative conditions. Although surgery for metastatic disease is massively invasive and has high neurological risk, an emergent nature, and variable patient postoperative status, the satisfaction rate of 80% was a high level of acceptance. In general, Japanese patients would not necessarily consider that autonomy in decision making was essential. There is a tendency for Japanese patients to prefer to entrust the decision to their physicians. However, the patients enrolled in this study were likely to have a positive attitude toward their surgical treatment, and 94.5% patients made the decision for surgery themselves. This might also contribute to the high satisfaction rate observed in this study.

The statistical analysis demonstrated that age below 65 years and neurological improvement both correlated with increased patient's satisfaction. These results indicate that younger patients were more inclined to take a positive attitude to treatment and to seek a functional improvement to give a good QOL for their limited life span. The finding of a correlation between functional improvement and QOL is consistent with previous reports [23–25]. Patients with end-stage disease often hope "not to be a burden to

Table 9
Family member's satisfaction and related factors

Factor	Crude OR	95% CI	p Value	Adjusted OR	95% CI	p Value
Gender	0.58	0.16–2.17	.421	3.01	0.29–31.8	.360
Age (y)	0.35	0.09–1.36	.129	0.93	0.84–1.03	.147
Neurological improvement	1.56	0.78–3.09	.206	2.09	0.85–5.11	.107
Pain improvement	2.52	1.06–5.97	.036*	4.01	1.10–14.6	.036*
Survival	0.23	0.06–0.92	.037*	0.15	0.025–0.89	.036*

OR, odds ratio; CI, confidence interval.
*p<.05 (statistically significant).

others." The close correlation between patient's satisfaction and neurological improvement is easily explained by such patient attitudes.

Interestingly, factors related to satisfaction in patients were different from those among their families. Statistical analysis demonstrated that improvement of pain status and of patient's survival increased the family member's satisfaction. In the case of terminal care, pain control was an important factor not only for patients but also for their families. Severe pain for a patient may also be a burden to their family members who are undertaking daily care. Moreover, although the patient's neurological condition or pain improved after surgery, the patient's survival was the most important factor for his/her family. The present results strongly suggest that mental satisfaction is crucial for people taking part in the care of the patients with terminal incurable cancer.

There were several limitations in the present study, including a small sample size and an objective bias. In cases where the patients had died, their family responded to the questionnaire, and the period between the surgery and the completion of questionnaire differed between patients (range, 3–69 months). The possibility exists that some patients or their families depended on unreliable memories when responding to the questionnaire. There was also a significant loss of follow-up in part because of the mortality and morbidity associated with cancer and because of the complex psychosocial issues that can affect patients. In the best of circumstances and with the most tactful and sensitive investigators, it can still be very difficult to obtain complete follow-up on patients who may be physically ill, emotionally upset, and in recovery after major surgery. The conclusions were dependent on the interpretation of 34 nonresponding patients. If the worst scenario for these remaining 34 patients without response was assumed, patient's satisfaction rate and family member's satisfaction rate were 42.2% and 38%, respectively. In contrast, if the best scenario for the remaining 34 patients was assumed, patient's satisfaction rate and family member's satisfaction rate were 90.1% and 85.9%, respectively. There were huge differences between these extreme hypotheses. To overcome the possible differences of interpretation, further prospective study should be undertaken. Despite these recognized limitations, this study clearly showed that, in cases of cancer metastasis to the spinal column, surgical intervention had a low rate of surgical complications and offered the patient definite benefits in terms of improved mental status, symptom relief, improved QOL, and improved daily functional status.

Conclusions

The satisfaction of patients and their families after palliative surgery for metastatic spinal disease was analyzed. Patient's satisfaction was affected by age and neurological improvement. Satisfaction of families was affected by pain improvement and patient's survival. The overall satisfaction rate of 80% indicated a high level of acceptance of this treatment. Palliative surgical treatment was a valuable procedure for the patients with metastatic spinal disease and limited life expectancy. Physicians must take into consideration the QOL of patients and their families when undertaking treatment for metastatic spinal disease.

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Long-Term Results of Cemented Total Hip Arthroplasty in Developmental Dysplasia With Acetabular Bulk Bone Grafts After Improving Operative Techniques

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Abstract: We present the long-term results (mean follow-up, 11.8 years; range, 6.3-15.4 years) of cemented total hip arthroplasty with acetabular bulk bone grafting in 147 dysplastic hips using improved surgical techniques. Operations were performed through a direct lateral approach with partial trochanteric osteotomy to avoid nonunion of the greater trochanter. Bioresorbable poly(L-lactide) screws were used for fixation of the acetabular bone grafts to prevent any possible delayed remodeling. Preoperative planning using computer simulation was performed to estimate the optimal size and position of the acetabular component. Analysis predicted rates of survival of the acetabular component of 96% and 91% at 15 years, with revision for aseptic loosening and radiologic loosening as the end points, respectively. Our results indicate excellent long-term clinical and radiographic survivorship of a cemented acetabular component with bulk autograft for acetabular dysplasia. **Keywords:** total hip arthroplasty, long-term results, acetabular autogenous bulk bone graft, improved operative techniques.

Total hip arthroplasty (THA) is a successful procedure for the restoration of hip joint function and the relief of pain for patients with osteoarthritis. Many midterm and long-term follow-up evaluations of THA have been reported, leading to several improvements in operative techniques [1-5].

Total hip arthroplasty in patients who have developmental dysplasia of the hip often requires autogenous bulk bone grafting to augment the acetabular bone defect when the acetabular component is placed at the level of the true acetabulum. This procedure is satisfactory in the short-term, but the results in the long-term have been much more variable [6,7]. We previously reported the long-term results of cemented THA with acetabular bulk bone grafting for developmental dysplasia performed between 1974 and 1988 [8]. Kaplan-Meier analysis predicted a rate of survival of the acetabular component at 15 years of 96% with revision for aseptic loosening as the end point and 75% with radiologic loosening as the end point. We identified the risk factors that were responsible for loosening of the acetabular component as follows: trochanteric nonunion, lateral placement of the acetabular component, and delayed trabecular reorientation of the grafted bone.

To improve the long-term results, we used a direct lateral approach, instead of a transtrochanteric approach, to prevent nonunion of the reattached greater trochanter and used bioresorbable poly(L-lactide) screws to fix the acetabular grafts, instead of crystalline alumina ceramic screws. Furthermore, we performed preoperative planning using computer simulation, which is valuable for placing the acetabular component more accurately at the level of the true acetabulum. In this study, we show the long-term success of cemented THAs with acetabular bulk bone grafting for developmental dysplasia of the hip using this improved surgical protocol.

Patients and Methods

Between 1991 and 1997, we performed 254 primary cemented THAs using the PHS KC prosthesis (Japan Medical Materials Corp, Osaka, Japan) with a 22-mm alumina ceramic head (Fig. 1A). During this period, 119

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Submitted January 15, 2009; accepted May 11, 2009.
No benefits or funds were received in support of this study.
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0883-5403/2505-0007$36.00/0
doi:10.1016/j.arth.2009.05.017

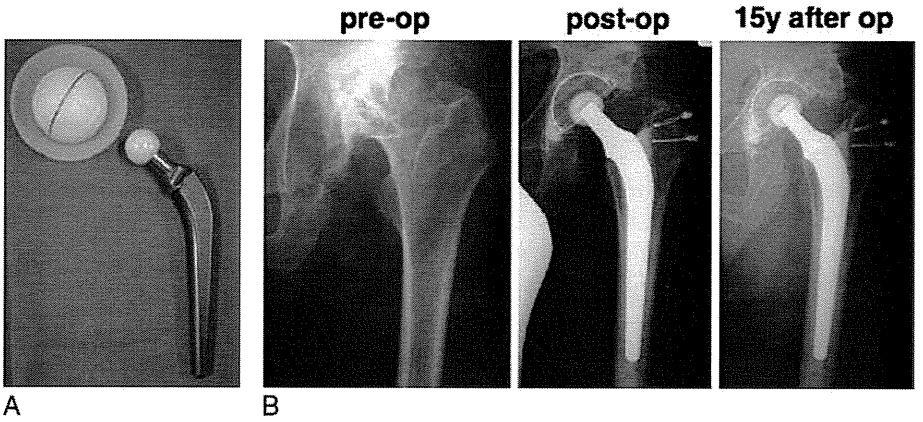

Fig. 1. (A) Photograph showing a PHS KC prosthesis and a 22-mm alumina ceramic head. (B) Radiographs taken preoperatively, postoperatively, and at 15 years after surgery.

patients (147 THAs) required acetabular bulk bone grafting and were observed for an average of 11.8 years (range, 6.3-15.4 years) forming the study group.

The patients consisted of 7 men and 112 women, with a mean age at the time of the operation of 56 years (range, 38-76), a height of 150.6 ± 5.7 cm, and a weight of 51.6 ± 7.9 kg. The diagnosis for all hips at the time of operation was secondary osteoarthritis caused by developmental dysplasia or congenital dislocation of the hip. The degree of subluxation was categorized according to Crowe et al [9] as shown in Table 1.

Before surgery, computer simulation for the planning was performed as described [10]. Briefly, images of hip joint computerized tomography with a line interval of 5 mm were entered into the computer using a digital camera. The level of the acetabular component center was decided from the original acetabulum. The diameter, the location of the component, the inclination angle, and the anteversion of the component were determined in relation to the anteroposterior diameter of the acetabulum and the thickness of its anterior and posterior lips. The area in need of a bone graft was shown by a line that represented the lateral half contour of the projected image of the component in the horizontal plane.

All operations were performed through a direct lateral approach with partial trochanteric osteotomy as reported by Dall [11]. The acetabular autogenous bone grafting using the resected femoral head was done as described by Wolfgang [5]. The grafts were fixed to the superolateral aspect of the acetabular roof with bioresorbable poly(L-lactide) screws in 113 hips, titanium screws in 17, and AO stainless steel cancellous screws in 7. All the acetabular components were fixed with CMW1 radiopaque cement (CMW Laboratories, Devon, United Kingdom), and all the femoral components were with CMW1 or CMW3 radiopaque cement. The cements were prepared by vacuum mixing and were applied into the femoral canal using a cement gun with autogenous bone chips packed into a femoral medullary canal as a bone plug.

Standard radiographs were taken after surgery and at 2, 4, 6, and 8 weeks; at 3, 6, and 12 months, and 6-monthly or yearly thereafter (Fig. 1B). The initial postoperative radiographs were used to measure the center and the degree of initial abduction of the acetabular components, the center-edge angle, and any lengthening of the limb. The presence of a radiolucent line around the acetabular components at the cement-bone interface in the 3 zones of DeLee and Charnley [12] was recorded. Loosening of the acetabular component was classified according to the criteria of Hodgkinson, Shelley, and Wroblewski [13]. The criteria of Harris, McCarthy, and O'Neill [14] were used to assess

Table 1. Details of the 147 THAs for Developmental Dysplasia of the Hip

Total patients	119 patients (males, 7; females, 112)
Total hip	147 hips
Mean (SD) age at operation (y)	56.3 ± 7.5
Mean (SD) height (cm)	150.6 ± 5.7
Mean (SD) weight (kg)	51.4 ± 7.9
Mean (SD) socket size (mm)	44.3 ± 2.4
Mean (SD) socket center-edge angle (deg)	5.6 ± 14.4
Mean (SD) initial abduction of the socket (deg)	40.9 ± 4.9
Mean (SD) horizontal positioning of the socket (mm)	22.1 ± 5.7
Mean (SD) limb lengthening (mm)	19.7 ± 9.6
Socket location	Superolateral, 3; superomedial, 5; inferolateral, 17; inferomedial, 122
Crowe type	
I	66
II	44
III	16
IV	21
Screw	
None	10
AO	7
Titanium	17
Poly(L-lactide)	113

radiologic evidence of loosening of the femoral component. Hip function was evaluated according to the scoring system of Merle d'Aubigné and Postel [15].

Statistical Analysis

We used the Kaplan-Meier product limit method to estimate the cumulative probabilities of revision and loosening. The survivorship curves for various subgroups were compared using the log-rank test.

Results

There were no early postoperative complications, including dislocation, nerve palsy, or infection. Nonunion of the osteotomized bone fragments of the greater trochanter occurred in 3 hips with no clinical symptoms. The mean Merle d'Aubigné and Postel hip score improved from 8.5 before operation to 15.2 at the final follow-up. Three hips required reoperation; 2 for aseptic loosening of the acetabular components. The femoral components in these patients were replaced with new components, although they had not loosened. One THA was dislocated 134 months after operation, and the femoral component was dislodged when closed reduction was tried. In this case, open reduction and femoral revision were needed. No reoperation was performed for aseptic loosening of the femoral component.

The Kaplan-Meier survivorship analysis, with revision for aseptic loosening as the end point, predicted a rate of survival of the acetabular component of 98.6% (95% confidence interval [CI], 97-99) at 10 years and 96% (95% CI, 92-99) at 15 years (Fig. 2A). For the femoral component, the rate of survival was 100% at 15 years with revision for aseptic loosening as the end point.

Radiologic Analysis: Acetabular Components

We estimated the distribution of the radiologic lucent lines around the acetabular component. Lucencies were present in 37.4% of hips in zone I, in 8.8% in zone II, and in 27.2% in zone III (Fig. 2B). At the most recent follow-up, 2 acetabular components had been revised for loosening and an additional 8 acetabular components showed evidence of radiologic loosening. The Kaplan-Meier survivorship analysis, with radiologic loosening as the end point, predicted a rate of survival for the acetabular component of 97% (95% CI, 92-98) at 10 years and 91% (95% CI, 87-94) at 15 years (Fig. 2C). Nonparametric survivorship analysis with the use of the log-rank test was applied to 9 variables as follows: the age and body weight of the patient, the size, horizontal positioning, initial abduction of the acetabular component, center-edge angle, limb lengthening, Crowe type, and trochanter nonunion. None of these parameters showed a statistically significant difference in the occurrence of radiologic loosening.

Previously, we indicated 3 risk factors that affected loosening of the acetabular component [8]. The position of the center of the acetabular component on the initial postoperative radiographs was assessed using the 4-zone classification [16]. Fourteen percent of the acetabular components were placed laterally and 5.5% superiorly. However, in this study, comparison of the laterally placed components with all others showed no

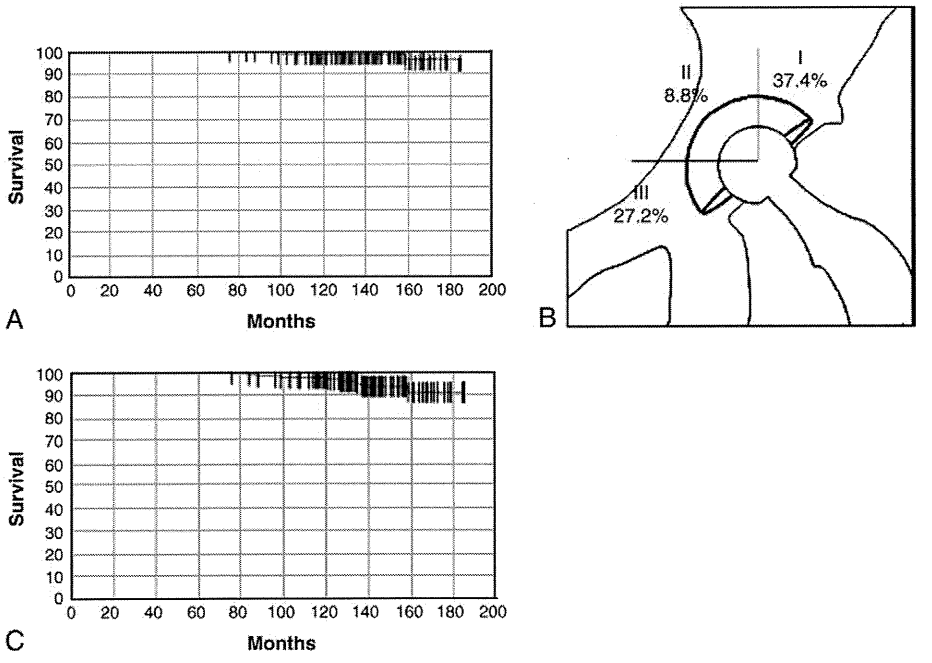

Fig. 2. (A) Kaplan-Meier cumulative probability of an acetabular component not needing revision for loosening. The vertical bars indicate 95% CIs. (B) Incidence of the radiologic lucent line shown in the 3 zones of DeLee and Charnley. (C) Kaplan-Meier cumulative probability of an acetabular component not showing loosening radiologically. The vertical bars indicate 95% CIs.

significant difference in the rate of loosening (log-rank test, $P = .8$).

In this study, we changed the operative approach from a transtrochanteric approach with wiring fixation of the detached greater trochanter to the direct lateral approach used by Dall [11]. In these cases, there were 3 hips with nonunion of the partially detached greater trochanter bone fragment, but the acetabular components of these hips were not loosened.

Previously, we fixed the grafted bone using 6.5-mm diameter crystalline alumina ceramic screws [8]. In this study, we used bioresorbable poly(L-lactide) screws to fix the grafted bones, and all the grafted bones were remodeled with trabecular reorientation within 36 months after operation. Neither nonunion nor collapse of the grafted bone was observed.

Radiologic Analysis: Femoral Components

At the most recent follow-up, no femoral component had been revised for aseptic loosening. The Kaplan-Meier survivorship analysis, with radiologic loosening as the end point, predicted a rate of survival of the femoral component of 100% at 15 years.

Discussion

Cemented THA for treating patients with a degenerative dysplastic hip using acetabular bone grafting has been controversial. We previously reported long-term results and survivorship analysis of the Charnley prosthesis and the Bioceram implant with a 28-mm alumina ceramic head with acetabular bone grafting for developmental dysplasia of the hip [8]. Kaplan-Meier survivorship analysis predicted a rate of survival of the acetabular component at 15 years of 96% with revision for aseptic loosening as the end point and 75% when radiologic loosening was used. In addition, using multivariate survival analysis with the Cox proportional hazards model, lateral positioning of the acetabular component, trochanteric nonunion, and delayed trabecular reorientation of the grafted bone were found to be risk factors for loosening of the acetabular component. From these findings, we changed our surgical techniques, resulting in a predicted survival rate of the acetabular component of 91% at 15 years with radiologic loosening as the end point. Although the large number of radiolucencies in zone I is worrisome, this is a significant improvement on our previous study.

In our revised approach, we first performed preoperative planning and simulation of placement of the acetabular component at the true acetabulum in all patients [10]. This computed tomography–based computer simulation system is useful for estimating of the optimal size of the acetabular component and determining the appropriate hip center before operation. Indeed, 20 of the 147 reconstructed acetabular centers (13.6%) were located lateral to the computer-determined center of the acetabulum. Only one component of these 20 was radiologically loosened, and there was no significant difference in the rate of radiologic loosening when assessed by log-rank test. In contrast, our previous study reported that 37 (27.8%) of 133 acetabular components were placed laterally. This showed a significant difference in the rate of radiologic loosening from those placed medially. In addition, this system enables estimation of the size and position of bone grafting. Thus, computed tomography–based preoperative planning and simulation may have contributed to the long-term survivorship of the acetabular component.

Second, to prevent nonunion of the greater trochanter by a transtrochanteric approach, we used a direct lateral approach with a partial osteotomy of the greater trochanter as reported by Dall [11]. In the present study, nonunion occurred in only 3 hips (2.0%: much lower than in our previous study [18.8%]). These hips were not associated with aseptic loosening of the acetabular component.

Last, to fix the grafted bone, we used 4.5-mm diameter bioresorbable poly(L-lactide) screws to minimize disturbance of any bone remodeling of the grafts. In our previous study, we fixed the grafted bone with 6.5-mm diameter crystalline alumina ceramic screws, and a rate of delayed trabecular reorientation was 11% at more than 36 months after operation [8]. In the present study, all the grafts were united with the host bone and remodeled within 36 months. Thus, although there has been no obvious evidence that bioinert alumina ceramic screws reduce bone union rates and remodeling, bioresorbable poly(L-lactide) screws with a smaller diameter used for grafted bone fixation might have the advantage of bone bonding and remodeling of the grafted bone.

In our previous study, we used a Charnley prosthesis and a variety of Bioceram implants with a 28 mm alumina ceramic head [8]. In the present study, we used a PHS KC prosthesis made of titanium alloy (Ti-6aluminum-4vanadium) with smooth surface roughness (0.3-0.4 μm) (Fig. 1A). The shape of this prosthesis resembles the Charnley prosthesis although the stem length is 1 cm longer for increased stability of the stem in the femoral medullary canal. The long-term result of this stem is excellent, and no aseptic loosening occurred during the follow-up period. We implanted a PHS KC prosthesis with a 22-mm alumina ceramic head. The 28-mm alumina ceramic head used in the previous study is the so-called old alumina. The average grain size is 5 μm, and surface roughness of the retrieved heads is the arithmetic mean roughness (Ra) = 0.028 ± 0.009 μm (the largest peak-to-valley height [Rmax] = 0.531 ± 0.270 μm) [17]. Since 1988, the manufacturer has made improvements in the properties of alumina ceramics, enabling the femoral head size to be reduced from 28-mm diameter to 22 mm (current alumina). The current alumina is high-purity alumina containing more than 99.8% Al_2O_3 and has a much smaller grain size (average, 1.3 μm) than the old alumina. The surface roughness of the retrieved heads was Ra = 0.013 ± 0.003 μm (Rmax = 0.105 ± 0.006 μm),

less than that of old alumina heads [17]. Our previous radiologic analyses of polyethylene wear showed a linear wear rate of 0.156 ± 0.078 mm/y for a 28-mm-old alumina ceramic head [17]. In contrast, the linear wear rate of the 22-mm current alumina ceramic head was reduced markedly to 0.090 ± 0.078 mm/y [17]. Thus, these improved implants with the smaller head size, resulting in less polyethylene wear and less osteolysis, have beneficial effects on the long-term success of cemented THA with acetabular bone grafting for patients with developmental dysplasia of the hip.

In Japan, osteoarthritis of the hip joint is mainly caused by developmental dysplasia or congenital dislocation of the hip. Because the acetabulum of these patients is small and shallow, acetabular bone grafting is required for adequate coverage of the acetabular component when the component is placed in the original acetabulum. Our improved surgical techniques and development of the prosthesis led to greater long-term success of the cemented THA for developmental dysplasia of the hip.

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